CONFERENCE PROCEEDINGS OF THE 2018 NATIONAL GOAT CONFERENCE

"Building Towards a Sustainable Future via a Healthy and Profitable Goat Industry"

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PREFACE

The 3rd National Goat Conference was held in September of 2018 during a critical period for the agricultural sector, wrought in corporate mergers and reductions in governmental funds previously directed to support agriculture and related areas. First established in 2010, the National Goat Consortium–An Initiate of the 1890 Land Grant Institutions, in collaboration with numerous organizations, including government, private, NGOs and other stakeholders, continues to carry on the legacy of the 1890 LGIs and their role and commitment to advancing the goat industry and supported farmers, including limited resource producers. It is incumbent on us, therefore, to further our efforts, building on our successes as we continue to explore emerging opportunities, as our obligation to those we serve is sustained through teaching, research and extension.

Other major changes in our nation and the world, ranging from a change in the outlook on the American government and its role as a global leader to increased changes in weather to changes in not only how we communicate, but also how information is collected through what was once only considered as communication devices, leaves us no choice but to strategize on the best way to meet the needs of individuals interested in the goat industry, which provides a viable economic opportunity for new and established farmers. Fortuitously, the National Goat Consortium has had the foresight to remain focused on its specific goal of developing strategies to advance the goat industry, particularly in the United States, which is in a position to address numerous challenges that we face from the decline in new/beginning farmers and ranchers to the 2050 challenge, which brings forth the issue of doubling food supply sustainably, which emerging technologies and utilization of big data could be part of the solution.

Given the rapid changes taking place in our society, this year's National Goat Conference is sure to allow us to see how the goat industry, though in its infancy, continues to remain a viable economic enterprise in the United States and beyond. For example, Mahendra Lohani with Heifer International will regale us with a powerful presentation demonstrating the Importance of Goats in the World. The commitment of USDA Programs to Support Small Farmers and Goat Producers will be addressed by Parag Chitnis, USDA NIFA Small Farms. It will take this support and that of others to ensure that the necessary advances needed in the goat industry are met.

Another highlight this year is the presentation of the Innovative Farmer Awards, which will be awarded to three farm families. Each operation is unique, but all are clearly committed to advancing not only themselves, but others associated with the goat industry through the sharing of information and ideas with other producers in their communities. Their stories are sure to have a great impact on attendees.

I would be remiss not to salute Angela McKenzie-Jakes, the original organizer of the National Goat Conference, who has continued to work tirelessly to ensure that farmers and agricultural professionals alike truly benefit from the dissemination of information at this event in addition to her efforts to obtain financial support to defray the costs of dozens of attendees. Further, this vision would not be without the support of others in the past and again this year. Included among these supporters are the agencies of the USDA, especially NIFA and APHIS-VS as well as Southern SARE. We also appreciate the support from the 1890 LGIs and TU, select supporters from the 1862 Institutions, the Alabama Farmers Federation, Sydell, Inc. and many others, including new partners such as Heifer International.

We trust that the papers within these proceedings will be of value to all and reflect the dynamic partnerships that came together to make this event a success. Many thanks!

Olga Bolden-Tiller

NGC Planning Committee Member
NGC Local Arrangements Committee Chairperson
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INTRODUCTION

The 3rd National Goat Conference was hosted by Tuskegee University on 16-18 September 2018 at the Tuskegee University Kellogg Conference Center, Tuskegee, AL and the Renaissance Hotel, Montgomery, AL.

The theme of the conference was "Building Towards a Sustainable Future via a Healthy and Profitable Goat Industry." The aim of the 3rd National Goat Conference is to:

- Create an avenue by which the conference participants can share research and/or production-based information, share concerns, resources, and technology in an effort to strengthen and enhance the goat industry in this country.
- Create a lively ambience in which research scientists, producers and stakeholders could meet and discuss the latest scientific innovations and results.
- Allow participants from government and academia an opportunity to become more aware of the significance of the industry and to share information about how they can support the industry (i.e., regulator issues, marketing issues).
- Encourage the extension agents and farm group-leaders to share what they have learned from the conference with producers from their respective communities through training meetings, workshops, field days, conferences, etc.

Increase the number of producers adopting sustainable goat production practices on their farms to improve the sustainability and viability of their goat enterprises

Today, goat production continues to be one of the fastest growing industries in the U.S. Persistence among ethnic consumers in maintaining their religious or cultural practices has increased demand for goat meat. Because of demand, many small and limited resource producers are raising goats as an alternative source of income. However, producers in many cases still lack the necessary skills and knowledge to produce quality meat goat products on a consistent basis to meet consumers' demand while sustaining a profit. Furthermore, with the influx of information on the internet and other sources, many producers are often misinformed on the appropriate management practices and strategies for raising healthy, productive animals. Limited access to information and limited opportunity for interaction among scientists working in the same area of interest are two of the major constraints to meat goat production in the United States, and in particular, the southeast regional area. It is against this background that the National Goat Consortium – An Initiative of the 1890 Land Grant System-has made the promotion and improvement of information exchange on meat goat research and development one of its major priorities in addition to collaborative research and extension. The consortium network has set out to achieve this goal through the organization and sponsoring of the 3rd National Goat Conference, amongst other channels. This provides a forum for meat goat scientists in the United States and elsewhere, developers, policy-makers and farmers to meet, exchange ideas and establish partnerships. The conference also provides opportunity for meat goat research in a priority setting.

The Conference will deal with all the topics concerning goats: health and well-being, reproduction and artificial insemination, breeding and genetics, nutrition, production systems, products and value chain, socioeconomics, in conventional and organic systems. The proceedings are organized into seven sections as follows:

Session I – Keynote, Plenary and General Session Addresses

Session II - History and Other Aspects

Session III - Animal Selection, Reproduction, and Biotechnology

Session IV - Disease and Herd Health

Session V - Nutrition, Forage, and Grazing System

Session VI - Goat Marketing and Value-Added Products

Session VII – Special Recognitions

In addition to these sessions, oral and poster presentations will be made and discussed. Five papers deal with the history and other aspects of meat goat production. Another seven describe animal selection, reproduction and biotechnology. There are six papers on diseases and herd health, reproductive problems and their solutions. Seven papers review the nutrition, forage and grazing systems prevalent under various management systems and present the solutions to these production constraints. The last nine papers deal with goat marketing and value-added products.

The opening session was highlighted by the keynote address entitled, "The Importance of Goats in the World" presented by Mahendra Lohan, Heifer International. This proceeding provides keynote lectures from the invited speakers. Among the keynote speakers, Parag Chtnis of the USDA NIFA Small Farms discussed the USDA Program to Support Small Farmers and Goat Producers. One key area that came out of this presentation was the emphasis on locally-owned value-added enterprises, or LOVAs, as crucial for the creation of sustainable agricultural system. Enrique Nelson Escobar of the American Consortium for Small Ruminant Parasite Control provided detailed insights regarding the best management practices for internal parasite control in small ruminants. Tom Boyer, of National Goat Federation discussed the major challenges of US goat producers and way forward, while Steve Hart of the International Goat Association talked about the current situation and future prospective of the goat industry in the U.S.

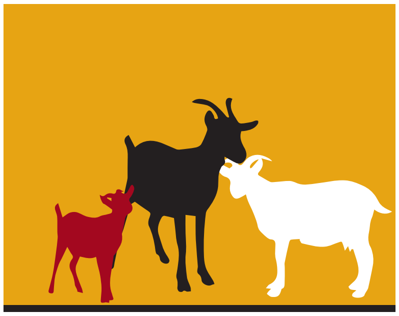
The National Goat Consortium acknowledges the long-standing commitment of our ongoing sponsors, the Tuskegee University, and Caprine Research and Education Unit, and the George Washington Carver Experiment Station for their continuous promotion and support of the activities of the consortium including the holding of the 3rd National Goat Conference and the publication of the proceedings. Linked with this has been the extraordinary support of other sponsors, vendors and commercial exhibitors who help us maintain such affordable registration fees for the conference. Many thanks go to the Department of Agricultural and Environmental Sciences, Tuskegee University for the usual superb logistical support. Meeting the needs of the rapid increase in conference attendees in recent years has been an exciting

challenge and the local organizing committee has worked hard to diversify the program offered. If we are succeeding, let us know; if we are failing, please give us your guidance.

We would love to thank the scientists, technicians, supporters, breeders, students and all who took part and contributed to the success of this event. Many thanks to the authors for their commitment in the editing process of this issue, as well as the valuable and precious support of the reviewers, for their comments and suggestions.

Chuck Okere and Olga Bolden-Tiller

Tuskegee University



SECTION ONE

KEYNOTE, PLENARY AND GENERAL SESSION ADDRESSES

THE IMPORTANCE OF GOATS IN THE WORLD

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ABSTRACT

Goats, which are among the earliest domesticated animals, with over 1,153 breeds, differ significantly in phenotypic characteristics and production types. In the last 30 years, the goat population of the world has more than doubled from about 483 million to over 1 billion. Goats survive and reproduce under a variety of extreme conditions, making them an ideal species for resource-poor farmers, often tagged as "bank on the hoof" and "walking refrigerators." Unfortunately, it continues to be a challenge to transform the mind-set of subsistence farmers to consider them a productive asset. The production potential of goats has not yet been fully realized. Goat health, breeding, housing and nutrition continue to be main challenges in a small-holder production system. The development of the goat market sector is still informal and underdeveloped. As a result, goats have not been identified as a significant contributor to the national gross domestic product. Many development organizations consider goats a preferred livestock commodity for poverty alleviation. Therefore, it is desirable to have a systematic approach to optimize goat production for small-holders. A small-holder goat value chain works well with a focus on improved goat production, increasing business and entrepreneurial skills and organizing communities for strong social capital. Heifer International has large-scale goat value chain programs for small-holders in many countries around the world. Partnership and collaborative efforts among academic/scientific, public/private sectors, producers and civil societies are critical for sustainable small-holder goat development.

Keywords: goats, small-holder farmers, value chain, poverty alleviation, partnership

1. INTRODUCTION

Goats are among the earliest domesticated animals and have been associated with humans for at least 10,000 years (Monteiro et.al, 2018). Due to their adaptability to different environmental and climatic conditions, they are dispersed all over the world (Mahmoud A.A. 2010). Goats are the most beneficial animals in the world, providing meat, milk, fiber, fertilizer, and draft power (Sinn, R. and P. Rudenberg, 2008). Over 1,153 breeds of goats (FAO, 2007) exist on our planet, living on every continent except Antarctica and in a quite astonishing range of environments, from humid tropical rain forests to dry hot desert regions and cold, hypoxic high-altitude regions (Hirst, K.K., 2017). They are different from one another by their size, shape and production types.

Goats survive and reproduce under a variety of extreme conditions, making them an ideal species for resource-poor farmers, often tagged as "bank on the hoof" and "walking refrigerators." Unfortunately, it continues to be a challenge to transform the mind-set of subsistence farmers to consider goats as a "productive asset" rather than "saving asset."

Traditionally raised for milk and meat, goats are one of the most commonly consumed meats in the world as they are an excellent source of protein. Goat meat and milk pose very few religious taboos among the diverse human population. It is low in fat and cholesterol and high in vitamins and minerals. Similarly, goat milk is widely consumed worldwide and, for many, is easier to digest. Its rich, complex flavor and nutritional qualities has helped the goat cheese industry become a major niche market in Europe and the United States. Goat products have become sought-after commodities in developed countries (Sinn and Rudenberg, 2008).

In rural areas of developing countries, the contribution of goats is highly significant and has an important role in feeding the resource-poor populations. When small-holder farmers can't raise cattle and other large animals, goats become the preferred choice. They are ideal for household milk and meat production and can be easily sold for immediate income. The milk and meat produced by one goat is the perfect balance: it is often sufficient to meet children's nutritional requirements, without the storage problems associated with the larger volume produced by large animals. Goats are readily adaptable and thrive in all types of climatic conditions (tropical, cold, dry or humid climates). Due to the size of goats as compared to other species, they can be raised in very small landholdings of resource-poor small-holder farmers.

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2. GOAT POPULATION IN THE WORLD

The current global goat population according to the Food and Agriculture Organization (FAO) is over 1 billion (FAOSTAT, 2018), which has doubled in the last thirty years. Figure 1 shows the trend of goat population, which was below 400 million during the early 1960s when FAO started collecting data and has increased to over 1 billion in 2018. The goat population has increased with the increase in human population, probably due to resource-poor small-holder farmers finding it suitable for diversifying sources of their income and nutrition. Goats are one of the best livestock available resources to meet that need.

Figure 2 suggests that goats are mainly concentrated in Asia (57.7%) and Africa (35.7%), making up 93.4% of the total number in the world (FAOSTAT, 2018). This is due to the importance of goats to the high number of poor and small-holder farmers in Asia and Africa. The production of small ruminants, especially sheep and goats, is largely rooted in specific regions, for both historical and religious reasons. This is the case in Muslim countries where pork is not a food option, and in India where beef is not eaten, in both cases due to religion.

Figure 3 shows the leading countries in goat production in five Asian countries (China, India, Pakistan, Bangladesh and Iran) and five African countries (Nigeria, Sudan-former, Sudan, Kenya and Ethiopia) (FAOSTAT, 2018). These goats are mainly raised for meat and milk, and to some extent for fiber.

3. GOATS AND Small-holder FARMERS

Goat farming is an integral component of small-holder farms in Asia and sub Saharan Africa. Goat meat and milk are produced and consumed locally among the poor in developing countries. Goats are also a source of immediate income in case of emergency and the reason why they are considered a "bank on the hoof." In terms of goat milk and meat production, developing countries are in the lead, reflecting the importance of these commodities to feed millions of small-holder farm families in these countries. Goats require less feed to raise because they are smaller, and they prefer brush and browse. These are some of the reasons why goats are a preferred species among small-holder farmers around the world.

Goats provide multiple benefits to farmers in developing countries. In a small-scale approach, the type of enterprise combination, ecosystem and production system must all be considered. Goats exhibit a very high productivity potential that, if well promoted, can easily help to improve the rural economy within a very short time.

4. GOATS FOR COMMUNITY DEVELOPMENT

Small livestock, especially goats, is vital for the livelihood of many rural resource-poor small-holder farmers and is often the only asset they possess. Goats significantly contribute to improving nutrition, providing food with high quality nutrients and micronutrients. Goats generate income and savings, especially for women, enhancing their capacity to cope with economic emergencies and reducing debt. During times of crisis, goats play an important role as "mobile" food assets (International Goat Association, 2014). Goats are often the "sacrificial" animal during religious festivals and social ceremonies. Goat-keeping has proved to be instrumental in achieving the Sustainable Development Goals.

The goat sector has not followed the same path of development and intensification as other livestock production sectors such as cattle, poultry, pigs, etc. It continues to be a challenge to transform the mind-set of subsistence farmers to manage goats as a "productive asset" rather than continuing the traditional practice of using it as a "savings asset." Goat marketing activities have been largely excluded from organized markets. It is important to recognize the opportunity that goat farming offers to nutrition and economic development. Goat production systems are multipurpose systems oriented towards production of milk, meat, manure, fiber and skin. Goat development projects generally consider these multifunctional characteristics.

International development agencies have varied practices of supporting small-holder farmers through goats. Providing goats to small-holder farmers along with technical trainings for increasing the capacity to raise goats and to increase income is one of the preferred methods development agencies employ. The provision of microcredit has also helped poor small-holder farmers to buy and raise goats. Support for improved production and health, product development (processing and marketing) and institutional development (farmer capacity, organization, market development, and small-holder farmer-friendly policies) are keys to the success of goat production at scale.

The critical first step for small-holders to earn a *living income* through goat raising is to build their capacity in production and marketing. Small-holders' engagement is essential for addressing the goat production and marketing gap and it also ensures that small-holder farmers are motivated for change.

5. HEIFER INTERNATIONAL'S EXPEREICNE IN GOAT PRODCUTION

Heifer International believes that the collective power of economic development, food security and nutrition, and environmental sustainability can empower small-scale farmers on the path to *living incomes*. When those components are multiplied by the positive impacts of women empowerment and social capital, communities achieve greater resilience and a sustainable reduction in hunger and poverty. A *living income* is all the income of a household earned/generated or transferred whether cash or in-kind, sufficient to enable all members of the household to afford a decent standard of living (Heifer International, 2017). This includes nutritious food, safe housing, education, clothing, health care, transportation, communication, culture and entertainment, and provision for external support and unexpected events.

Heifer International has learned that the most reliable, sustainable way to end hunger and poverty where it works is to develop and strengthen inclusive local economies. Heifer does this by helping people start or expand farmer-owned agri-businesses, cooperatives and social enterprises so they can profitably participate in pro-poor wealth creating value chains.

Small-holder farm entrepreneurs in Nepal, India, Bangladesh, China, Zimbabwe, Senegal and Haiti (to name a few) are playing a key role in rural economic development via large-scale goat value chain projects. These small-holders design and commercialize products and services, create jobs and generate new waves of economic development in their communities. Heifer equips socially minded entrepreneurs, especially women and youth, with the skills and resources they need to earn living incomes. Heifer's large-scale goat value chain program in Nepal includes more than 200,000 households and more than 70,000 households in India.

5.1 **Heifer International Theory of Change**

Heifer's work focuses on improvements in the five domains below, which work together to take small-holder farmers from vulnerability to sustainability. Physical aspects (red blocks) combined with social aspects (orange blocks) form a multiplier effect that accelerates processes and expands impacts as shown in figure 4. Goats are serving as an entry point of these Heifer programs. The large-scale goat programs have helped small-holder farmers to move out of poverty through combined efforts to address increasing animal production and productivity, building social capital and collective businesses.

5.1.1 **Improved Goat Production**

Heifer works with small-holder farmers to increase goat productivity by focusing on all aspects of animal well-being. Strategically selected community members are trained on primary animal health care and business skills. The graduated technicians are called Community Agro-Vet Entrepreneurs (CAVEs). CAVEs are mobilized to increase farmers' access to veterinary services and inputs for their goats. CAVEs earn their living income by selling technical services and animal production/health inputs to farmers for improved goat production and management. Nutritious fodder and forage for goats is extensively promoted along with mineral blocks and supplement feed made from locally available ingredients. Selection breeding, strategic placement of genetically superior quality bucks and prevention of inbreeding are practices consistently applied to improve the genetic potential of goats. Small-holder farmers are also trained in maintaining health and production records. As a result, there has been a significant increase in goat production and productivity. The average goat productivity has increased by 42% in Heifer project areas in Nepal in four years (Heifer International Nepal, 2016) and average kid production per doe per year has increased from 1.54 to 2.4 at the end of a five year project period as shown in figure 5 (Heifer International Nepal, 2017).

5.2 **Goat Breeding**

Technical interventions by most development organizations often lack focus in breed improvement of goats. Due to a lack of a continuous, structural and established genetic improvement programs, the indiscriminate breeding practices by small-holder farmers often yields negative genetic impact. The result is decreased genetic merit of goats leading to a decline in productivity. This results in inadequate availability of improved breeds for multiplication. Therefore, a systematic scientific approach for breed improvement aiming at the production of seed animals of generic merit is indispensable for increasing the impact.

Selection breeding practices within the breed can be adopted through the participation of community members to produce seed goats and to improve the genetic performances of the goat flocks. This is only possible through the introduction of performance recording (Solomon et.al., 2014) and selection as a tool of technical intervention for the improvement of breeds of native goats so that gradual, permanent genetic gain could be achieved over years. Heifer has successfully carried out a "community initiated genetic improvement in goats (CIGIG)" program. The analysis of this project clearly indicated that goat breed improvement through selection could be done with the participation of community small-holder farmers. Breed improvement analysis in this research was done by comparing the change in the value of the parameters of the average daily weight gain, average five months' live weight gain and three months' litter weight per doe at one-year intervals (Table 1).

5.3 **Goat Health**

At the small-holder farmer level, management of goat health is a critical aspect for improving goat production. Periodic vaccination and deworming of goats can reduce disease incidences. Reducing kid mortalities with better management practices is also very important for small-holders. Heifer facilitates the improvement of goat health through a community-based approach utilizing locally trained community members called community Agro-Vet Entrepreneurs (CAVEs). These CAVEs also support small-holder farmers in improving their animal management skills (not only limited to goats) and use their own farm as a demonstration site. Through these relationships, CAVEs build steady client bases for their services and products. This opportunity is attracting youth to agribusiness, reducing their migration to cities in many Heifer-supported communities around the world. The selected CAVEs go through a series of trainings including but not limited to animal health and husbandry, agribusiness and enterprise development, and facilitation and communication skills coupled with Heifer's social capital training. Due to enhanced animal health services provided by CAVEs, goat mortality has reduced significantly. Heifer India reported overall goat mortality below 2% in fiscal year 2016 (Heifer International India, Annual Report 2016). CAVEs are instrumental in providing preventive services like periodic vaccinations and deworming, treatment and first aid services, and input supply to small-holder famers. CAVEs also provide training to farmers on new advances in animal production and health technology as part of the embedded service of their business. Heifer's current data shows that more than 2,400 active CAVEs, community animal health workers (CAHWs) and animal health promoters are serving small-holder farmers in Heifer communities (figure 6)

5.4 **Goat Feeding and Nutrition**

Most of the goats kept by small-holder farmers in developing countries are seldom fed with concentrate feed, cereal grain or good fodder, resulting in lower production and performance. Goats can damage fragile environments if not properly managed. When goats are properly managed, they can serve as highly effective tools for improving the environment.

Heifer works with small-holder farmers who possess small plots of land. Heifer promotes zero grazing practice in its projects. Heifer promotes improved fodder and forage production as a movement and facilitate cut and carry method for goat feeding. Small-holder farmers are utilizing unproductive and unused lands, public lands through leases, borders of irrigation canals, on two sides of roads and trails, terraces and bunds of the farmlands for fodder and forage production. Community nurseries managed by small-holder farmers are the main source of seedlings and saplings, in addition to leveraging similar resources from local government agriculture and forestry departments. Small-holder goat farmers in Nepal have planted more than 8,000 hectares of land (Figure 7) in the last four years (Heifer International Nepal, Annual Report 2016). Likewise, Heifer International India has planted more than 500,000 fodder/forage plants in fiscal year 2016 alone (Heifer International India, Annual Report 2016). This trend is increasing in all countries where Heifer has a footprint. Altogether, more than 1.4 million different species of fodder and forage were planted, and more than 3,400 hectares of land was utilized for forage and pasture management in fiscal year 2017 (The SCAPH Bulletin, 2018).

Heifer has also introduced the concept of feeding home-mixed concentrate feed and mineral block to improve goat productivity. To minimize feed wastage, improved and separate feeding troughs and waterers for the goats have been introduced. The concept of community fodder banks to address the challenge of feed shortage in dry season has also been working effectively (Heifer International India, Annual Report 2016).

5.5 **Risk Management in Goats**

Goat insurance is one risk management option available to small-holder farmers. But it is not widely practiced due to one or more reasons such as limited access to insurance centers, remoteness of communities, hurdles in verifying claims and complicated reimbursement processes. Within these realities, Heifer has been practicing community -managed insurance programs for goats and other livestock species, in addition to formal insurance if and where available. In community-managed insurance programs, the community members themselves develop guidelines, processes and templates for ensuring their livestock, as well as setting premiums and developing mechanisms for verification and payment in case of goat death.

5.6 **Farmer Field Schools for Goats**

Farmer Field School (FFS) is a widely used extension approach in the field of agriculture. Farmers participate in FFS to learn the new technology by testing it in their own context and/or in a stage of the production cycle. It gives farmers an opportunity to compare existing management practices with new improved practices in order to make decisions over the whole production process. Farmers design their study, conduct experiments, make observations and draw conclusions to put into practice.

Heifer has a long history of finding innovative ways to increase goat productivity. Heifer country programs are innovatively adapting FFS in their goat projects. Using the improved practice, the average growth rate of goats was almost doubled as compared to traditional practices by small-holder farmers in Nepal, and the average time from birth to mating was reduced by more than 100 days. This means more and larger goats in less time, which translates to higher profits for the farmers. Figure 8 shows how the improved practices through FFS have increased the body weight of goats in six months (Heifer International Case Study Series-1, 2012). Improved practices in this case study include improvements in goat sheds with proper ventilation and manure management; improvements in feeding with supplemental locally-made concentrate feed, provision of water and mineral blocks; periodic vaccination against *peste des petitis ruminats* (PPR) and deworming. Traditional practices do not include any additional interventions.

5.7 **Strengthening Social Capital and Market for Goats**

Heifer's Values-Based Holistic Community Development model is a package of practices that creates social capital and builds an enabling environment for sustainable development work. Major components include a strong community structure to pool resources, discuss, identify and prioritize needs, plan and execute activities to empower groups such as cooperatives and producer associations and positive changes at a cognitive level, including strong social capital and positive attitudes among community members. Values-Based Holistic Community Development gives marginalized groups the capacity and drive to initiate enterprise activities and integrate into the market economy. The organized small-holder farmers in self-help groups (SHGs) and cooperatives are getting greater benefits along the goat value chains and have increased income through working as additional market actors in addition to their role as goat producers. The small-holder farmers who are part of large-scale goat value chain programs have started developing production strategies according to consumers' interests and demands rather than what they can produce. Heifer has observed a paradigm shift among small-holder goat farmers from production driven to market driven goat value chains.

Pro-poor wealth creating value chains (figure 9) integrate poor and vulnerable groups into market activities in an equitable and fair manner. These value chains create lasting wealth that is rooted and stays in communities through local ownership, mutually beneficial linkages and inclusive business relationships. Heifer International works with farmers and communities to:

- Determine the best value chain opportunities
- Identify, support and strengthen agri-enterprises
- Deploy capital and technology
- Mobilize values-based private sector partnerships

6. Partnership and Collaboration

There are many challenges facing the small-holder goat industry, including low productivity, high mortality and frequent disease outbreaks, insufficient and inappropriate feeding practices and inferior breed quality including inbreeding. Most research organizations and universities engaged in the genetic improvement of goats are in developed countries. Research and development investment to improve low levels of goat productivity, especially in developing countries and breeds of goats available there, have not been exploited fully. Goats will be an important source of livelihood for small-holder farmers in the coming years (Mahmoud, A.A., 2010) and deserve more attention at the household level as well as at the country level. Raising awareness of decision-makers in national governments and development agencies about pro-poor goat development for poverty reduction is a key strategy to be considered. Funding adaptive and participatory research engaging small-holder goat farmers (who bring problems based on their current goat production practices) to identify appropriate and sustainable, economically viable and environmentally friendly goat production can be done through partnership and collaboration with research institutions and universities (that bring solutions to the problems faced by small-holder goat farmers). With this approach, the problems faced by small-holder goat farmers can be addressed using science and technology. The dissemination of field-tested and proven successful goat production technologies through various platforms is equally as important as the adoption of market-led approaches supported by effective and qualitative services and market infrastructure.

7. CONCLUSION

Goats are the preferred livestock of small-holder farmers around the world as they are excellent converters of fodder/forage not preferred by other livestock species into very valuable sources of human nutrition and income. Asia and sub-Saharan Africa, where the goat population is concentrated, require more attention to improve goat production and productivity. These regions also house the highest human population living below the poverty line. There is a strong need for collaboration between research institutes and universities, and small-holder farmers for increasing goat production and productivity. Best practices and innovations around improved goat production are limited to specific geographical locations. Market development in goats is still in its infancy as compared to other livestock species. All the stakeholders of goat development (national and international development organizations, research institutes and universities, private sector players, government agencies and small-holder farmers) should work together in a public-private-producer-partnership (PPPP) model to enable higher production, for creating sustainable goat markets and for meeting the nutritional and income needs of resource-poor small-holder farmers.

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Figures

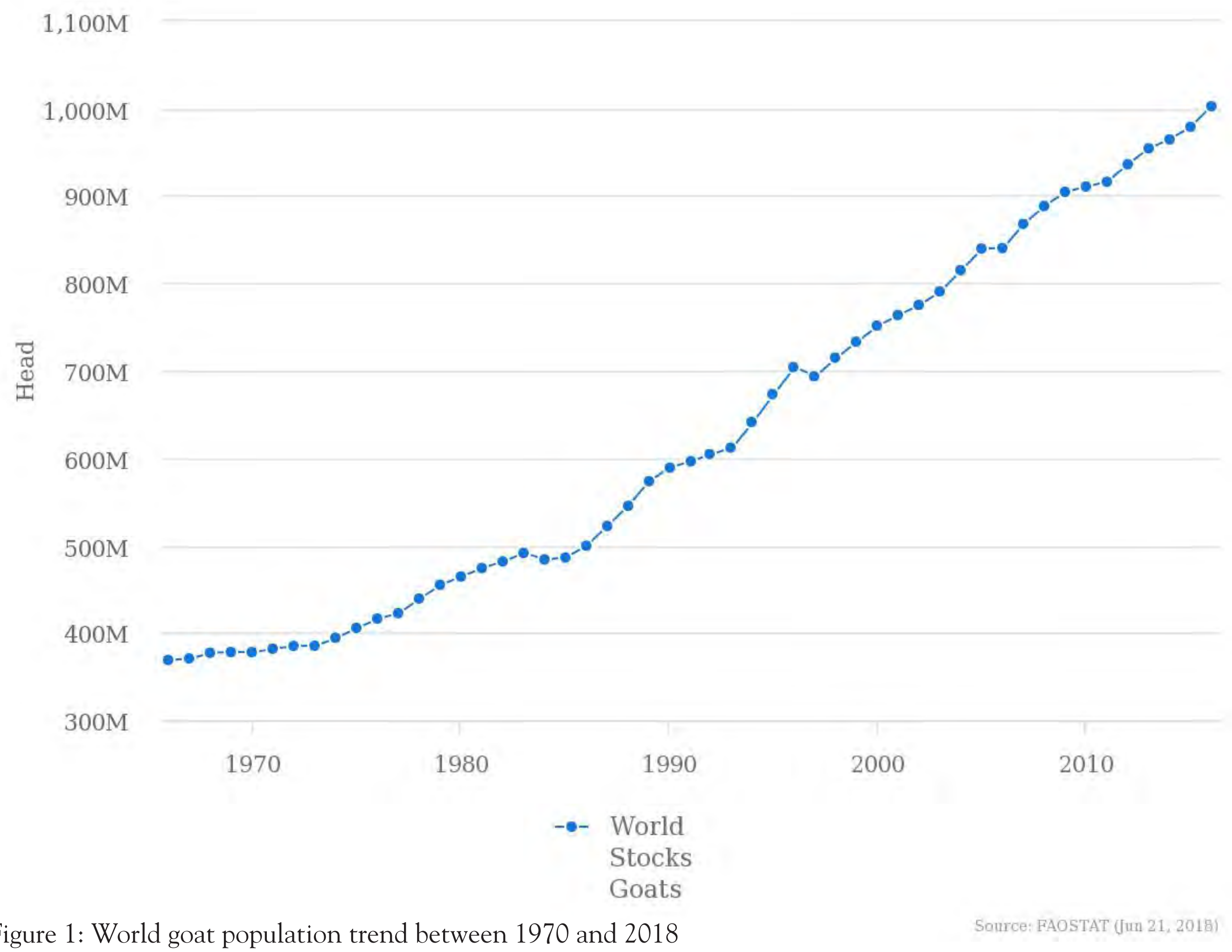

Figure 1: World goat population trend between 1970 and 2018

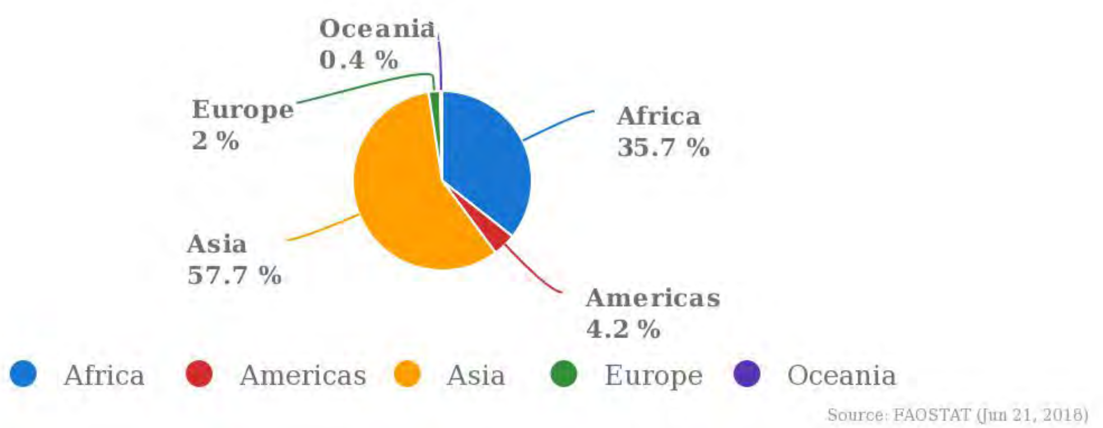

Figure 2: Production share of goats by region, average between 2000 and 2016

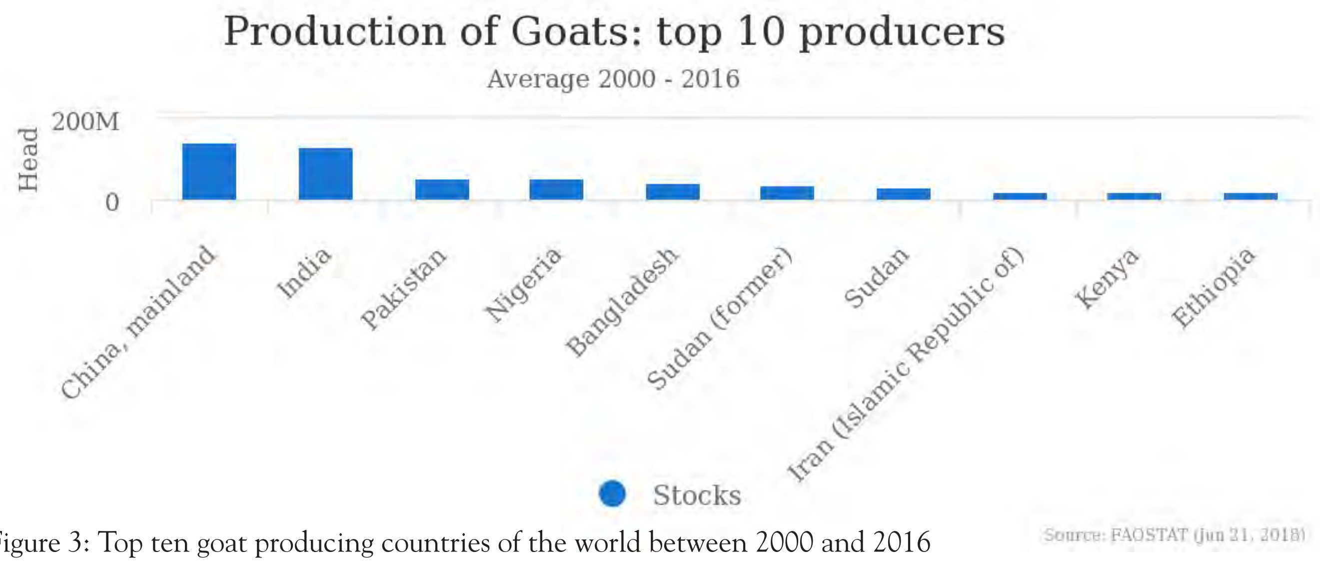

Figure 3: Top ten goat producing countries of the world between 2000 and 2016

Figure 4: Heifr International Goal and Theory of Change

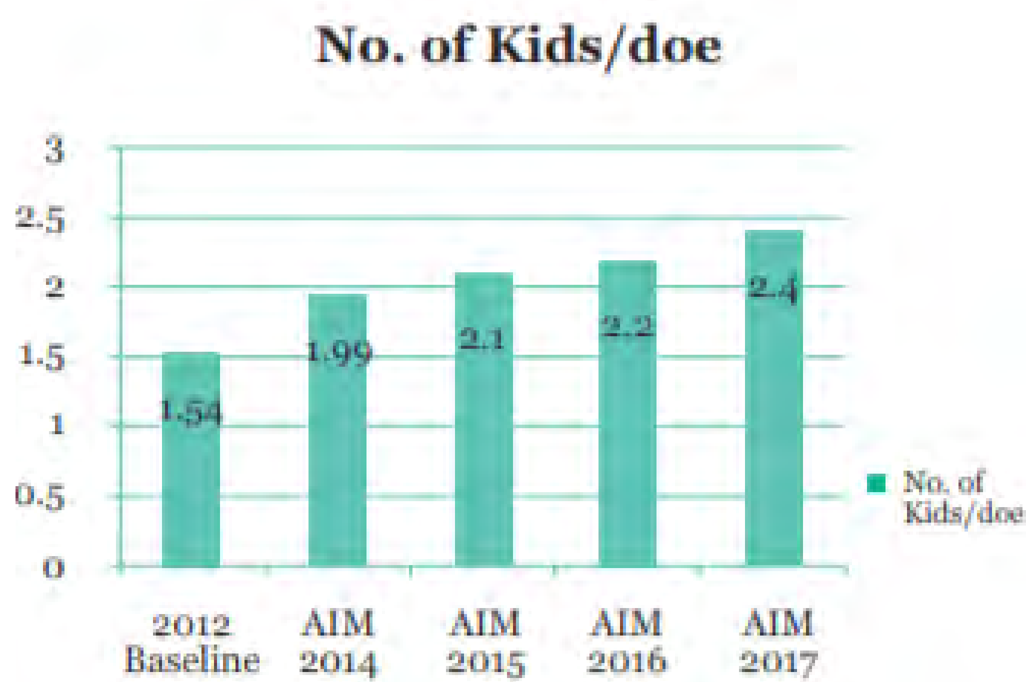

Figure 5: Increase is goat productivity (kids/doe/year) in Nepal

AIM: Annual Impact Monitoring

Figure 6: Number of active CAVEs, CAHWs and animal health promoters in Heifer country programs. Highlighted are the countries where Heifer is currently working (as of May 2018)

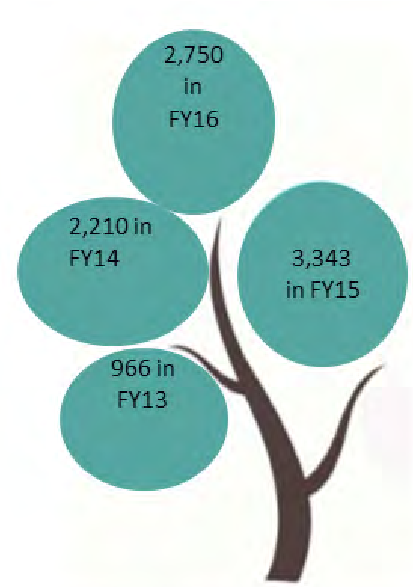

Figure 7: Fodder and forage plantation in Nepal in hectares

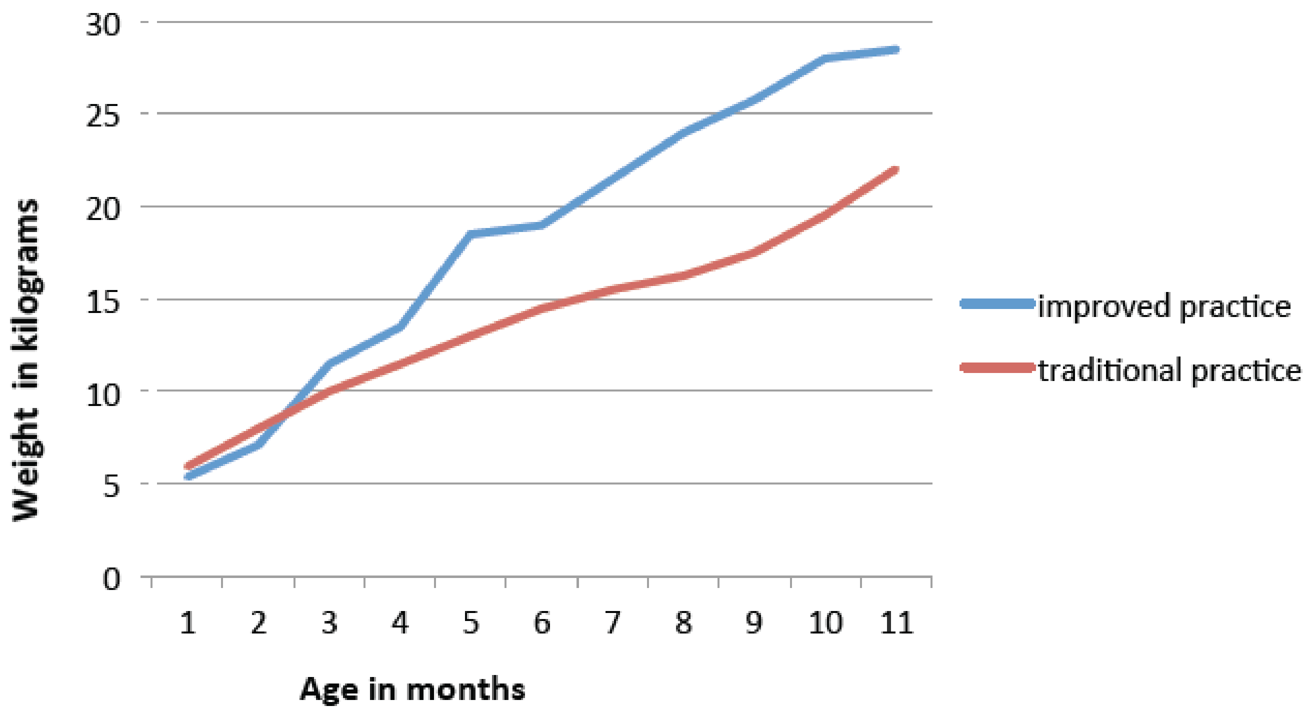

Figure 8: Growth trend of goats under improved vs. traditional system

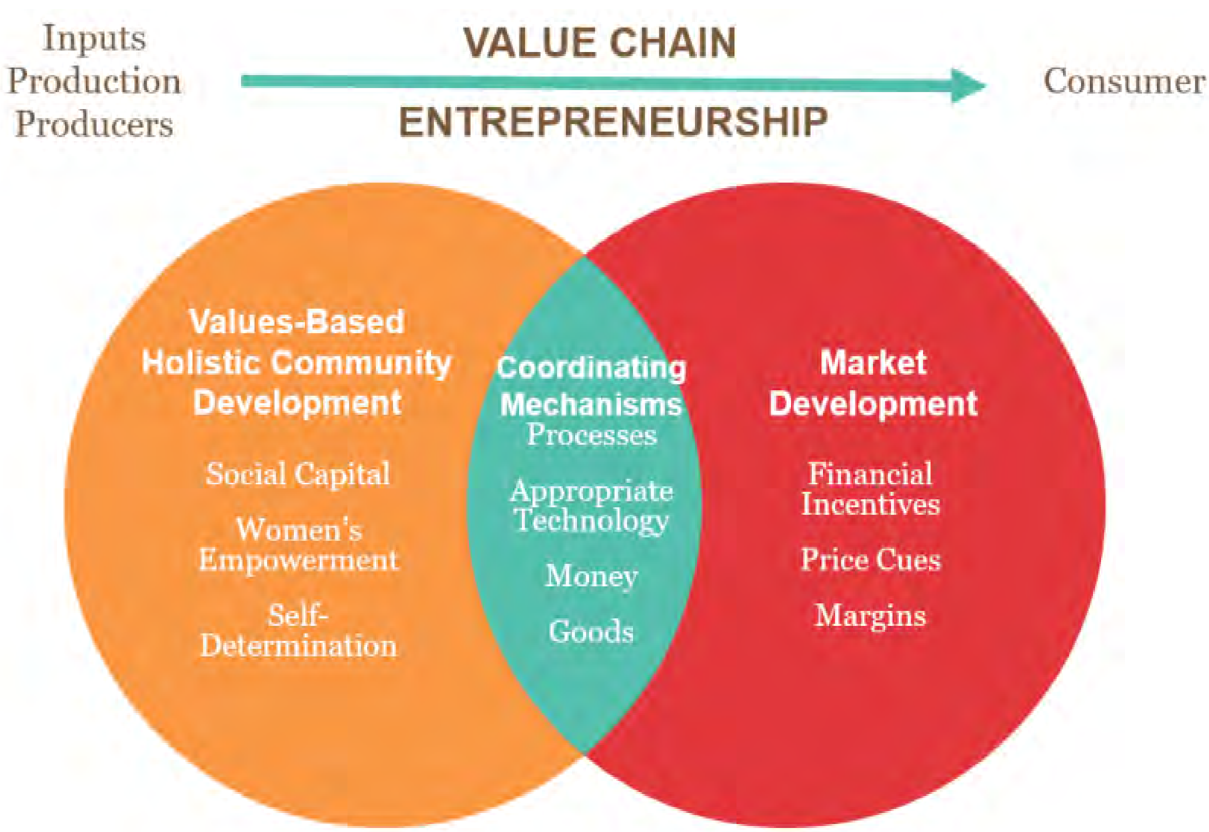

Figure 9: Heifer International's pro-poor wealth creating value chain approach

Table

Table 1: Analysis of Goat Breed Improvement (Jamnapari X Khari cross) in CIGIG, 2014

Parameters	1st year	2nd year	3rd year
1. Average daily weight gain till five months (g)			
Male kids	81.90 ± 22.38	88.67 ± 21.93	95.23 ± 18.79
Female kids	72.14 ± 13.80	81.21 ± 18.02	84.08 ± 17.01
2. Average weight at five months (kg)			
Male kids	14.12 ± 3.39	15.46 ± 3.52	16.36 ± 3.43
Female kids	12.53 ± 2.06	14.14 ± 2.68	14.92 ± 2.59
3. Average three months-litter weight (kg)			
First kidding	10.93 ± 4.14	12.13 ± 4.38	13.00 ± 4.35
Beyond first kidding	13.43 ± 5.42	14.70 ± 6.10	16.11 ± 5.12

(Source: Heifer International Nepal, CIGIG research report-unpublished, 2014)

BEST MANAGEMENT PRACTICES FOR INTERNAL PARASITE CONTROL IN SMALL RUMINANTS

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ABSTRACT

Internal parasites represent a significant obstacle to a profitable and sustainable US goat industry. According to USDA statistics, internal parasites accounted for the highest percentage of non-predatory losses of goats in 2015, resulting in 87,000 goat and kid deaths (USDA, 2017). All stakeholders in the Needs Assessment Survey for the upcoming NAHMS 2019 Goat Study ranked internal parasites as the most important disease concern (USDA, 2018). In some states, internal parasites are a year-round problem. In other states, they are a more seasonal challenge. Traditionally, parasite control methods relied heavily on antiparasitic drugs called anthelmintics or dewormers. Long-time use and sometimes misuse of these drugs has resulted in worm populations that are increasingly resistant to this approach, necessitating more holistic or integrated methods of parasite control. No single practice will likely control internal parasites in a goat herd. A combination of practices will usually be necessary to achieve a satisfactory level of control. This paper will discuss best management practices for controlling internal parasites in small ruminants, including pasture and grazing management, nutrition, zero grazing, and genetic selection, as well as more novel methods, such as targeted selective treatment (TST), bioactive forages (e.g. sericea lespedeza) and copper oxide wire particles. Because judicious use of anthelmintics is essential to effective parasite control, the paper will also discuss proper use of antiparasitic drugs, including how to measure and manage drug resistance.

INTRODUCTION

According to USDA statistics, internal parasites accounted for the highest percentage of non-predatory losses of goats in 2015, resulting in 87,000 goat and kid deaths (USDA, 2017). All stakeholders in the Needs Assessment Survey for the upcoming NAHMS 2019 Goat Study ranked internal parasites as the most important disease concern (USDA, 2018). In some states, internal parasites are a year-round problem. In other states, they are a more seasonal challenge. Traditionally, parasite control methods relied heavily on antiparasitic drugs called anthelmintics or dewormers. Long-time use and sometimes misuse of these drugs has resulted in worm populations that are increasingly resistant to this approach, necessitating more holistic or integrated methods of parasite control.

BEST MANAGEMENT PRACTICES

Biology

In order to control internal parasites in a goat herd, it is first necessary to understand the biology of the parasites and the host animals. Goats can be infected with a wide range of internal and external parasites. In fact, it is normal for goats to have some level of parasitic infection. *Haemonchus contortus* (barber pole worm) is the most pathogenic worm species and tends to be the most numerous parasite in warm, moist climates or during periods of warm, moist weather (in cooler climates). Other important parasites include *Teladorsagia* (*Ostertagia*; brown stomach worm) and *Trichostrongylus* (black scour worm).

The barber pole worm is found in the abomasum, where it feeds on blood, causing blood and protein loss. Anemia and "bottle jaw" (submandibular edema; accumulation of fluid under the jaw) are the most common signs of clinical infection. *Teladorsagia* and *Trichostrongylus* feed on intestinal tissue or fluids, causing digestive disturbances; diarrhea (scours) is common and production losses (e.g. reduced weight gain) are the primary concern.

Worm eggs are shed in the manure of infected goats. The cells inside the egg form larvae that hatch out of the egg. After hatching, the larvae feed on bacteria and go through two molts, before becoming infective third stage larvae (L3). The L3 make their way out of the manure onto the forage, where they are ingested by grazing goats. The length of time that the L3 can survive on pasture varies and is affected by environmental conditions. The life cycle of the barber pole worm is 17 to 21 days. The female is a prolific egg layer.

When environmental conditions are not conducive to their development, Ingested larvae develop into a "hypobiotic" or arrested stage, where they do not continue their development, but "hibernate" in the stomach or small intestine until environmental conditions improve. In fact, hypobiosis is the primary means by which parasites survive the winter months. Hot, dry weather can also cause parasites to undergo hypobiosis. In warm, wet climates, hypobiosis is less important, as year-round weather conditions may permit the parasites to complete their life cycles.

Copper oxide wire particles

Copper oxide wire particles (COWP) are tiny rods of copper oxide. They are a slow release form of copper versus copper sulfate, which is rapidly absorbed and potentially toxic, especially to sheep. While results can be variable, there is scientific evidence that COWP reduce barber pole worm infections in goats.

Recommended dosage is based on age, not weight. Doses that have proven effective are 0.5 to 1 g for kids and 1 to 2 g for mature goats. It is recommended that cattle boluses be re-packaged into smaller doses for goats. Some of the COWP boluses that are sold for goats contain more copper than is necessary for anthelmintic treatment, as these products are formulated to provide supplemental copper to goats whose diets are deficient in copper.

Similar results can be expected from different commercial sources of COWP (Burke et al, 2016). Administering COWP can be tricky. COWP can be administered with an appropriate size balling gun or a small PVC pipe with a wooden dowel. A little peanut butter will keep the bolus from falling out of the balling gun.

A recent study (with lambs) showed that when COWP were combined with albendazole (Valbazen®), treatment efficacy was more effective than either treatment alone (Burke et al, 2016). Unpublished data suggest a similar advantage when COWP are combined with levamisole (Burke et al, 2016).

Genetics

Genetics may offer the best long term solution to internal parasite control in small ruminants. Resistance is the ability of the animal to limit infection. Fecal egg count (FEC, reported as eggs per gram or EPG) is the primary measure of parasite resistance. Resilience is the ability of the animal to "tolerate" infection. Resilient animals will have lower (better) FAMACHA© scores and other indicators of superior health and performance. Resistance and resilience are both heritable traits and should respond favorably to selection.

Resistant animals will shed fewer eggs and have consistently lower fecal egg counts than their more susceptible herd mates. In the scientific literature, heritability estimates for fecal egg count in goats range from 0.2 to 0.33. A Lincoln University study estimated heritability of FEC in goats to be 0.11 ± 0.07 (Thomas et al, 2016).

More resistant bucks and does should produce more kids that are more resistant to parasites. Since the male influences most of the genetics in the herd, it is imperative that he demonstrate resistance to internal parasites. The most susceptible does in the herd should probably be culled and their offspring should not be saved for replacement.

To identify resistant goats in a herd, the fecal egg counts of similar animals should be compared. It is important that the parasite challenge be sufficient. A group average of at least 500 epg is recommended; 1000 epg is better. Allowances should be made for does raising multiples versus does raising singles or kids raised as multiples vs. singletons.

In the scientific literature, there are no estimates for the heritability of FAMACHA© scores in goats. The Lincoln University study estimated the heritability of FAMACHA© scores in goats to be 0.11 ± 0.08 (Thomas et al. 2016). FAMACHA© scores and other performance indicators can be used to select resilient animals. FAMACHA© scores and fecal egg counts tend to be correlated, so selection for more resilient animals should result in more resistant animals as well.

An alternative to selection is to raise more resistant/resilient breeds of goats. Breed comparison studies conducted at Tennessee State University showed that Spanish and Kiko goats were more worm resistant than Boer goats (Wang et al, 2017). Myotonic goats had the lowest fecal egg counts among the breed types compared (Wang et al, 2017). Crossbreeding may also aid in parasite control.

Management

Effective parasite control starts with good management, hygiene, and biosecurity. Overstocking and overgrazing are primary causes of clinical parasitism and outbreaks of coccidiosis. Feeders and water receptacles need to be kept free from fecal matter. Pens need to be kept dry. "Hot spots" on pastures need to be avoided. Hot spots are places where the risk of parasite infection is greater, such as wet areas and areas where animals congregate.

In some climates, kidding in the winter or fall can reduce parasitism, as environmental conditions may be less conducive to the development of parasites. Weaning age can impact parasite risk. Early-weaned kids are more susceptible to parasitic infection than those that remain with their dams for longer periods of time. If kids will be grazed, it is recommended that they not be weaned before 90 days. A recent study with lambs showed that delaying weaning until 120 days had a beneficial effect on parasite status (Campbell et al, 2017).

Zero grazing is a popular strategy for controlling worms, especially in lambs. In a zero grazing situation, there is no vegetation for grazing; thus, no opportunity for infection or re-infection. Animals can be kept in barns or in dry lots. Feed is brought to them and fed in feeders. Zero grazing is an especially good strategy for at-risk animals, such as growing kids and periparturient females. Coccidia can still be a risk, since it is transmitted in feces.

It is important not to introduce resistant worms to a farm. Newly acquired animals should be put in quarantine and administered dewormers from each dewormer class. Ideally, they should not be released from quarantine until their fecal egg counts are zero.

Managing dewormer resistance

Numerous studies have documented widespread resistance to all dewormers and dewormer classes (Crook et al, 2016; Schoenian et al, 2017). On average, resistance is highest in the benzimidazoles and avermectins and lower in moxidectin and levamisole. Some farms, especially those in the South, have resistance to all dewormers and dewormer classes. Resistance varies by geographic area and individual farm. Farms and geographic areas that have dewormed more frequently will likely have greater levels of resistance. Resistance is/was inevitable. All that producers can do is control the rate by which resistance develops.

Most producers start to suspect drug resistance when clinical signs persist and/or fecal egg counts remain high following a properly administered drug treatment. There are two ways to determine drug resistance: the fecal egg count reduction test (FECRT) and the DrenchRite® larval development assay (LDA).

With the FECRT, drug effectiveness is determined by comparing before and after (7-14 d) fecal egg counts or by comparing fecal egg counts from treated and untreated (control animals). The FECRT can be done with individual and pooled fecal samples, but the same animals must be sampled each time. Ten to 15 samples are needed for each drug. A minimum fecal egg count of 250 epg is needed. Much higher egg counts are preferred and will greatly improve accuracy. Fecal egg counts can be performed by veterinarians and diagnostic labs. Producers can learn to do their own fecal egg counts.

The DrenchRite® test determines resistance to all dewormer groups simultaneously from a single pooled fecal sample. Fecal samples from approximately 10 animals are needed. A minimum fecal egg count of 500 epg is required. In addition to determining resistance, the DrenchRite® test does a larvae ID, letting producers know which parasites are infecting their animals. Ray Kaplan's lab at the University of Georgia is the only place in North America that does the DrenchRite® test.

For both tests, if fecal egg count is reduced by less than 95 percent, drug resistance is present and steps need to be taken to manage resistance.

Nutrition

Nutrition is a very important aspect of internal parasite control. Supplemental protein, especially by-pass protein, has been well-documented to both reduce the negative effects of parasitism as well as bolster the immune system to prevent parasite infection. Incorporating legumes into pastures is one way to provide additional protein. Goats can also be supplemented with a source of by-pass protein, such as cottonseed meal. Young animals have higher protein requirements and are more subject to protein undernutrition. Since nutrition requirements do not factor in the effects of parasitism, it is often necessary to feed protein in excess of nutrient requirements in order to meet requirements and/or derive additional benefit.

In addition to protein and energy, minerals and vitamins are also important to immune system function. It is generally recommended that grazing animals be supplemented with minerals and vitamins. A loose formulation is preferred to a block. Prices and quality of minerals vary. Consider mineral content and recommended consumption when deciding which product to buy. Mineral supplements should contain sufficient levels of minerals which are deficient in your area.

Goats in better body condition are better able withstand the effects of parasitism. Body condition score is part of the Five Point Check© and should be used as a deworming criteria. Goats should be handled regularly to determine body condition score. Those below 2 (scale 1 to 5) will be at greater risk for parasitism and should be managed appropriately.

Parasite and grazing management

Since goats get infected with infective worm larvae when they graze, pasture and grazing management will obviously have a large effect on level of infection. When implemented correctly, rotational grazing can decrease exposure to infective worm larvae. If goats are forced to continuously graze, they may re-graze the same areas, potentially re-infecting themselves with parasites. Rotational grazing allows producers to control how short plants are graze, the length of time animals graze a paddock, and the length of time between grazing events. The majority of infective worm larvae is found in the first 3 inches of vegetation. For this reason, pastures should not be grazed shorter than 3-4 inches. Because it takes 4-5 days for worm eggs to develop into infective third stage larvae (L3), it is recommended that animals be moved frequently, e.g. every few days.

The use of annual forages can reduce the risk of parasite infection, as not only do they offer clean grazing (initially), but grazing height is usually higher. Allowing goats to browse on woody plant species encourages higher grazing and less chance of picking up infective worm larvae. In fact, browsing is the natural means by which goats avoid getting infected with parasites. They are not intended to graze, like sheep and cattle. This is why their development of immunity is inferior to other species.

Multi-species grazing can be another effective grazing strategy, as cattle and horses generally do not share the same parasites as goats (and sheep). Mixed species grazing can also lead to better pasture utilization and may lead to improved predator protection.

Proper use of dewormers

Anthelmintics (dewormers) are a valuable, but limited resource. It is important that they be used properly to ensure their continued effectiveness. There are three classes of dewormers commonly used to treat goats (Table 1). Dewormers are separated into classes based on their chemistries and common modes of action. Dewormers in the same class can exhibit cross-resistance.

Drug class	Drug ingredients	Tradenames
Benzimidazoles	Fenbendazole* Albendazole* Oxydendazole	SafeGuard® Valbazen® Synanthic®
Macrocylic lactones	Ivermectin Eprinomectin Doramectin Moxidectin	Ivomec® Eprinex® Dectomax® Cydectin®, Quest®
Nicotinic agonists	Levamisole Morantel* Pyrantel	Prohibit®, Leva-Med® Rumatel®, Positive Pellet Strongid®

*FDA-approved for goats

Proper use of dewormers starts with giving the proper dose of medicine, as under-dosing is one of the primary causes of drug resistance. Dosage should be based on actual (accurate) weights. If scales are not available, weigh tapes and weigh calculators can be used for dairy and meat goats, respectively. Because goats metabolize drugs more quickly, it is recommended that they be given 1.5-2 x the sheep dose. Most of the drugs have wide margins of safety. Levamisole has the narrowest margin of safety (3x dose); so care should be taken not to overdose it. It should be given to goats at 1.5x the sheep dose.

All dewormers should be administered orally using an oral dosing syringe. Drugs should be delivered over the tongue, deep into the oral cavity. Depositing a drug into the mouth may cause the drug to bypass the rumen, which will reduce effectiveness. Withholding feed for 12-24 hours may increase the efficacy of treatment with the benzimidazoles and/or ivermectin; however, feed should not be withheld from certain classes of animals, e.g. does in late gestation. Repeat (multi-day) dosing is another strategy that may increase efficacy. Long-acting preparations should not be used, as their use accelerates drug resistance.

It is no longer recommended that dewormers be rotated after use. Combination treatments are now recommended as a means to prolong dewormer effectiveness. A combination treatment is when multiple dewormers are administered at the same time. Combination dewormers are available in other countries, but none are available in the US. To administer a combination treatment, each dewormer should be administered sequentially (at full dose) in a separate dosing syringe. The most potent drug from each drug class is given. The recommended combination treatment is Albendazole (Valbazen®) + moxidectin (Cydectin®) + levamisole (Prohibit®, Leva-Med®). Dewormers should not be mixed, as they are not chemically compatible.

As none of these dewormers are FDA-approved for goats, veterinary approval is required for this strategy. In fact, any time a dewormer that is not labeled for goats is given or a labeled product is given at a higher dose, veterinary approval is required. Goat producers need to have a valid Veterinarian-Client-Patient Relationship (VCPR) in order to use drugs extra-label, even if the drugs can be purchased over-the-counter. It is not possible to establish a VCPR online or via the telephone.

It is essential that combination treatments only be administered to clinically-parasitized animals, as determined by the FAMACHA© system, Five Point Check®, or other performance indicators. If combination treatments are administered to all animals in a group or herd, resistance will develop rapidly to all drugs in the combination treatment. The withdrawal period of a combination treatment is the withdrawal period of the dewormer with the longest withdrawal period (usually Cydectin®).

Sericea lespedeza

Sericea lespedeza *Lespedeza cuneata*) is a tannin-rich warm season perennial legume. It has been called "poor man's alfalfa" because it grows on marginal soils with minimal inputs. It is especially well-adapted to the warm, moist climate of the southern and eastern US. However, it is important to note that sericea lespedeza is classified as a noxious weed in some states (Kansas and Missouri) and is considered weedy or invasive in some 30 states.

Research conducted over the past 10-15 years has demonstrated that sericea lespedeza has anti-parasitic effects against the barber pole worm, as well as coccidia (*Eimeria* spp.). It can be grazed, fed as hay, processed into whole plant or leaf meal pellets, or ensiled; processing does not seem to alter its anti-parasitic properties. Including SL in the diet of goats has the potential to reduce parasitism.

Targeted selective treatment (TST)

Targeted selective treatment is now widely accepted as a means to slow the rate by which worms develop resistance to the drugs. TST means only deworming those animals that require treatment (or would benefit from treatment). TST reduces deworming frequency and increases "refugia." Refugia are worms that have not been exposed to drug treatment. They are par amount to maintaining dewormer efficacy.

Several tools exist for implementing TST on farms. The FAMACHA© eye anemia system identifies animals which require deworming by using a score card to estimate the level of anemia in the animal. Anemia (pale mucous membranes) is the primary symptom of the barber pole worm. The color of the lower eyelid is examined and matched to the FAMACHA© scale; 1-5, with 1 being red (no anemia), 3 being pink (marginal) and 5 being white (very anemic). In order to receive a FAMACHA© card, producers must participate in an approved training.

It is generally recommended that goats with FAMACHA© scores of 1 and 2 not be treated, whereas goats with FAMACHA© scores of 4, or 5 be treated. While some producers don't routinely treat FAMACHA© scores 3, it is advised that kids and periparturient does with FAMACHA© scores of 3 be treated.

Because the FAMACHA© system is only effective for blood feeding parasites, such as the barber pole worm, the Five Point Check© was developed as an extension of the FAMACHA© system. It incorporates five check points on the animal's body, which allows assessment for all parasites commonly affecting small ruminants. The five check points are 1) eye; 2) jaw; 3) back; 4) tail; and 5) nose. The eye (lower eye lid) [1] is examined for determination of FAMACHA© score. The jaw [2] is examined for presence of bottle jaw (accumulation of fluid under the jaw). The back [3] is examined to determine body condition score (1-5). The tail [4] is observed for scours (diarrhea). Poor body condition score and diarrhea are both signs of parasitism, especially with the scour-causing worms. The nose [5] is the final checkpoint. A nasal discharge may be indicative of nasal bots (bot flies) in sheep. Goat producers can replace the nose checkpoint with a coat condition score [5a], as a poor quality hair coat could be indicative of disease. The Five Point Check® is especially useful for determining the need to deworm goats with FAMACHA© scores of 3.

In situations where the barber pole worm is not the primary parasite, other indicators of parasitism can be used to make deworming decisions. The “Happy Factor” is a model whereby an animal’s growth performance is matched to a mathematical prediction of its performance. If the animal fails to reach its performance target, it is dewormed. The “Happy Factor” can be applied in a less sophisticated way. A farm in Maryland received a SARE grant to compare average daily gain (ADG) to FAMACHA© for making deworming decisions. In the first year of their study, ADG was in agreement with FAMACHA© scores 70 percent of the time.

Other performance indicators can be used to determine deworming need. In dairy goats, it is common to deworm does with higher performance, as they are under the most stress. UK researchers used litter size as a criteria for managing the parasite risk of periparturient ewes, recognizing that single-bearing ewes are at less risk for parasitism than twin-bearing ewes, but that triplet-bearing ewes are at the greatest risk. Australian researchers have used body condition score as a criteria for deworming, only deworming ewes at the lowest end of the condition scale. Fecal egg counts can be an indicator of parasitism, but they should only be used in combination with other criteria. In LatinAMerica, researchers have combined FAMACHA© scores with FEC to make deworming decisions.

Other

Duddingtonia flagrans is a naturally occurring fungus with anti-parasitic effects. When the spores are fed to livestock, they pass through the digestive system into the manure, where they are activated when parasitic worm larvae become active. They trap, paralyze and kill worm larvae. They have no effect on the host animal. It is anticipated that the fungus (BioWorma) will be licensed for use in the US in 2018, giving producers another tool for controlling internal parasites (The Land, 2018).

No other natural remedies have been determined to be consistently effective at controlling internal parasites in small ruminants. Organic producers and those who use natural remedies are encouraged to continually monitor their animals and administer effective dewormers to those that are clinically parasitized.

CONCLUSION

No single practice will likely control internal parasites in a goat herd. A combination of practices will usually be necessary to achieve a satisfactory level of parasite control.

AMERICAN CONSORTIUM FOR SMALL RUMINANT PARASITE CONTROL

The Southern Consortium for Small Ruminant Parasite Control (ACSPRC) was organized in 2000. The name was changed to American as the membership expanded. The consortium is a group of scientists, veterinarians, and extension specialists devoted to (1) developing novel methods for sustainable control of gastro-intestinal nematodes in small ruminants and (2) educating the stakeholders in the small ruminant industry on the most up-to-date methods and recommendations for control of gastrointestinal nematodes.

Soon after being organized, the consortium established a web site to disseminate research-based information to producers and those who advise producers. The web site is intended to be the go-to place for information about parasite control in small ruminants. The consortium is in the process of developing a set of twelve fact sheets, “Best Management Practices for Controlling Internal Parasites in Small Ruminants.” All fact sheets will be written and reviewed by members of the consortium. From August 2013-November 2017, the consortium published 58 “Timely Topics” to the web site. These articles were written by members of the consortium and are archived on the web site. They are also in the process of being developed as fact sheets. The web site also includes an image gallery and video library. The resources on the ACSRPC web site are for information purposes only and do not replace veterinary advice.

www.wormx.info

www.acsrpc.org

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MAJOR CHALLENGES OF US GOAT PRODUCERS AND WAY FORWARD

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The Three Major Limiting Factors Facing World Food Production

The world is faced with 3 major bottleneck resources that will affect world food production and our ability to feed the world going forward to 2050. Those 3 limiting resources are: Arable Land – There is a direct connection between available arable land and world food security. The world's arable land is decreasing constantly for a variety of reasons. Water – This is a very limiting resource that limits production in all parts of the world. Clean, safe water for crops and livestock is a critical production component. Ag Talent – While this is a fixable factor limiting production, it is the most limiting factor we have right now. There is a major shortage of well educated, knowledgeable and capable people who can manage crops and livestock. Goat production is no exception to this problem as the age-old perceptions about goats even among livestock people still persist. The story needs to change and change shortly! We need to encourage quality management utilizing the latest technology which will utilize goat genetics to produce high quality protein for human consumption. Further, the associated products derived from goat production including premium fabrics, health and beauty products are both in high demand. All these products result from utilizing forages that otherwise would likely go unused.

US Supply & Demand Factors Affecting Goat Production

Imports – We currently import the majority of goat meat consumed in the US and the import amount is increasing annually. Imported goat meat is both helpful and harmful. It is helpful in that it provides market fulfillment that covers our production shortage. It is harmful in that it is often lower quality and it further undercuts our production based on external factors such as the value of the dollar.

Markets – Our markets are unstructured and lack accurate price discovery in many cases, leaving producers without adequate financial returns. While marketing goats directly from the farm to consumers is both economically efficient as well as providing immediate trace back, it also comes with the lack of price information that is published thereby informing others as to what current pricing was for a particular commodity on a particular day. This lack of information results in many producers either over selling or more often under selling their production. We can look up prices for most categories of goats at a few major auctions immediately on the Internet. Those auctions are often a long distance from a producer and thus they create their own price and it is not shared. This situation results in significant price variations that often leave producers with less income and net profit than otherwise would be available.

Fragmented Industry – Our US Industry is seriously fragmented, leaving producers without adequate drugs, vaccines, and antibiotics approved for use in goats. These shortages result in lower quality animal welfare, higher losses and lower production. Without a voice at the national table, goats have long been overlooked and not included in key decisions making involving these products as well as important relevant research. Further fragmentation results in goats are not being a recognized source for seed stock, slaughter, or distribution channel for live animals, meat or other goat related products. There is great value in a well-organized national organization that provides industry oversight, representation and leadership to move the industry forward on an equal basis with other livestock organizations. The American Goat Federation is that voice! It is the voice of all goat producers in the U.S. It does represent every producer in all aspects of goat production. For example, we are at the table at the APHIS Industry Sector meetings each year. Our concerns are heard and are being addressed. Your input is not only taken but desired and even demanded so we can appropriately represent your needs.

Livestock Production Opposition

Extremist Groups – There are numerous groups that wish to eliminate all livestock production in the US. They brand livestock production as cruelty to animals, unsafe production methods; meat is bad for your health and a variety of other bogus reasons. These groups are both well financed and very active. They represent a profound threat to the future of animal production as we know it. The American Goat Federation provides professional representation on these issues and have a joint voice with other animal industry groups giving a voice of reason. The Carbon Footprint argument is one example of a strategy used to reduce or eliminate livestock production via the emission of harmful gases from livestock production. They use bogus science to back their claims of environmental damage from livestock. Animal Welfare – The gap continues to grow wider separating production agricultural producers from consumers. Many practices long used to produce healthy livestock and quality meat products are now under attack due to ignorance. Unfortunately, there are just enough cases of real animal abuse to fuel the continuation of the animal welfare debate. Such cases result in paradigm shifts that create negative welfare for animals – such as wild horses in the west.

Change is Hard!

Nobody likes to be changed! Change is critical! It allows us to discover our untapped potential. Change is often disruptive and often comes from outside. The goat industry is undergoing change with such change needing to continue at an increasing rate. We lag behind our sister animal groups on many fronts including genomics and research. There are great examples of disrupting innovators includingAMazon the world's largest retailer that has no inventory, Uber – the fastest growing transportation group that owns no cars, Airbnb – which owns no homes. Disrupters in the goat industry – Genomics, EBV's, autonomous vehicles, drones, robotics, RFID (Radio Frequency Identification Device) & Internet Marketing all provide profound changes and opportunities immediately! We need to adopt all proven current technology to increase production, improve profit margins, maximize animal welfare and all other quality industry improvements. We desperately need to use social media to tell our story – Goats are one of the most productive animals on earth, they improve the environment, they do not require large amounts of feed concentrates and they provide great companion animals. We need to launch a major offensive effort telling the world about the value of goats in the economy, environment and healthy food. It is imperative that we produce our products using the best technology while providing top notch food security. There are great potential advantages for goats in the future as we are not in the sights of oppression groups. We have made great progress on the Scrapie and Q Fever fronts. Scrapie is down to the lowest level in years and if we can support the surveillance program we should be able to return to exporting our animals in the near future. Pay attention to the program requirements, plastic tag your animals! Observe your animals and report any suspects – we can clean this disease up. Q Fever is a manageable disease that we can also deal with as we move forward in the future. Without proper knowledge and management this disease can be costly! Watch for our AGF Posters that will give you the information you need to deal with both issues!

Support the American Goat Federation – Your voice in Washington, D.C. Your Industry Voice.

CURRENT SITUATION AND FUTURE PROSPECTS OF THE US GOAT INDUSTRY

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ABSTRACT

Current demand for goat meat in the US outstrips domestic supply. There is great potential for industry growth in the meat and dairy sectors. Whereas fiber prices have improved, loss of animals and market resources, labor costs for shearing, and lack of animal genetic resources will prevent growth in the short term. As producers age, there is opportunity for new producers to enter the marketplace. Significant challenges exist, such as access to local markets and abattoirs, dewormer resistant parasites, and feed costs. Establishing goat feedlots can increase meat supply and industry commercialization. Technologies used for cattle will be expanded for use in goats with interconnected sensors collecting health and production data. The field of genetic improvement will change from current production testing to identifying superior animals at an early age using DNA analysis. A quality assurance program is needed to address animal welfare issues and promote consumption of domestic products to consumers.

I. INDUSTRY BACKGROUND

The US goat industry has been strong for the last 20 years and has great potential for growth and profit in the future for meat, milk, or fiber (mohair and cashmere) commodities. The goat industry has been blessed with strong market demand, but lagging production has caused high domestic commodity prices resulting in the need to import goat products to meet demand. We need to understand how the goat industry has developed to its current state before we can predict the future of the industry.

Historically, the US meat goat industry was concentrated in the Edwards Plateau region of Texas. In 1987, that region was home to 73% of the US goat population (US Agricultural Statistics, 1987). Since then, Texas goat numbers have decreased while goat numbers have increased in other states; however, Texas still accounts for 38% of today's US goat population (USDA NASS, 2018b). Angora goats were once not only a source of fiber but also the main source of goat meat and numbered 1.4 million head from 1909 to 1915. Angora goat numbers increased to 3.6 million head in 1931 and peaked at 4.6 million head in 1965 before shrinking to 2 million head in the 1980s (Pinkerton, 1991) followed by a rapid decline to present numbers of only 150,000 head after the cessation of the Wool and Mohair act in 1993. Meat goats were not enumerated until the 2005 agricultural census. Prior to that, most Texas ranchers in the Edwards Plateau region had some Spanish goats for brush and weed control, gave them minimal management, and often had little idea of the number of goats on their ranch, but regularly marketed excess animals for meat.

The introduction of the South African Boer goat breed in 1994 rapidly changed the direction of the US meat goat industry. LandCorp Farming NZ introduced the Boer goat breed to the US and merchandised the new breed especially to non-traditional goat producers who were persuaded to pay high prices for these animals. The Boer goat has since become the most popular breed of goat for meat production in the US and has fueled the growth and expansion of the meat goat industry.

II. CURRENT PRODUCTION AND OUTLOOK

Total US goat numbers are estimated to be 2.62 million as of January 2018 (USDA NASS, 2018b; Figure 1) comprising 380,000 head of dairy goats (a slow increase over the last decade) and 142,000 Angora goats with the remainder being meat goats. Total goat numbers have declined by 15.3% in the last 10 years, almost all due to the 21.5% decline in meat goat numbers. Southern states, where goat numbers had grown for the previous 20 years, experienced the largest reduction in goat numbers while the goat populations in northern states increased.

Speculation on reasons for the overall decrease in meat goat numbers includes sell off of breeding stock due to the recession in 2007, the prolonged drought in the southern US, dewormer resistance increasing production costs and mortality, and hobby producers who grew tired of taking care of animals liquidating their herds.

In 2017, 488,000 goats were slaughtered in federally inspected plants and 108,900 in other plants such as state inspected facilities; however, not all states report state inspected goat slaughter (USDA NASS, 2018a, Figure 2). There is substantial on-farm slaughter of goats but exact numbers are unknown. Pinkerton and McMillin (personal communication) estimate in addition to federal and state harvest figures, another 120,000 goats were slaughtered using data from the USDA National Animal Health Monitoring System (NAHMS) reported kid crop, replacements, and kid mortality loss. Adding this estimate to reported numbers gives a total of slaughter of 717,000 head. In 2017, goat meat imports totaled 20,952 metric tons worth $143,737,000 (USDA FAS GATS database accessed July 27, 2018). This equates to 1.35 million 34-pound goat carcasses. Goat meat imports provide 70.6% of the goat meat consumed in the US. This is beneficial in that imported meat feeds the demand and maintains the market from year to year. However, it also represents goats that could be produced in the US with money retained in the US. Meat goat budgets conservatively estimate a profit of $21 per hd. Assuming 6 goats can replace one cow, raising goats would return $126 in profit as compared to a $38 loss as found in the most recent cow-calf enterprise budget released by Oklahoma State University (Anon, 2018).

Dairy goat numbers stand at 380,000, a 5.5% increase from 2002 (USDA NASS, 2018b). In 2017, there were 504 goat herds on DHI test representing 19,919 head with an average herd size of 39 goats. Average milk production was 1,901 pounds for a 305-day lactation, a 9% increase from 1,750 pounds in 1996 (The Council on Dairy Cattle Breeding database searched July 27, 2018). Milk goats are concentrated in CA, WI, IA and New England due to availability of small scale milk processing facilities (2012 Census of Agriculture; Figure 3). There were 308 million pounds of goat milk produced in 2010. Unfortunately, no data is currently being collected on goat milk production. There are increasing numbers of large goat dairies, replacing small hobby and cottage industry size dairies, to provide larger quantities of milk necessary for commercial processing. The biggest problem for the dairy goat industry is the dumping of cheap frozen curd from other countries into the US market that is mixed with fresh goat milk to make an acceptable cheese product. This is estimated to reduce goat milk prices by $2/cwt.

The dairy goat industry will increasingly migrate toward larger dairies, but cottage and hobby size dairies will remain numerous and important, providing registered stock and show quality animals. There are numerous US cheese makers that produce gourmet goat cheeses of equal or better quality than imported goat cheeses. The industry can compete with European dairy goat milk products and there is a future in domestic goat cheese production and the milk production required to support that portion of the industry. There is potential to produce a goat milk based infant formula that would create a tremendous market for goat milk and the industry should pursue development of such a formula. Dairy goat producers are learning how to raise male kids to profit from the strong goat meat market. One problem both the meat and dairy goat industries must address in the future is Johne's disease.

The price of mohair has been in excess of $8/pound, (USDA, FSA 2018) a price that makes mohair production economic, but the loss of infrastructure and difficulty of finding shearers will likely prevent much growth in the industry. Cashmere is selling for $25 to 35 per pound; however, there is little interest in producing cashmere because goats need to be sheared when the weather is cold and harvest of the fiber is labor intensive. Genetics for high levels of cashmere production are scarce in the US.

A. Who Will Raise Goats in the Future?

According to the US Ag Census of 2012, the average age of a sheep or goat producer was 55 years old. About 75% of sheep and goats were raised on farms of less than 49 acres and small ruminants were not the main source of income in those households (USDA NASS, 2015). Approximately two-thirds of US goats are raised in herds of less than 100 animals and an estimated 29.7% are in herds of less than 20 animals, accounting for 80% of all goat operations (USDA APHIS VS, 2017). Contrarily, Ostia et al. (2016), conducted a survey of goat producers who were more commercial in nature and showed an average of 62 goats per meat goat farm, still a much smaller scale of production than seen in the beef and swine industries.

The advancing average age of livestock producers will open opportunities for younger operators to enter the business. However, economic barriers of land and facility lease or purchase, cost of stock, and health care and feed costs will prevent many new producers from establishing large goat herds, particularly meat goats. Thus, the current small ruminant raising situation will likely continue where the majority of US goats are raised on small farms. A six-year goat market study conducted by Texas A&M AgriLife found producers received little to no premium for meat goats sold in lots above 6 to 12 animals, underscoring the appeal of goat raising for small scale producers (Byrns, 2016).

The demographics of who farms and raises livestock in america are also changing as more minority groups begin or expand farming activities. For example, from 2007 to 2012 the number of Hispanic principal farm operators increased by 21% (USDA NASS, 2014). Sheep and goat farming was the principal commodity on 6% of those farms. Diversity of goat producers is expected to increase in the future along with the shifting demographics of the US population and growth of foreign-born US residents (Passel and Cohn, 2008).

B. Increasing Current Productivity

The US currently imports a substantial amount of goat meat due to an inadequate domestic supply. This offers great opportunity for US goat producers to increase production. Production can be increased through adding animal numbers or increasing productivity per animal. Additional goats raised can come about either by increasing herd size of existing producers, or by increasing the number of producers. Producing more meat, milk, or fiber per animal can be done through a variety of means with technologies and recommendations already present. This includes improvement in management, herd health, use of selection indices, etc. In the arena of meat production, simply selling meat goats at a higher live weight would be beneficial. A heavier animal would produce more meat; however, current market preferences for whole carcass purchase would have to be adjusted. Should acceptance of supermarket cuts of goat meat such as chops, roasts, leg, or ground product grow, an increase in live weight of slaughter goats would be warranted. Such cuts could also be used in precooked meats or as part of “meal kits” for consumers to cook at home. Research funded by the industry on consumer acceptance, taste, cooking methods, and the like would support this growth.

New goat producers may be established livestock herdsmen who switch from another species to raising goats, add goats to their existing species, or people with little to no livestock experience. In all cases there will continue to be a need for producer education. Increasingly producers turn to on-line resources for information. A number of “apps” are available that can assist farmers with inventory, drug treatment, management, etc. On-line education programs, such as those of Langston University (goats.langston.edu under Training), offer information and may provide a means of receiving “certification” that some producers use as a marketing tool. No matter the on-line information source, it must have correct and current information. New educational or training programs will be needed that deal with emerging topics addressed elsewhere such as increased use of genomics in animal selection. New advances in genetic and other technologies will call for training not only of producers but also those persons supporting the US goat industry, i.e., extension personnel, veterinarians, other farmer educators, and university personnel.

III. INDUSTRY CHALLENGES

An industry survey in 2013 identified 4 important challenges to goat production: high cost of goat production, lack of clear marketing system for goats, lack of goat meat processor close to areas of large production, and internal parasites (Gillespie et al., 2013). Higher goat prices and reduced corn prices since then have alleviated the first problem. Goats, because they are such a small market as compared to other meat producing species, will always have market problems. However, when goat numbers increase in an area, goat buyers will come. It is worthwhile to investigate goat marketing options in an area. There has been a reduction in the number of small scale abattoirs for all animal species as demand for their services has decreased. Some states allow home slaughter that facilitates direct farm sales to consumers who wish to do their own butchering or purchase animals for religious or other festivals. The majority of goats are processed in states near large urban centers having great demand for goat meat, primarily along the east coast and upper Midwest. Approximately 25% of all goats slaughtered in federally inspected plants are processed in New Jersey, necessitating transporting goats from distant production areas (USDA NASS, 2018a; Figure 4). Parasites have become a major problem as goats have moved into more humid areas conducive to parasite survival. There is a consortium (American Consortium for Small Ruminant Parasite Control, https://www.wormx.info/) conducting collaborative research and developing educational materials to address the parasite problems of goats.

A. Integrating Goats with Other Livestock

Goats will continue to be integrated into many other enterprises to efficiently utilize natural resources or increase monetary returns. One of the best known and publicized use of goats is for vegetation management. Private companies, government agencies, and local municipalities all have used goats to economically control weeds and brush to reduce machinery costs or herbicide use due to public pressure. In many situations, goats may be the only economically viable method. There have been few rent-a goat operations in the US with labor costs, fencing, and predator losses being major constraints. Some operations herd goats with experienced hired shepherds from Peru, for example, but entry into the US for such work has become much more difficult and limited the economic viability of these operations. In some areas, portable electric fencing is suitable but large expanses of territory or difficult terrain can prevent its use. Management and daily electric fence monitoring and maintenance may also be cost prohibitive. However, when fencing is needed, portable electric fence may be the only viable option because the cost and labor needed to establish a conventional fence is four times greater than that required for electric fencing.

Grazing goats with cattle is economically viable because goats consume brush and weeds that cattle do not, which helps producers realize additional savings on herbicide, burning or mechanical weed control no longer needed. One farmer practicing intensive rotational grazing uses one wire on pigtail posts to control his cattle but only has the perimeter fence built to hold goats. He rotates his cattle among pastures but lets the goats go wherever they wish to locate weeds and brush. Several cattle operations in Kansas are using goats to control sericea lespedeza to utilize this unwanted plant and rehabilitate pastures. Other forage species that can be controlled by goats include salt cedar, poison ivy, and red cedar, among others. Cattle producers can modify fences to control goats by adding 3 strands of barbed wire, adding low net wire labeled 8-32-12 having a 12" spacing of vertical wire strands, or adding two strands of electric wire in front of a conventional barbed wire fence (Hart and Potraz, 2015).

Goats can be used to consume cover crops, especially on homesteads or vegetable production farms with small acreages, converting the forage to manure and reducing the need for tractor operations to kill the cover crop and prepare the land for planting. The number of small farms for local food production is increasing and cover crops have been found to be very useful to condition the soil. The small size of goats fits well with homestead production of milk or meat.

B. Feedlot Goat Meat Production

Most meat producing livestock and poultry in the US are raised in some form of intensive feeding operation, such as drylots for cattle and some lambs and other feeding facilities for swine and poultry. However, large-scale feedlot or drylot production of goats, while being done in other countries, has not been practiced in the US. Feedlot finishing of goats has great potential to increase meat production while reducing investment required for land; however, management and nutrition concerns need to be addressed. For economic viability, low-cost feedstuffs such as byproducts or crop residues must be utilized.

Feedlot operations could purchase weaned stock directly from farmers for finishing, purchase from producers who buy kids and "background" them in a manner similar to the beef industry, or could raise does and produce their own kids in a vertically integrated concept. In the latter system, early weaning and creep feeding are essential to reduce feed costs. It is very important to have a cheap source of feed, such as feed byproducts, for the economic success of the feedlot. Intensive reproduction management is possible, facilitating genetic progress through artificial insemination and progeny testing as well as the ability to time kidding to meet holiday market demand. There should be lower kid losses, especially due to predators and parasites. Close confinement increases potential for disease spread, requiring a good health program. Goats are not as well adapted to intensive production as other food species, being susceptible to acidosis, enterotoxemia, polioencephalomalacia, and urinary calculi. However, several generations of selection could produce an animal better adapted to this production system. Information could be gleaned from cattle drylot production systems to increase the chances of success with this production system.

C. Animal Welfare and Quality Assurance

Animal rights and welfare concerns have had a significant impact on production practices in the swine and poultry industries and similar effects are expected for the goat industry. Goat producers need to be proactive in identifying and correcting potential animal welfare problems or issues. Procedures causing pain and discomfort such as dehorning and castration would be initial concerns. Current FDA regulations require analgesics to be administered under the direction of a veterinarian, which has potential to significantly add to production costs. Australian scientists have successfully reduced pain during castration by developing an anesthetic that is topically applied by a producer to the spermatic cord using a gun applicator prior to cutting the cord (Lomax et al., 2010). Australian scientists have also developed a gel administered orally that is rapidly absorbed through the roof of the mouth to alleviate the pain of castration in lambs (Small et al., 2014). The latter has greater potential for approval for use at the producer level.

Another area of welfare concern is suffering caused by parasites, poor nutrition, disease occurrence, etc., all of which are issues relating to poor management. The industry should work as a whole to educate producers on how to prevent these problems from occurring. Practice judicious sharing of videos of sick animals or other problems on YouTube or other social media. The general public is far removed from agriculture and may not be aware of some of the management techniques normally used on farm livestock. This can lead to misunderstanding of many benign, safe procedures, such as artificial insemination, that can lead to persons feeling offended or wishing to place additional regulations on livestock producers.

A growing segment of consumers want to have input in how their food is produced. This has become evident in various fast food chains sourcing eggs and meat from cage-free production systems, pork from farrowing stall free production systems, or purchasing organic or grassfed products. Still other consumers have different concerns regarding how goats look, needing to be unblemished, intact, etc., for use in religious holidays or festivals. However, all consumers want animals to be raised humanely, following standards requiring adequate care, nutrition, and management. To assuage those public concerns, most major food animal industries have a quality control program in place. Currently, there is no goat industry quality assurance program to let the public know how producers care and raise their goats. Serious consideration should be given to creating a goat quality assurance program before one is forced on the industry.

Presently, the goat industry has three certification programs available: Animal Welfare Approved by A Greener World, Certified Humane by Humane Farm Animal Care, and American Humane Certified by the American Humane Association. These three organizations have established their lists of acceptable and unacceptable practices for welfare certification; bear in mind these lists are debatable and not necessarily science based. The Sheep Safety and Quality Assurance Program involves certification for training, certification for developing a farm production program that meets criteria in the training program, and then implementation of the program on the farm with audits to assure compliance. Will the goat industry develop its own quality assurance program? Where will the money come from to finance development and audits and maintain the program? Other livestock species have used a checkoff program to finance development and implementation of a quality assurance program.

IV. ROLE OF TECHNOLOGY

A. Genetics and Genomics

Performance testing and genetic evaluations are proven methods for identifying genetically superior animals; however, the number of producers and animals involved in performance testing is decreasing year after year (ADGA, personal communication). Genomic selection (GS) is a quickly evolving field and one that may soon revolutionize the identification of genetically superior individuals and selection for breeding purposes (Goddard, 2009; Goddard and Hayes, 2007) GS has the capability of transforming selection within the goat population if embraced by the industry.

According to Meuwissen et al. (2016)the discovery of massive numbers of genetic markers (single nucleotide polymorphisms; SNPs, GS involves the estimation of genetic merit of an individual based upon its DNA—actually its single nucleotide polymorphisms (SNP). A principal component of GS is the genus-specific identification of SNPs. Initially, a genome-wide association study (GWAS) must be undertaken to determine the influence of each individual SNP to the trait(s) under selection, such as milk production, milk fat or protein content, average daily gain, cashmere yield, etc. This involves evaluating an initial animal group that has both phenotypic and genomic data, often called the reference population. Then for GS, the SNPs of an individual will be compared to the reference population. The size of the reference population required depends upon the heritability of the trait and upon the desired accuracy (Goddard, 2009). This reference population does not exist in meat or fiber goats but is being constructed for dairy goats (Carillier et al., 2013; Mucha et al., 2015)using the goat SNP50 BeadChip (Illumina Inc., San Diego, CA.

SNPs can also be used for parentage. Rodriguez Y Ramirez (2015) developed a SNP panel for parentage testing and, using 143 AI bucks that were sons of 48 AI bucks, concluded 15% of assumed pedigrees were incorrect. Talenti et al. (2016) used a SNP panel for parentage testing of 154 animals from producer herds and concluded 40% of the pedigrees were incorrect.

B. IoT (Internet of Things)

IoT is a network of electronics, software, and sensors that processes data and communicates information from or to the user. Gartner Research recently estimated that by 2020, there will be 20.4 billion IoT applications (van der Meulen, 2017). The vast majority of these IoT applications will involve smart homes, smart cars, and smart phones. A very small but growing sector of IoT involves agriculture and row-crop farming leads in adopting IoT technology. According to a USDA survey, using technologies such as yield monitors, auto-guidance systems, and variable-rate application has enabled farmers to become more profitable through higher yields per acre but lower fuel and fertilizer expenses (Schimmelpfennig and Ebel, 2011).

Livestock producers have also adopted smart farming techniques but not to the extent of their row-crop counterparts. A recent review of electronic sensors used in the dairy cattle industry analyzed a total of 126 publications between 2002 and 2012 describing 139 sensor systems (Rutten et al., 2013). These studies investigated the detection of estrus, locomotion problems, mastitis, and/or metabolic problems with some studies investigating more than one aspect of dairy cattle management. In the future, IoT will change the way livestock are managed. As sensors are developed in other livestock industries, they will be adapted for use in goats.

As sensors evolve, it is important to ask what the sensors should monitor. The simplest condition to monitor is identification. Electronic identification monitoring of livestock had its impetus with a two-fold objective of permanent identification and of implementing traceability. Studies examining various formats for passive radiofrequency identification (RFID) have deduced rumen boluses have a much higher retention rate than RFID ear tags or other forms of external tags with a higher than acceptable loss rate (Carné et al., 2011, 2010; Kluever et al., 2012)2,482 boluses were administered to goats from dairy (Murciano-Granadina, n=1,326; French Alpine, n=381. In a partnership with the University of Barcelona, Langston University was one of the first to study the effect of size and specific gravity of rumen boluses upon retention (Carné et al., 2009).

Studies in dairy cattle found an increase in core body temperature is an early indicator of disease occurrence (Schutz and Bewley, 2009; Timsit et al., 2011) and the onset of estrus (Bewley and Schutz, 2010; Suthar et al., 2011). Core body temperature will elevate just prior to ovulation (Kyle et al., 1998; Piccione et al., 2003). In goats, this corresponding elevation in temperature was also noted in rectal and vaginal temperature (Fakruzzaman and Akter, 2012).

As important as core body temperature is for detecting illness or estrus, rumination seems to be even more important for determining animal wellbeing. Soriani et al. (2012) noted a nearly 50% decrease in rumination time during dairy cow calving followed by a quick return to pre-parturition level; however, this response rate was slowed considerably in cows with disorders associated with parturition. In a study examining the effect of estrus upon rumination time in cattle (Reith and Hoy, 2012)cows were equipped with a microphone-based sensor system that allowed continuous recording (in blocks of 2 h, a nearly 20% decrease in rumination time at estrus was noted. Remote sensing hardware and management software could be developed to help identify animals in estrus.

Currently, the only monitoring device for rumination time is a collar worn by cattle. This collar system has been used in studies on dairy cattle (Schirmann et al., 2009;AMbriz-Vilchis et al., 2015) and on beef cattle (Goldhawk et al., 2013) with conflicting results. Other methods have been devised to measure eating/ruminating behavior (Penning, 1983) using a pressure-sensitive noseband device (Braun et al., 2013; Kononoff et al., 2002; Ungar and Rutter, 2006). Recently, the HOBO Pendant G data logger has been used to gather movement behavior (Dalton et al., 2016; Mattachini et al., 2014; Zobel et al., 2015). The HOBO Pendant G logger measures acceleration and angular displacement in three axes allowing the collected data to be translated into rumination patterns.

V. FUTURE ROLE OF LIVESTOCK EXTENSION

The role of livestock extension will change in the coming years. Extension personnel have already become increasingly proficient in electronic communications and social media. As technology gains importance in the goat industry, extension personnel will collaborate with scientists and professionals having a wide array of expertise to develop practical applications. However, extension personnel cannot lose sight of the continued importance and need for traditional, face-to-face exchange of information and the hands-on teaching of management techniques. This is particularly true considering that 1 in 5 adults in rural areas do not use the internet for a variety of reasons (Anderson et al., 2018).

As mentioned, the background of goat producers is becoming more diverse. This will drive change in who conducts traditional extension activities and the information presented. Language and cultural differences must be taken into account when adapting current information and when creating new content. There may be a larger role for producer groups having specific language abilities as content providers or to conduct training. These persons can work with traditional extension personnel to receive training and educational materials.

VI. INDUSTRY FUTURE

What is the future of the goat industry? There is no doubt the meat goat industry has strong product demand, good prices, potential for great profitability, and the services of goats are needed to control various invasive plants that have seriously degraded grazinglands. However, profitability has been insufficient motivation to attract producers to raising goats. While small producers have been the backbone of the goat industry, there is a need for many large producers to significantly increase goat meat production, lessening the need for imported goat products. Cattle producers could capitalize on goats as a second species to control weeds and brush. There is great potential for running large herds of goats to control invasive species and reclaim grazing lands. Other benefits of grazing goats include fire prevention and reduced herbicide use.

There is a growing interest in confinement production of goats. Confinement production is not new to the industry; but has not been profitable in the past in part due to health problems. Hopefully, strong goat prices and new knowledge will help this segment of the goat industry be profitable and contribute to meat production. Goat markets will develop where there are sufficient goat numbers. Marketing has always been important for profitability and goat numbers will attract goat buyers and competition for goats.

There is potential long-term danger that second and third generations of traditional ethnic consumers may not consume as much goat meat as their ancestors. If this does come about, demand will slowly decline allowing the industry to address this problem through alternative markets such as promoting healthy aspects of goat meat consumption to new consumers and increasing upscale restaurant goat products.

Fortunately, new internal parasite control and mitigation strategies developed and promoted by the ACS-RPC have somewhat reduced the problem posed by problematic intestinal nematodes. Still, many producers suffer lost production due to lack of implementation of these strategies. Dewormer resistance will continue to get worse, especially for producers not using the FAMACHA© system and Targeted Selective Treatment. Genomic selection will increase in importance in the goat industry; however, application may be hindered by the different production goals of segments of the meat goat industry. Some producers will want to stress hardiness in range conditions while others will want animals selected for high rates of gain adapted to confinement. Some producers will want to stress maternal characteristics while others will prioritize show animals. The industry needs to develop a quality assurance program before one is forced on them.

The dairy goat segment is on the way to success in working to develop goat cheese markets here in the US and capitalizing on cheese markets with premium quality cheeses. An infant formula developed using goat milk could greatly increase demand and the industry should pursue this area through supporting research and market development. There will be more large goat dairies as larger quantities of milk are required for economical processing into cheese and other products. The industry should also pursue research on goat milk for persons having cow milk allergies or are lactose intolerant because this may also provide a viable market for goat milk and goat products.

Electronic technologies developed for dairy cattle will gradually migrate over to the large goat dairies. Genomic selection could have great application in the industry, but must be developed. Although the economic dumping of frozen curd on the dairy goat industry is illegal, the Federal Government is very unlikely to address the problem for such a small segment of US business. However, the industry could develop a quality stamp for product produced with 100% American goat milk and promote its use. Research is needed with the veterinary industry to develop methods to reduce pain for dehorning and castration.

Mohair production will not likely grow. Although it is economically viable, the lack of shearers is a limitation not likely to be overcome. There are significant numbers of farms with few animals used to produce mohair for spinners and hair for dolls and these will likely shrink as handicraft hobbies fade away. Cashmere is produced by small groups of goats for hand spinning markets and demand is unlikely to grow in the future.

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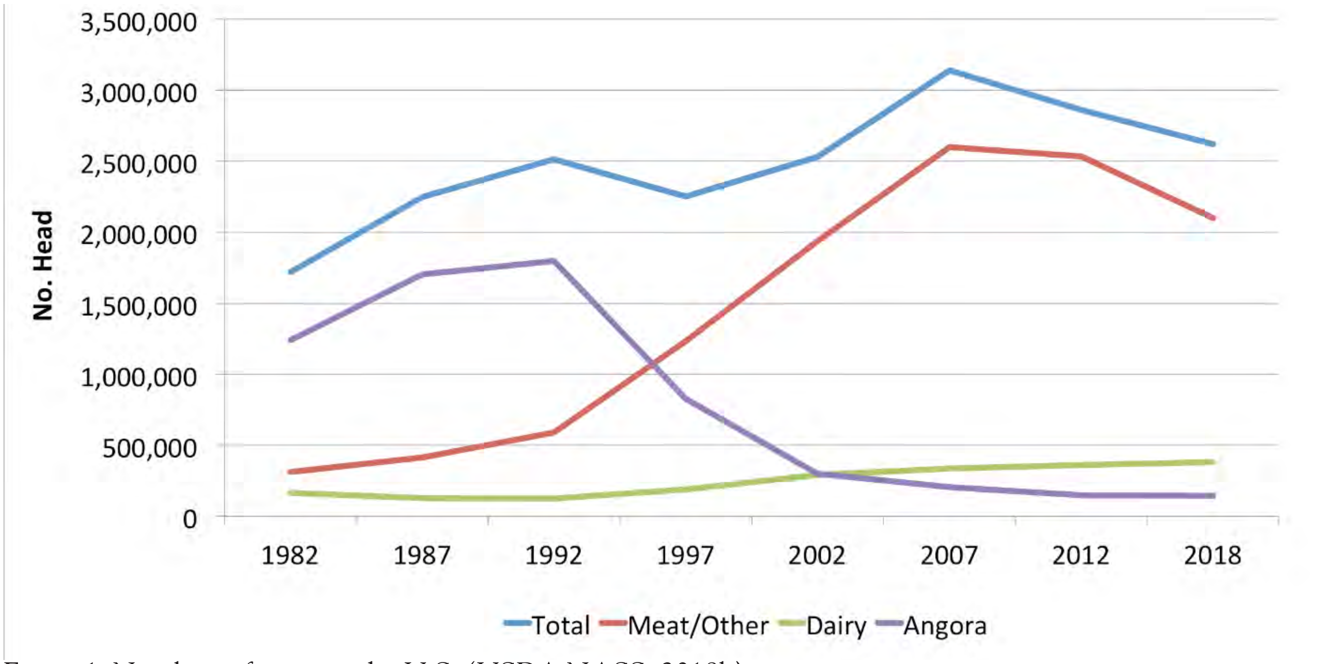


Figure 1. Numbers of goats in the U.S. (USDA NASS, 2018b).

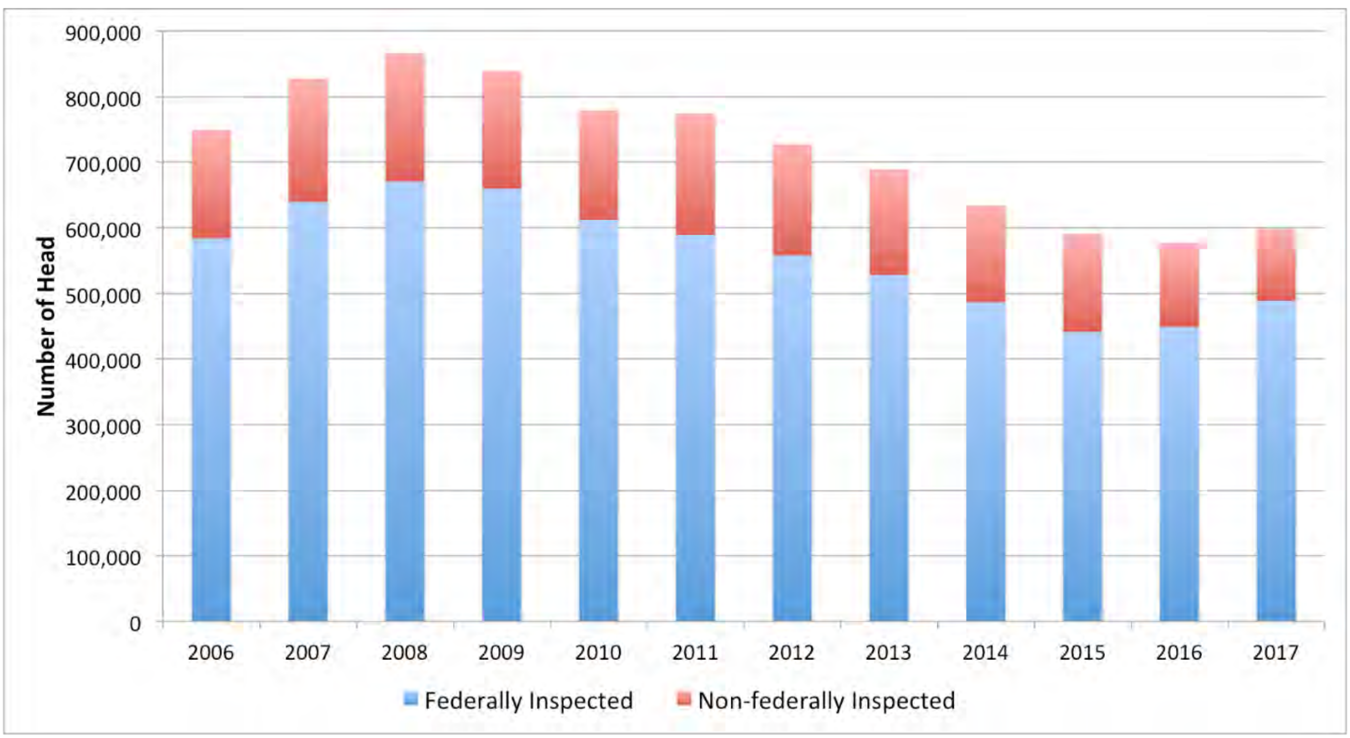


Figure 2. Number of goats slaughtered in federally and non-federally inspected facilities (USDA NASS, 2018a).

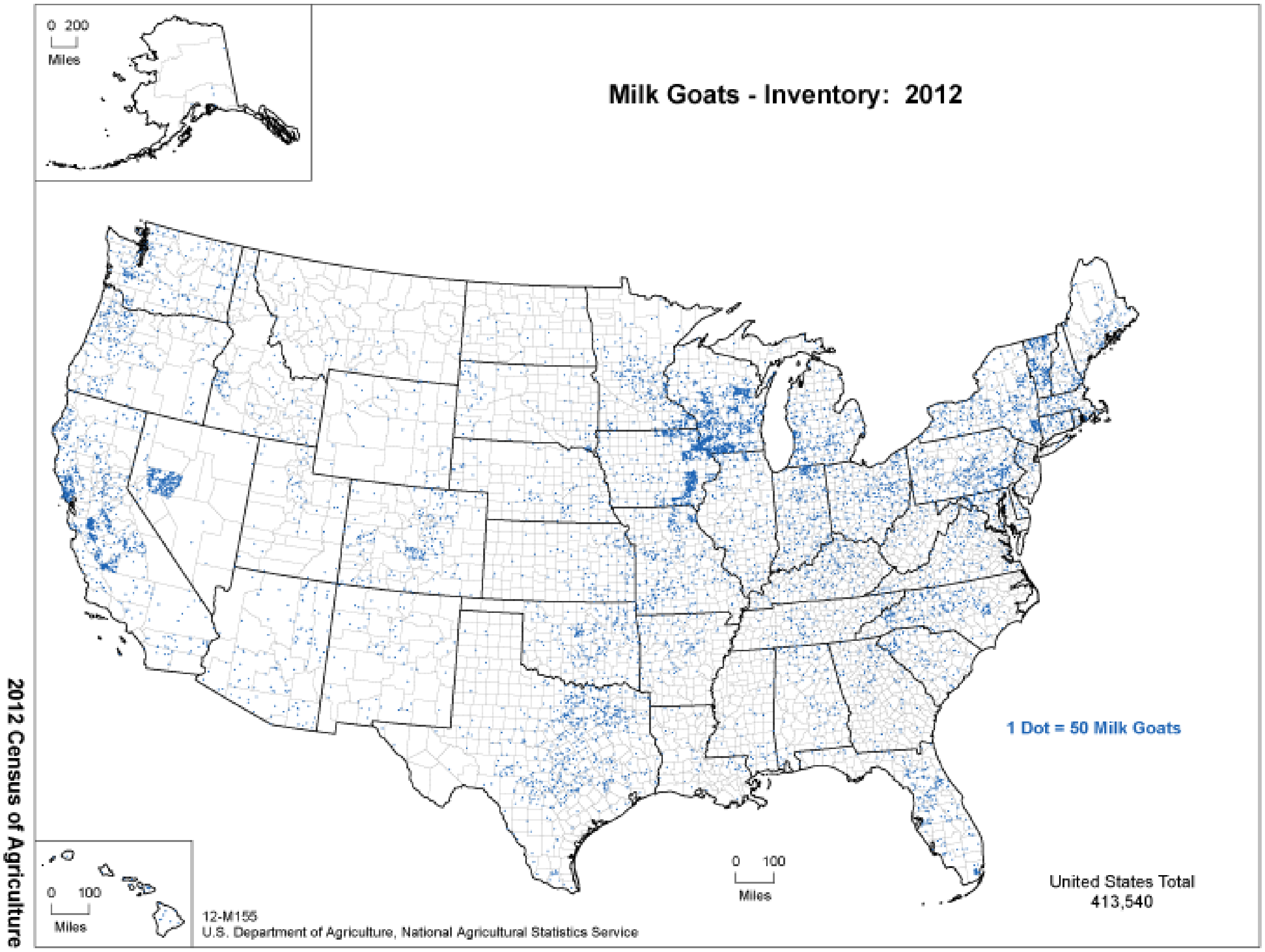
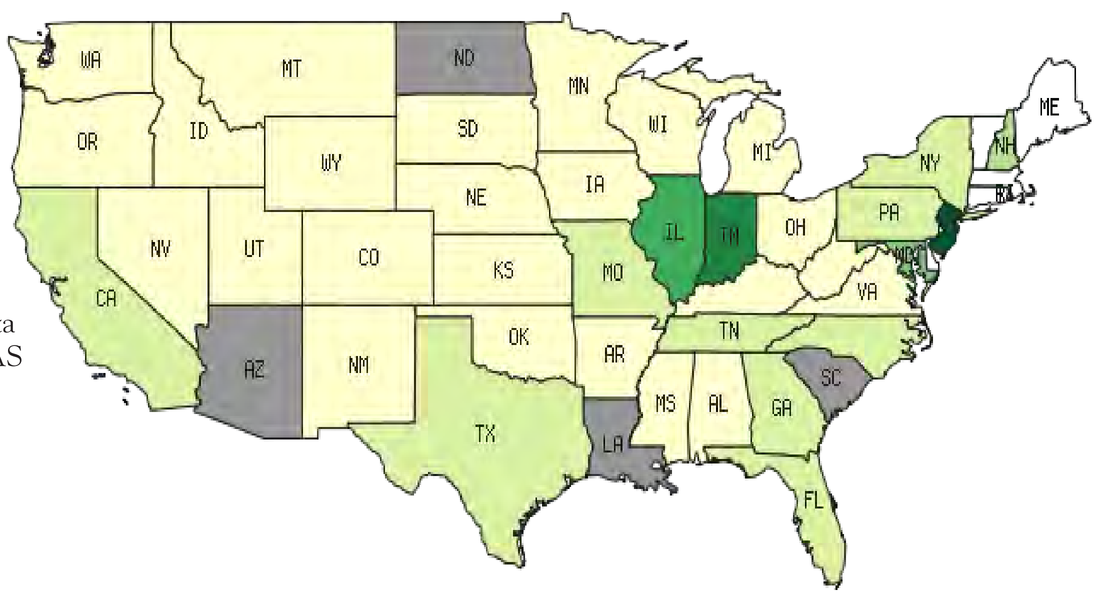
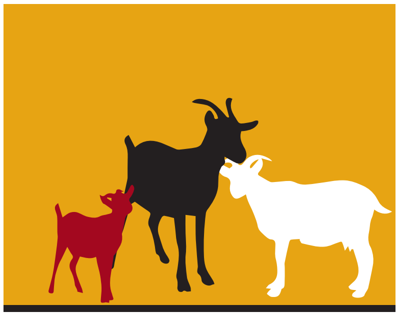


Figure 3. Dairy goat inventory, 2012.

Figure 4. Distribution of federally inspected goat slaughter measured by head, 2017. Darker green color indicates greater slaughter numbers. Gray indicates no data available. (USDA FAS GATS database)





SECTION TWO

HISTORY AND OTHER ASPECTS OF THE GOAT INDUSTRY

History of the U.S. Goat Industry

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ABSTRACT

Goats were first domesticated in the Fertile Crescent and then spread throughout the world. Goats were brought to North America into the southwestern U.S. in the 17th century by early Spanish explorers and clergy. These goats are the ancestors of the Spanish goat of Texas and the Lamancha breed of California. English and other European settler also brought their goats as they moved into the eastern U.S in the 18th century. Angora goats were first imported in the U.S. in the mid-19th century and the earliest importation of officially recognized dairy goat breeds occurred in the late 19th century and early 20th century. Most recently the Boer and Kiko goats were imported into the United States in the late 20th century. Numbers of goats have fluctuated over the years but generally have increased. However, Angora numbers have plummeted precipitously after repeal of a production incentive program.

Keywords: goats, domestication, history

INTRODUCTION

Goats (*Capra hircus*) are not native to North America and were introduced to the continent by European explorers and settlers. The type of goat raised in Europe over the centuries were the goats that populated the livestock landscape in North America.

DOMESTICATION

Goats (*Capra hircus*) were domesticated during the late Neolithic, approximately 10,500 years ago, in the Fertile Crescent (Alberto et al., 2018; MacHugh and Bradley, 2001; Figure1)sheep and goats were domesticated in the fertile crescent 10,500 years before present (YBP. The ancestor of the domestic goat is the bezoar (*Capra aegagrus*); however, the domestication of the goat may have resulted from multiple domestication events at several different geographical locations (Kahila Bar-Gal et al., 2003; Schlumbaum et al., 2010) but one major single domestication event has given rise to nearly all modern domestic goats (Akis et al., 2014; Kadowaki et al., 2016). Evidence for this single major domestication event is that more than 90% of present-day domestic goat belong to haplotype A while less than 10% belong to the other five haplotypes (Naderi et al., 2007)the transportation of domestic

Figure 1: Fertile Crescent

animals resulted in genetic and demographic processes that explain their present distribution and genetic structure. Thus studying the present genetic diversity helps to better understand the history of domestic species.\n\nMETHODOLOGY/PRINCIPAL FINDINGS: The genetic diversity of domestic goats has been characterized with 2430 individuals from all over the old world, including 946 new individuals from regions poorly studied until now (mainly the Fertile Crescent. Ancient goat DNA found in bones from an archeology site in eastern Turkey belonged to haplotype A (Akis et al., 2014). Also, ancient goat DNA extracted from bones found in the oldest known farming villages in the southern Caucasus, present day Azerbaijan, yielded haplogroup A, which is in stark contrast to DNA extracted from present day bezoars found in the region (Kadowaki et al., 2016)seven ancient samples were obtained from two early agricultural villages in west Azerbaijan (G\u00f6ytepe and Hac\u0131 Elamxanl\u0131 tepe, dated to ca. 6,000\u20135,500 cal BC, the Pottery Neolithic period. This implies that present domestic goats arose from a domestication event that took place in southeastern Anatolia (Colli et al., 2016; Taberlet et al., 2008). Domestic goats were highly portable and could easily be herded along migration routes; thus, the spread of domesticated goats from the Fertile Crescent to Europe and Africa in the west and India in the east was a quick and easy process.

EUROPE

As the domesticated goat spread from the Fertile Crescent into Europe, human exerted minor selection pressure. The largest genetic change happened through natural selection and random genetic drift, the latter causing genes to be fixed in small population (Lande, 1976). As humans exerted selection pressure on domesticated goats, geographical difference arose. Presently there are three distinct clusters of related groups in Europe (Canon et al., 2006). In Figure 2, the eastern-most circle represents present-day goat breeds in the Fertile Crescent and descendants of the first domesticated goat. The second-eastern-most circle (green) represents goat breeds in the central Mediterranean, the third-eastern-most circle (blue) represents goat breed in northern Europe, and the western-most circle (red) represents goat breeds in the western Mediterranean. The goat breeds in the western Mediterranean are actually more closely related genetically to goat breeds in the Fertile Crescent than are goats in northern Europe. This is because the migration of domesticated goats out of the Fertile Crescent followed a route along the northern coast of the Mediterranean Sea but also along the southern coast (Pereira et al., 2009). Two major historical events shaped the raising of goats in Europe, especially northern Europe. The first event, which happened approximately 3,000 after the domestication of the goat, and was a small mutation in the human population (Laland et al., 2010). This mutation was in a regulatory region near the gene for lactase that allowed lactose tolerance to persist into adulthood (Fan et al., 2016; Sabeti et al., 2006). With this mutation, goats and cattle could serve another important role other than meat and hides. Milk is a complete food and easily digested. This mutation was so important that nearly all Europeans and people of European descent carry this mutation. The second event was the defeat of the Umayyad Caliphate army by Charles Martel and his Frankish troops near Poitiers (central France) in 732 AD. The Umayyad Caliphate conquered North Africa and swept into the Iberian peninsula (Spain and Portugal) in 711 AD (Cachia, 2017) and soon thereafter, established settlements in southwestern France (Gleize et al., 2016). In 732 AD, Abd ar-Rahman, Umayyad governor of Iberia, marched his forces north to the city of Poitiers, where he engaged the Frankish troops. Charles Martel and the Frankish forces were able to attack the encampment of the Umayyad forces. Fearing that their loot would be taken, some of the Umayyad forces broke ranks and returned to defend their encampment. However, this maneuver drove the Umayyad forces into disarray and proved fatal for their leader, Abd ar-Rahman. With the death of Abd ar-Rahman, the Umayyad forces retreated to southern France without breaking their camp (Watson, 1993). One of the items left behind by the fleeing Umayyad forces were their goats that they used for milk and cheesemaking. The majority of the Umayyad forces were composed of peoples of North African origin, also known as Moors or Maures, in French. According to tradition, cheesemaking using goat's milk in this region of France had its start with this failed invasion and has grown to be a major industry. The iconic Sainte-Maure goat cheese is the most popular style of goat in the world and is produced in the area around Poitiers.

UNITED STATES

Importation/history

Records and history of the importation of goats into North America are rare. However, the first goats in North America came with the Spanish explorers and missionaries as they traveled throughout the southern and south-western future United States (Weber, 2000). The descendants of some of these goats from Spain are the Spanish goat of Texas and the Lamancha of California. As the Spanish explored the west coast, present day southern California, and as a means of provisioning, the Spanish would release goats onto nearby islands. The released goats acted as a food larder and could be harvested as needed. Examples of this are the Channel Islands off the coast of southern California. Goats were probably placed on Santa Catalina Island of the Channel Islands off the coast of southern California by Spanish explorers for provisioning (Hess et al., 2018). Not so for San Clemente Island, onto which goats were introduced at the end of the 19th century, more than two centuries after goats were introduced onto Santa Catalina (Johnson, 1975) and well after California became the 31st state in 1850. However, it is possible that goats were introduced to San Clemente Island from Santa Catalina Island (Hess et al., 2018). As back in Spain, only the hardiest goats survived to breed and to pass on their genes to the next generation in the new world. The majority of the present dairy goat breeds were brought to the United States by English settlers. These early goats would have been descendants of the Old English Milk goat or goats from continental Europe. Dairy goat breeders formally organized into the American Milch Goat Record Association (AMGRA) in 1903, which was a necessary step for the "milch" goat show 1904 World's Fair, in St. Louis, MO. In 1964, the AMGRA changed its name to the American Dairy Goat Association (American Dairy Goat Association, n.d.). However, not many dairy goats were shown at the 1904 World's Fair and the main goat show featured Angoras with more than 300 entries from across the United States (Irwin, 2018). Angora goats were first developed in Asia Minor, Turkey, for their hair and were first introduced in the United States in 1849 by James P. Davis. Seven adult goats were a gift from Sultan Abdülmecid I of Turkey in appreciation for his services and advice on the raising of cotton. The word Angora is derived from Ankara, the capital of Turkey, and the word mohair is derived from the Arabic word "mukhayyar", which means "select" or "selected". Angora goats began to thrive in the southwest, particularly in Texas (Ekarius, 2015). The latest breeds imported into the United States are the Boer goat from South Africa and the Kiko goat from New Zealand. The Kiko were first imported in 1992 (Wade, 2004) but were overshadowed by the importation of the Boer goat a year later. The Kiko goat was developed as a meat goat in New Zealand originating from European and feral goat stock. The Boer goat was developed in South Africa (Casey and Van Niekerk, 1988) from indigenous African and introduced European goat stock. The unique aspect of the Boer is that is was the only goat breed subjected to a central performance test for meat production (Campbell, 1984). Thus, the Boer goat selected intensively in South Africa for muscling and rate of growth (Sahlu et al., 2009).

Current status

The USDA National Agricultural Statistical Service (NASS) only inventoried Angora goats prior to 2005. Inventory numbers over the past 50 years (Figure 3) reveals that populations of Angora goats fluctuated between 1.5 and 2 million head with the vast majority of those Angoras found in West Texas. In 1995, President Bill Clinton and Congress repealed the National Wool Act of 1954, which provided incentive payments to wool and mohair producers. The final incentive payments were made in 1996 and one can see in Figure 3 the drastic decline in Angora inventory post 1997. Prior to 2005, the Texas Department of Agriculture (TDA) conducted an annual census of livestock including Angora goats and all goats; thus, it is possible to calculate other breeds, primarily Spanish goats. However before 1989, TDA only collected census data on the category of all goats; thus, prior to 1989, it is not possible to estimate different categories. Although modest in numbers, dairy goats have seen a gradual increase over the past decade. Conversely, meat goats saw a sharp increase in the late 2000's, then an almost equally sharp decrease, and then leveled since 2013. Texas, which is the state with the largest meat goat inventory (Figure 4), suffered a severe drought in 2011, which saw record numbers of goats going to market. States with zero (0) meat (Figure 4) or dairy (Figure 5) goats does not mean that those states have no meat or dairy goats. USDA disclosure policy is to protect individual producer's identity under the Confidential Information Protection and Statistical Efficiency Act (CIPSEA) of 2012 and if releasing inventory numbers for a state would violate CIPSEA, then USDA will aggregate those states into "Other States." However, states with zero (0) inventories for Angora goats (Figure 6) probably represent no or virtually no Angora goats in those states. For Figures 4, 5, and 6, the numeric value within the state represents the inventory (× 1,000 head) for that state and for that type of goat.

Other Uses

In addition to milk, meat, and fiber production, goats have been used to control brush and other unwanted vegetation (Bebe et al., 2015). Goats will consume vegetation that cattle or sheep will not (Hart, 2001). There is growing interest in using goats as pack animals (Sharp and Sharp, 2018). Being smaller than mules and more nimble than horses, goats are ideally suited for packing. Goats are highly intelligent animals, affectionate, and make excellent companions (Miranda-de la Lama and Mattiello, 2010).

CONCLUSION

Goats were originally domesticated in the Fertile Crescent and followed Neolithic farmers to Europe in the west and Asia in the east. Goats are an introduced species into North America and were brought here primarily by Spanish and English explorers and settlers. The primary goat industries in the United States are meat, dairy, and fiber production. Meat goat inventories are the largest sector, followed by dairy, and then fiber. Angora (fiber) goat inventories have declined dramatically over the last half-century.

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Figure 7. Inventory numbers by type over years (source: USDA/NASS).

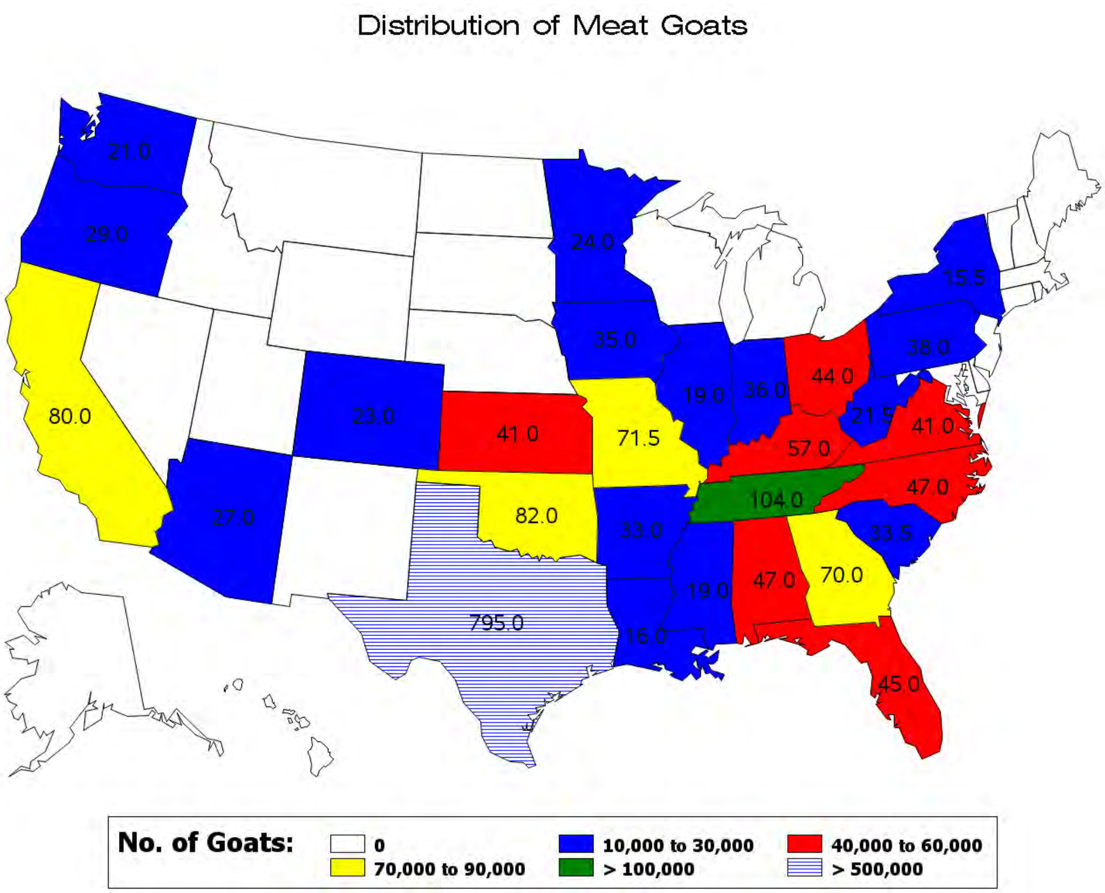

Figure 4. Distribution of meat goats by state (2018; source: USDA/NASS).

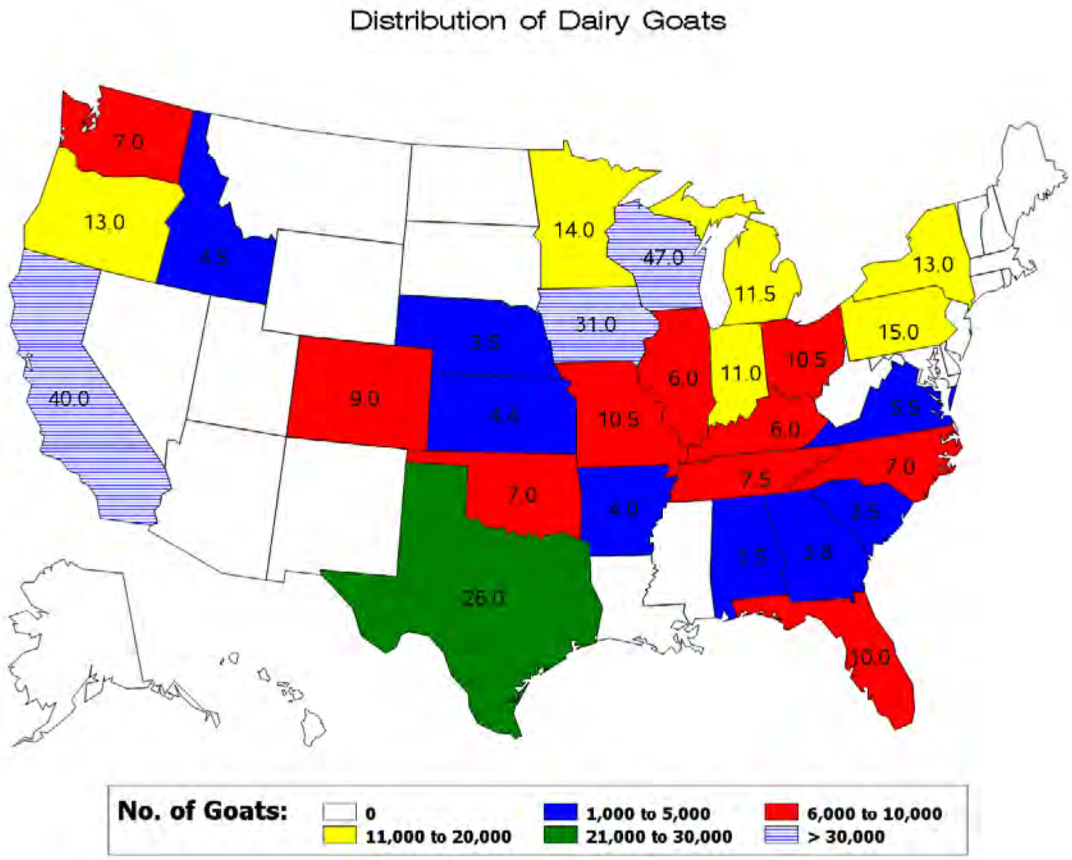

Figure 5. Distribution of dairy goats by states (2018; source: USDA/NASS).

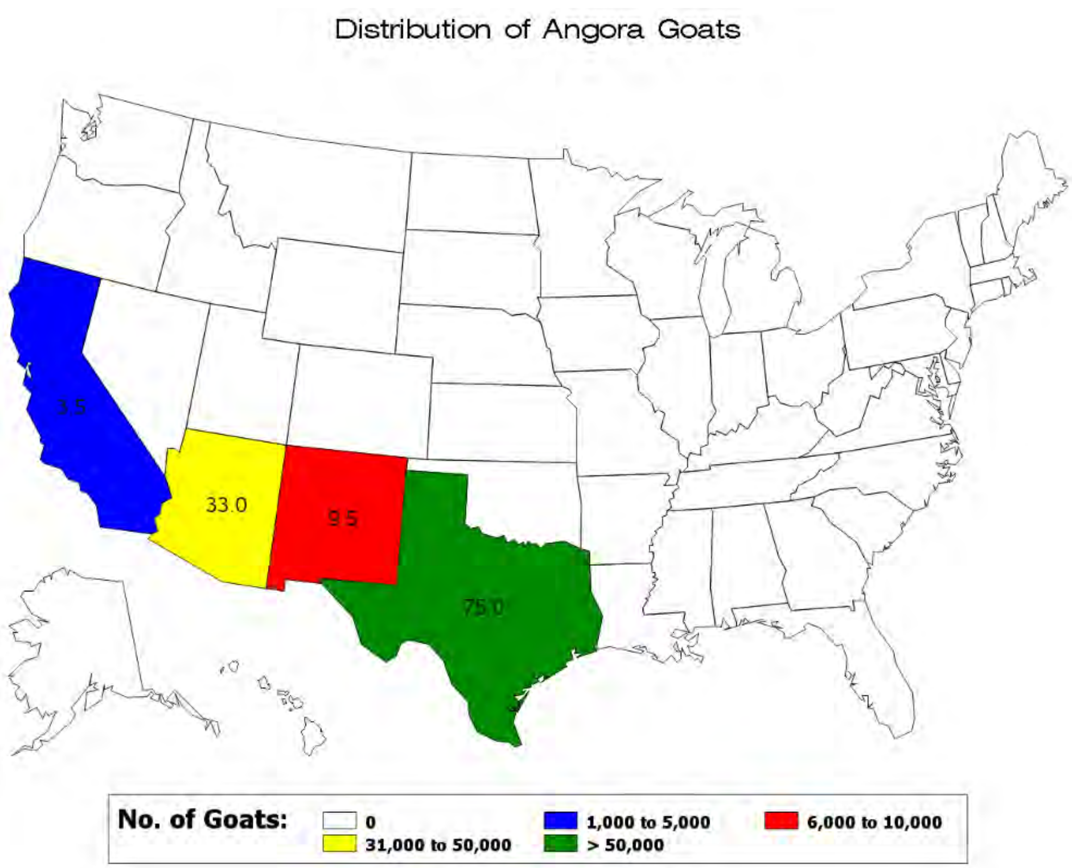

Figure 8. Distribution of Angora goats by state (2018; source: USDA/NASS).

Goat Mortality Composting

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ABSTRACT

All livestock producers will have animals that die. Leaving carcasses to decompose on the ground surface is illegal. The five lawful methods of carcass disposal are rendering, incineration, landfills, burial, and composting. Mortality composting is an environmentally friendly method of carcass disposal that provides the producer with a valuable soil amendment. Composting sites should be away from water sources and public areas. Some states require a dedicated facility and/or permit for carcass composting so producers should check with their State Veterinarian. When properly done, animal composting generates little to no odor and temperatures generated during composting are high enough to kill most pathogens. Mortality composting should be an aerobic process and piles require a proper C:N ratio achieved by using a high carbon source to envelope the carcass, a moisture content of roughly 50%, and available oxygen. Common composting materials are sawdust, ground hay or straw, rice hulls, and stable waste. Mortality composting can be done using permanent structures or low-cost alternatives such as livestock panels, wire, or old pallets. Too much moisture and improper C:N ratios, such as too many carcasses in one pile, can result in poor decomposition, cause pile odors, and attract flies. About one-half of the resulting compost can be used to establish a new pile. Compost from mortality composting can be used on pastures, in landscaping, and other uses. It is not recommended to use the compost on crops harvested for direct human consumption.

KEYWORDS: Mortality, Composting, Goat

I. WHY COMPOST GOAT MORTALITY?

All livestock producers need a plan to dispose of livestock mortality. Dead animals must be disposed of promptly because carcasses left on the ground have the potential to spread disease, contaminate surface and ground water, feed coyotes and other predators, and cause complaints by neighbors and passersby. Further, improper disposal is illegal. Criminal statutes prohibit leaving a carcass to decompose in the open. As an example, in Oklahoma carcasses may not be deposited within ¼ mile of surface water, dwellings or public highways, or be buried along streams or other waterways. Livestock owners have the duty to lawfully dispose of their animal mortality.

There are five lawful options for animal carcass disposal: rendering, incineration, landfills, burial, and composting. Finding a rendering service for goats is difficult. Due to regulations concerning the handling of ruminant carcasses and offal and the risk of transmissible spongiform encephalopathies (i.e., BSE and scrapie), many rendering facilities either do not accept goat carcasses or offal or disposal fees may be prohibitively high. Open-air incineration of goats is prohibited and producers wishing to use this option must purchase a closed incinerator. Not all landfills accept carcasses and producers must pay disposal fees as well as trucking costs. Trucks hauling dead animals should be cleaned and disinfected after use.

Burial is a viable option for many producers who own the needed equipment; but if machinery must be leased the cost may be high. During winter, frozen soil can prevent prompt burial of mortality forcing producers to seek other disposal options. Further, there are state regulations on burial that must be followed and producers should contact their local extension service or state department of agriculture for information.

Composting is an inexpensive, environmentally friendly method of disposing animal mortality that is commonly used in the poultry and swine industries. Mortality composting allows producers to legally dispose of carcasses, preventing contamination of ground or surface water and the feeding of predators that can occur with indiscriminate carcass disposal. Mortality composting can become part of a farm biosecurity plan to deal with disposal of dead animals and prevent disease spread.

When done properly, animal composting generates little to no odor and the high temperatures generated kill most pathogens. Animals suspected to have died from zoonotic diseases (diseases that can be passed to humans) should not be composted. Sheep and goats that die from scrapie should never be composted because the prion agent responsible may not be killed at common compost pile temperatures. However, for most cases of mortality, composting is a safe, low-cost alternative to other carcass disposal options.

As with burial, producers are advised to seek out information on their state's rules and regulations regarding mortality composting. Although some states only require concentrated animal feeding operations to obtain permits to compost mortality, other states may require permits for any amount of mortality composting. Often states will base acceptable mortality composting practices using the standards set forth by the Natural Resources Conservation Service (NRCS) found in Conservation Standard Practice, Animal Mortality Facility Code 316, and Composting Facility Code 317. The Cornell Waste Management Institute has a website on U.S. Mortality and Butcher Waste Disposal Laws providing information on state requirements at http://compost.css.cornell.edu/mapsdisposal.html. Another website with state information is the Veterinary Compliance Assistance website, under Carcass Disposal (http://www.vetca.org/lacd/).

II. MORTALITY COMPOSTING BASICS

In the same way microorganisms degrade vegetative waste and turn it into a rich soilAMendment, animal carcasses can be turned into an organic matter-rich material that can be spread on pastures and other agricultural land. To successfully compost animal mortality requires attention to the basics of any good compost pile: proper carbon to nitrogen ratio (C:N), moisture content, available oxygen, and temperature.

A. Carbon:Nitrogen ratio

Microorganisms doing the work of composting require nutrients in the form of carbon and nitrogen in a C:N ratio of roughly 30:1, or 30 parts carbon for each part nitrogen. Animal carcasses are high in nitrogen (having a low C:N ratio, Table 1) and the surrounding compost material should be high in carbon to create an acceptable C:N ratio. There are many suitable carbon sources for mortality composting. When selecting a carbon source, consider year-round availability, amounts needed, and cost. Seek out easily obtained materials for composting to make the process as easy and economical as possible. Materials such as wood chips from utility companies or municipalities or forage unsuitable for feeding can be used. Used bedding after a livestock show at a local fairgrounds or horse arena can be an easily obtained, inexpensive carbon source. Other carbon sources used in mortality composting include old or moldy hay, crop residues such as straw, corn stover, silage, rice hulls, and ground corncobs (Table I). One commonly used material is sawdust. Sawdust has a high C:N ratio, good particle size, and the ability to absorb and retain moisture.

Particle size of the carbon source affects aeration of the pile with subsequent effects on pile temperature and decomposition rate. A general guideline for particle size is roughly 1/8 to ½ inch (up to 1 cm) in diameter. Materials such as hay, straw, and corn stover will work better if coarsely ground prior to use. Alternatively, these materials can be mixed or layered with other material, such as manure or finished compost, in a 50:50 mixture and used.

Table 1. Carbon:Nitrogen ratio of some common composting materials.

Material	C:N ratio (weight basis)
Sawdust	200 – 750:1
Straw	48 – 150:1
Wood chips	40 – 100:1
Corn stalks	60 - 73:1
Finished compost	30 – 50:1
Horse manure	22 – 50:1
Cattle manure	19:1
Goat manure	16 – 21:1
Turkey litter	16:1
Poultry litter	14:1
Animal carcasses	5:1

Sources: On-Farm Composting Handbook. 1992. NRAES-54, Natural Resource, Agriculture, and Engineering Service, Ithaca, NY. ISBN:0-935817-19-0. EBAE172-93. 1996. North Carolina Cooperative Extension Service, Raleigh, NC.

B. Moisture Content

Microorganisms require proper moisture conditions to work. The optimal moisture content for a compost pile is approximately 50%. If the compost pile material is too dry, bacteria have insufficient moisture and composting will be very slow. If the material is too wet, water fills the pore spaces in the compost pile, causing desirable aerobic bacteria to be replaced by anaerobic bacteria. Decomposition by anaerobic bacteria is very slow, generates odors, and does not produce sufficient heat to inactivate pathogenic organisms in the compost pile. Too much water also increases the chance for liquid (leachate) to run out of the pile, potentially contaminating soil and water. Add water to the carbon material to obtain an adequate moisture level.

To test for moisture content, squeeze a handful of the compost material. If water drips out, it is too wet. If none sticks to your hand, it is too dry. The material should feel like a damp sponge. For a more accurate moisture level reading, use a portable moisture probe.

C. Available Oxygen

In addition to proper carbon and moisture content, aerobic microorganisms require oxygen. The amount of oxygen available to microorganisms in a compost pile is largely dependent on the particle size of the carbon material used. If particle size is too small, there will be inadequate pore space for oxygen movement. If the material is too large, there can be too much air transfer allowing heat, odors, and moisture to escape the pile. Sawdust, mixtures of shavings and manure, or bedding and manure all have good-sized particles providing adequate pore space and oxygen circulation.

D. Temperature

Microorganisms working in a compost pile include bacteria, fungi, and actinomycetes; bacteria by far outnumber other organisms. In initial stages of composting, mesophilic bacteria that work best at temperatures of up to about 105°F dominate. As temperature increases, thermophilic bacteria that grow at temperatures up to 160°F take over. Mortality compost piles work best in a temperature range of 130 to 150°F. To reduce pathogens, the NRCS standard practice recommends a compost pile reach a temperature of at least 130°F for a minimum of 5 days. Temperature in excess of 145°F kills most weed seeds. A pile temperature that is too high, greater than 160°F, can affect bacterial survival, hampering the composting process.

It is best to monitor temperature using a 36" or 48" compost thermometer (Photograph 1) thrust into the pile's core. If a thermometer won't be used, insert a long piece of metal rod, such as a piece of rebar, into the pile's core withdrawing it occasionally to feel if the pile is heating. At temperatures above 130°F, the tip of the rod can be held in one's hand for only 1 or 2 seconds.

Photograph 1. Compost thermometers are 3 to 4 feet long.

E. Site Selection

Producers should check with their state department of agriculture to determine if specific guidelines exist for mortality composting site placement. If there are no specific requirements, use guidelines for animal burial to properly situate mortality compost facilities. In general, the site should be 300 feet away from water sources, public areas, roads, and property lines. A firm surface near the pile is needed for equipment and vehicle access and for storage of the carbon source. Some states may require an impermeable base to any mortality compost pile. Water should be available for use in building piles. Mortality compost piles can be made with no surrounding structure; however, curious animals may dig into the pile so some type of surrounding wall or fence is beneficial.

III. MORTALITY COMPOSTING BINS

Different types of bins can be constructed, taking into consideration your state's mortality composting regulations, the level of mortality expected, the amount of funds available, and the permanence desired. These may be permanent structures or bins made from stock panels, wire, or old pallets. The number of bins needed depends on expected mortality. For most goat farms a simple three-bin system will be sufficient.

A. Permanent Bins

Permanent bins may be new structures specific to composting or they may be unused sheds, cribs, or other buildings. Permanent composting structures should have a concrete or packed surface floor and sufficiently high ceilings to allow use of a tractor or skid steer. A concrete pad prevents runoff and liquid seepage into the ground and provides a good working surface. A graveled area around the pad helps when working in wet weather. A permanent mortality composting structure should have at least three bins: two working bins and a third bin to cure compost, store carbon source, or use as an additional working bin if needed (Photograph 2). A roof will shelter the pile from weather, allowing better control of composting conditions. If a roof is not built, covering bins with a tarp in areas with abundant rainfall helps protect the pile from becoming too wet, creating anaerobic conditions leading to poor decomposition and odor generation.

In general, bin width should be 6 to 8 feet or 1.5 times the width of tractor or skid steer buckets used in constructing and turning piles. Bin depth should be at least 6 feet and is often equal to or greater than the width, up to 10 feet, depending upon expected mortality. Bin wall height should be 5 to 6 feet to accommodate piles of layered carcasses. The front of the bin could be closed with wood or a hinged gate or left open if bin depth is sufficient and animals cannot enter the area. Bin walls are commonly built from pressure-treated wood, although cement or cement blocks can be used. Spaces can be left between boards to encourage air exchange.

Photograph 2. A permanent three-bin wooden mortality composting structure.

B. Low-cost alternatives

There are many low-cost alternatives to constructing permanent structures for small herds having minimal mortality. These low-cost bins can be placed on a concrete pad if state regulations mandate, or on a soil base. Two stock panels wired to form a circle, eight wooden pallets on edge held in place by T-posts or wired together, or woven wire and T-posts can be used to make easy, low-cost bins (Figure 1). Three large round bales can be placed to form a three-sided bin in which mortalities can be placed. A surrounding fence can prevent disturbance from wildlife and dogs.

Mortality composting bins should be 6 to 8 feet in diameter. This size can hold one to two adult goats and one to three kids, depending upon size, composted in two layers. Too small a compost pile will have insufficient insulating qualities and poor heat retention. The pile will not heat properly and composting will be slow.

When building small compost piles in the open, the final covering layer of carbon source should be piled into a cone shape to shed rainwater, preventing the pile from becoming too wet. A tarp tied to cover the pile is beneficial in areas with high rainfall. Preventing a pile from becoming too wet is easier than drying a pile that has become too moist and is not composting properly.

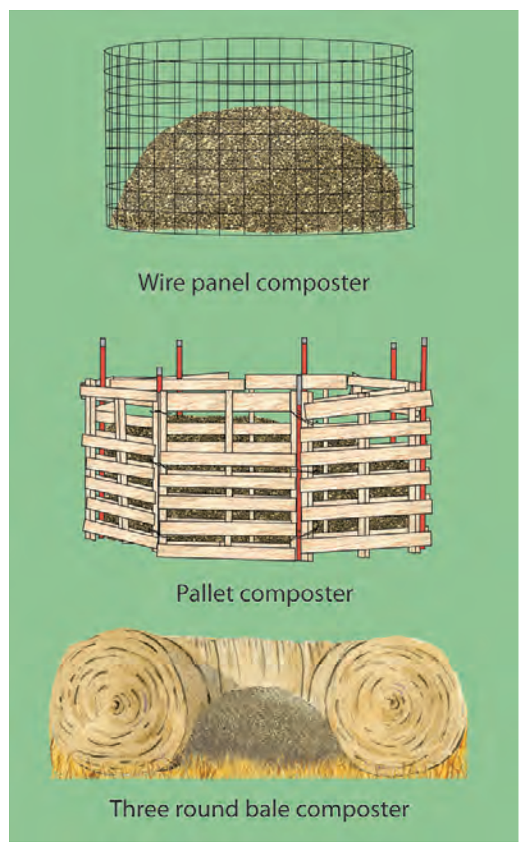

Figure 1: Low-cost alternative compost bins

V. MORTALITY COMPOSTING PROCESS

Ensure you have plenty of carbon source material before beginning mortality composting. The amount needed for wooden bin composting can be estimated from the volume of the bin. For alternative bins made from wire, pallets, round bales, or other material, the amount will depend upon the diameter of the bin and height of the final pile. However, a rule of thumb is approximately 100 ft^3 (3.5 yd^3) or 4 to 5 tractor buckets of the carbon source mixture for each 100 pounds of mortality. If two or three carcasses are layered in a bin, the total will be somewhat less on a per animal basis as the base layer will be used for more than one carcass. However, too thin a base or covering layer of carbon source will lead to poor decomposition, excessive leachate, or odors.

A. Building the pile

1. Cover the base of the bin with a minimum of 18 inches of carbon source material as an absorbent layer to trap liquid leached from the carcass during composting. The base layer can be laid down several days prior to adding carcasses so it begins to heat. This will speed up the initial stage of carcass decomposition.

2. Add a carcass in the middle of the base a minimum of 12 inches from bin walls or sides. Limbs may be tied or removed and laid next to the body if needed to keep away from bin sides.

3. If the bin is of sufficient size and two or more carcasses need to be composted, add a second carcass to the layer. Place adult carcasses back to back 8 to 10 inches apart and lamb or kid carcasses 6 inches apart with feet pointing to the pile's edge.

4. Use a knife to lance the rumen. This provides access by microbes to the inside of the carcass and prevents the rumen from bursting due to gas build-up from ruminal microbes. Additional cuts can be made on the limbs or torso allowing bacteria to enter, speeding up the decomposition process.

5. Add enough water to the surrounding carbon source to create a moisture content of roughly 50%. One to two 5-gallon buckets of water may need to be added per 100 pounds mortality. Adjust the amount depending on the dryness of the carbon source. Do not get the layer too wet. The carcass contains significant water and this must be considered when adding additional water.

6. Cover the carcass layer with 6 to 12 inches of carbon source material if a second layer of carcasses is to be added. If not, proceed with the covering layer.

7. A second layer of carcasses can be added as mortality happens. Scoop out a portion of the layer covering the first carcasses and lay fresh carcasses on top. Maintain at least 6 inches between layers. Lance the rumen and add additional water as needed. If composting in deep wooden bins, complete layers in the back before beginning to compost in the front area of the bin.

8. After all carcasses have been added, top off the pile with a minimum of 18 inches of carbon source material creating a cone shape to shed rainwater if no roof or tarp covering will be used.

9. After a couple weeks, the pile will have shrunk and additional carbon source may be added to the covering layer. Check the pile occasionally to ensure animals have not disturbed it and that no portions of the carcass are visible. Also, check for noticeable odors and pile temperature.

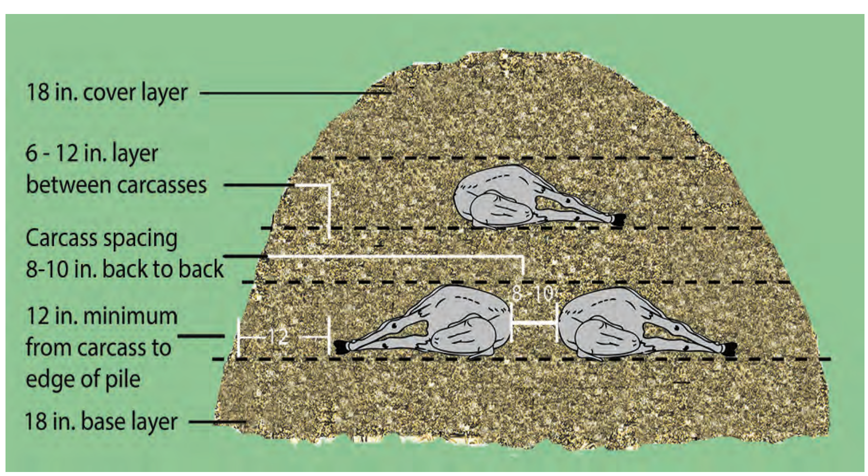

Figure 2: Carcass and layer spacing in a small ruminant

B. Heat cycles and aeration

Mortality compost piles should undergo two heat cycles, the first cycle after building the pile, and a second cycle after turning the pile. After building the pile, bacteria will be working and generating heat. After 3 or 4 days, pile temperature should reach over 130°F and may remain at that temperature for up to 2 weeks or longer before beginning a gradual decline. This heat is important to speed up decomposition and to reduce pathogens. Pathogens are destroyed due to the combination of pile heat and length of exposure. For this reason, it is important to monitor pile temperature. This need not be done daily but at a minimum temperature should be checked every 2 to 3 days.

The first heat phase continues until pile temperature begins to drop. By this time, all flesh and soft tissues will have decomposed and mainly large bones are left. In a well-working pile containing carcasses of adult animals, this occurs in roughly 10 weeks at which time the pile can be turned. Use a tractor bucket to pick up material and either dump it back on the pile or into a second bin. Allow the material to fall from the bucket. This aerates the pile and mixes the contents. Use additional carbon source material to ensure enough covering layer is put on the turned pile. Moisture can be added if the pile is too dry or the pile can be allowed to dry if it is too wet, from trapped rainfall, for example. During the first heat cycle most small bones will be degraded. When turning the pile, collect larger bones and place them in the pile center.

Photograph 3. Goat rib bone after 10 weeks of composting.

After turning, the pile will heat again and reach temperatures over 130°F. This is particularly important in reducing pathogens because not all parts of the original pile may have reached high temperatures for a sufficient length of time. Redistributing pile contents via turning increases the probability all portions of the compost will heat up sufficiently to kill disease-causing pathogens. Monitor temperature of the pile as it heats. After a second 10-week period, the compost pile can be left to cure for several weeks before use. Any large bones left at this time should be added to a future compost pile for further break down.

Although turning compost piles speeds up the process, the decision to turn piles will depend upon the producer's reasons for composting and available equipment. If a producer wishes to create compost for use on pastures, turning piles to initiate a second heat cycle and speed up decomposition is best. If a producer's main interest is lawfully disposing of mortality, turning is optional. This would also be true of producers who may not have machinery to easily turn mortality compost piles. Piles left unturned, referred to as static piles, will continue to decompose, only at a slower rate.

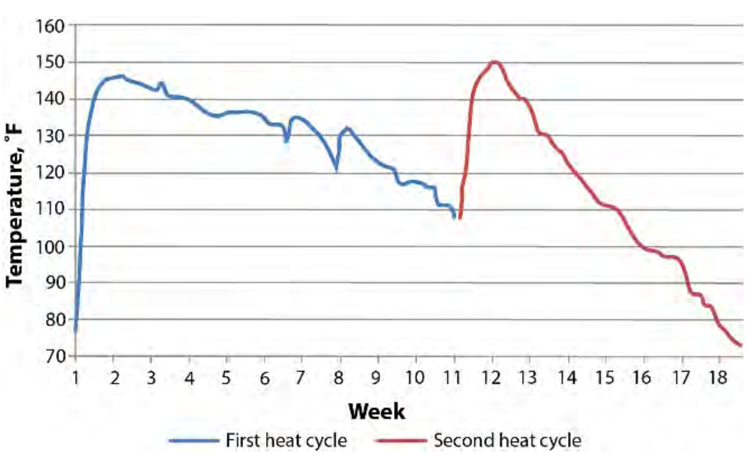

Figure 3. Temperature of a goat mortality compost pile turned at 11 weeks.

C. Cold weather composting

Composting can be done at any time of the year, even in winter. It can be difficult to establish a new compost pile in very cold weather, but active piles with sufficient covering layer insulation will continue to heat and decompose carcass material even if covered with snow and ice. Winter mortality composts best when added to an active pile or if hot, active compost from an existing pile is used as the main portion of the carbon source for a new pile. If possible, do not let carcasses freeze before adding to a working compost pile. Add additional cover layer to insulate the pile and retain heat when very cold. The composting process may take longer in winter, but the carcasses will degrade.

V. TROUBLESHOOTING MORTALITY COMPOST PILES

Common problems that occur with mortality compost piles are low temperature, odors, and failure to decompose. The causes of these problems are often too little or too much moisture, improper C:N ratio from too many carcasses in the pile, or too much air movement. Too much pile moisture will reduce oxygen in the pile, creating anaerobic conditions that cause low temperature, slow decomposition, and odor. Open the pile and allow it to dry a little. You can also turn the pile and mix additional carbon source to create better conditions for composting. If a pile is too dry, add additional water.

Adding too many carcasses to a mortality compost pile results in an improper C:N ratio. Odors may be generated and flies noticed around the pile. Add more carbon source, check moisture, and ensure a thick covering layer. Flies will not be seen around a well-built pile.

If there is too much air movement in the pile, heat will escape and decomposition will be poor and odors noticed. This may happen if using corn stover or unchopped straw or hay. Ensure a proper particle size of the carbon source. If using long-stem hay or straw, mix or layer manure or another suitable carbon source in the pile. Make sure carcasses are a minimum of 12 inches from the side of the pile or bin and that the covering layer is at least 18 inches thick. The covering layer not only acts to shed rainwater, it also serves as a biofilter trapping gasses and odors generated by the composting process.

Fluids seen running out of the pile indicate too thin a base layer, compost that is very wet, or a pile containing too many carcasses. In these cases, the pile may have to be rebuilt or split into two piles.

Scavengers may disturb pile contents if the surrounding structure cannot prevent entry. For example, the openings between slats in a pallet may not stop wild animals from entering the pile, particularly if odors are present. If entry becomes a problem, additional wire surrounding the pile may be needed.

VI. COMPOST USE

About one-half of the material from a mortality compost pile can be reused in a new pile and mixed with additional carbon source material. This reduces the amount of carbon source that needs to be on hand and also provides a source of bacteria for the new pile. The remaining composted material is a nutrient-rich medium that can be applied to pasture and other agricultural land. Mortality compost should be included in a total farm nutrient management plan and spread accordingly. It is not recommended to use small ruminant mortality compost on vegetables or areas where food is produced for direct human consumption.

VII. SUMMARY

Mortality composting is an easy, lawful, low-cost alternative for producers to dispose of livestock losses. Select sites away from water sources and the public. Producers can construct permanent wooden bins on a concrete pad or use simple wire or pallet enclosures. A carbon source such as sawdust, wood shavings mixed with manure, stable bedding, or other carbon-rich material is needed to combine with the carcass. Proper moisture content of approximately 50% is essential to ensure a working pile. Temperature in a properly made pile is high enough to kill most pathogens. A portion of the resulting compost can be reused and the remainder spread on pastureland. Producers should check with state and local officials for any laws, rules, or guidelines that must be followed concerning mortality composting and use of resulting compost.

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eXtension Goat Industry: The Source for Science Base Knowledge

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ABSTRACT

The eXtension Website provides research based information in ten resource areas: Community, Disaster Issues, Energy, Environment, Family, Farm, Health and Nutrition, Lawn and Garden, Pest Management, and Youth. Under each resource area are Communities of Practice (CoP). The Goat Industry Website (http://www.extension.org/goat) is a specific community of practice on the eXtension site that provides scientifically based information for goat producers, extension educators and consumers. Currently, this site contains announcements, a glossary of terms, a meat goat management tool and instructional videos. Additionally, there is information on breeds, economics and business planning, facilities, fiber production, genetics, health, marketing, management, milk products, nutrition, reproduction, pastures and forages, predator control, vegetation management and youth. Resources on the site benefit people interested in learning more about goats.

Keywords: eXtension, Goat Industry, Website

I. INTRODUCTION

eXtension is a Website that provides research based information on topics as diverse as horses, fire ants and energy conservation. In developing a Website on eXtension, a first step is for a group of people with a common interest, such as goats, to come together, forming a Community of Interest. Once they are approved by eXtension and begin developing and placing information on the eXtension website about a topic such as goats, they are now a Community of Practice. Communities of practice (CoP) are formed under one of ten resources areas (Table I). At the time that this article was written there were 70 published communities of practice in eXtension. Table I shows the current CoP's under the resource areas that can be found on the eXtension Website. Information found in the communities of practice is developed by extension specialists and researchers from land grant universities, veterinarians, and numerous specialists from various USDA agencies across the United States. eXtension, therefore, is considered to: 1) offer credible expertise, 2) provide reliable answers based upon sound research, 3) have connections to the best minds in American universities, 4) provide creative solutions for today's complex challenges, 5) supply customized answers to your specific needs, 6) offer trustworthy, field-tested data and 7) provide dynamic, relevant and timely answers to your questions. More details about eXtension can be found at https://www.extension.org/ .

A. Community of Interest in Goats

Recently, members of the 1890 land grant universities took the lead in developing a Community of Interest in goats and eventually Community of Practice on the Goat Industry. It was felt that this was important to place on the eXtension website because of their growing importance in the U.S. In the United States, goats are used mainly for meat, milk and fiber production. Approximately 80% of goats in this country are meat goats, 15 % are dairy goats and 5 % are fiber goats (USDA-NASS, 2018).

The January 2018 goat survey conducted by the National Agricultural Statistics Service, which has been conducting extensive goat surveys since 2005, indicates that there are approximately 2.66 million goats in the United States of which 2.15 million are meat goats (USDA-NASS, 2018). These numbers increased by 1% over the past four years (USDA-NASS, 2018).

Dairy goat numbers in the United States showed an increase of 7% since 2014 (USDA-NASS, 2018). For more information about the Goat Industry trends and outlook go to the following Website: http://www.extension.org/pages/Goat_Industry_Outlook#Trends_in_the_U.S._Goat_Industry.

Producers, in all phases of production (meat, dairy and fiber) have expressed a need for current, correct information on how to raise goats and produce wholesome products in demand by the public. Information is needed in all areas, from basic housing and management to nutrition, breeds, herd health, reproductive issues, marketing, product safety, and value-added products.

With this in mind, the objective was to develop an eXtension Website designed to meet the educational needs of goat producers, extension educators and farmers. The goals were: 1) To provide information from basic housing and management to nutrition, breeds, herd health, reproductive issues, marketing, product safety, and value-added products to goat producers; 2) To provide learning opportunities that are science based and peer-reviewed; 3) To create collaboration among goat industry professionals resulting in a resource that provides valuable educational materials benefiting the user; and 4) To highlight goat industry resources.

II. MATERIALS AND METHODS

A. Development of Goat Industry CoP Leadership

The initial CoP leadership team consisted of a USDA Program Leader, a CoP Administrative Advisor, a core leadership administrator and members from 1890 institutions shown in Table II. The core team would not exceed 12 members. Today, the leadership team consist of members from 1890 institutions and two 1862 institutions (Cornell University and Washington State University).

B. Making the Goat Industry CoP National in Scope

The national team of experts includes state goat extension specialists, research and teaching faculty, veterinarians, regional educators and professionals at education centers. The community of practice membership currently includes 14 of the 18 1890 land grant universities, 34 of the 1862 land grant and state universities, and the USDA Agricultural Research Service. Total membership is 117. Members continue to be added to this list as the community of practice develops and will include additional 1862 universities, other institutions, and professional organizations and societies. It is anticipated that marketing efforts through presentations at regional and national scientific meetings throughout the nation and through word-of- mouth will increase the awareness of the goat community of practice. These experts will be recruited as they are identified. Member institutions are shown in Table III.

C. Communication, Meetings and Continued Productivity

Year 1 included an organizational meeting for developing this proposal and occurred on January 31 - February 1, 2007. A meeting was planned for June 23- 24, 2007, just prior to the eXtension training conference. At this meeting we began adding content to the CoP. The committee convened during the National Animal Science meetings held July 7 -12, 2007, in Indianapolis, Indiana, and one or two additional meetings were scheduled as the need arose. Web-based calls were held among the CoP leadership during year 1. It is anticipated that data on the number of visits to the Website, interaction with ask the experts, and increased number of certifications will continue.

It is also expected that some of the universities will likely incorporate interactions with eXtension into the normal duties of extension professionals. Once this activity becomes a component of the evaluation and promotion process, continued productivity of a community of practice is assured.

D. Content on Goat Industry Website

Currently, the site contains information on breeds, economics, establishing a goat operation, facilities, fiber production, genetics, goat milk products, health, marketing, management, nutrition, organic goat production, reproduction, pastures and forages, predator control, target grazing, vegetation management and youth. In addition to the above information, there are also announcements, assessment and outlook of the goat industry, a glossary of goat terms, a meat goat management tool, goat related resources, and instructional videos. Resources are continuously being added to the site to benefit the people interested in learning more about goats.

E. Ask an Expert

If a person has a question about goats they can go to the site and ask the questions and within 48 hours the person will have an answer from one of our experts.

F. Analytics for the Goat Industry Website

To determine how the Goat Industry Website is doing, eXtension provides Google Analytics (Google Analytics, 2018) to determine the Website traffic and marketing effectiveness.

III. RESULTS

A. Initial Start of the Goat Industry CoP

The Goat Industry started as an eXtension CoP in March, 2008. The CoP was launched to the live site of eXtension one year later in March 2009. Resources continued to be added to the Website.

B. Analytics for the Goat Industry Website

The following Google Analytics reflect the eight years of the Goat Industry since the launch of the Website (March 2009- March 2017). During the eight years, visitors viewed 68,046 pages of the top content of eXtension and these were viewed a total of 52,140,523 times. Of all content viewed during this time on eXtension, Goat Sexual Maturity and Puberty was eighth and the Goat Industry Website was 44th out of the top 100 content viewed. Goat Sexual Maturity and Puberty was viewed 189,764 times while the Goat Industry Webpage was viewed 71,437 times.

C. Top Content of the Goat Industry

The top content viewed during the eight year period was Goat Puberty and Sexual Maturity page viewed 9% of the time. The eXtension Goat Industry Webpage and Goat Vaccination Program pages were viewed 3% of the time. The top content (top ten) that was viewed and number of times these pages were viewed are shown in Table IV.

D. Ask an Expert

During the eight years, the number of questions answered was 1,225. Questions that were resolved from outside of the United States were 180. The majority of questions asked ranged from, genetics, health, management, reproduction to predator control and pasture management.

IV. DISCUSSION

The Goat Industry Website provides basic information for the producer, consumer and extension personnel. This Website provides opportunities for persons interested in learning more about goats to find the information, and if it is not there they can ask an expert and receive an answer within 48 hours.

Since the launch of the Website in 2009, the leadership team has met and added information on dairy goats, fiber production, basic goat facilities, basic herd health procedures and biosecurity, crossbreeding, farm business planning and budgeting, organic goat production, risk management, economics of goat production, business plans and enterprise budgets, and disaster preparedness .Retrieved from "http://cop.extension.org/wiki/Goat_Industry_Content_Curriculum_Plan"

Eventually, the Goat Industry Website (http://www.extension.org/goat) will be a one-stop source for goat information.

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Table I. eXtension Communities of Practice

Community
Agricultural and Food Law
Civil Dialogue
Community Planning and Zoning
Community, Local and Regional Food Systems
Cooperatives
Creating Healthy Communities
Diversity, Equity and Inclusion
Enhancing Rural Community Capacity
Entrepreneurs & Their Communities
Geospatial Technology
Internationalizing Extension
Network Literacy
Program Evaluation
Volunteer Administration
Women in Agriculture

Disaster Issues
Agricultural Disaster Preparedness and Recovery
Drought Resources
Floods
Wildfire

Energy
Farm Energy
Home Energy
Wood Energy

Environment
Prescribed Fire
Trees for Energy Conservation

Family
Child Care
Companion Animals
Drinking Water and Human Health
Family Caregiving
Food Safety
Military Families
Parenting
Personal Finance
Child and Family Learning Network

Farm
Ag Safety and Health
Animal Manure Management
Animal Welfare
Apples
Bee Health
Beef Cattle
Blueberries
Climate, Forests and Woodlands
Dairy
Forest Farming
Freshwater Aquaculture
Goats
Grapes
Horses
Marine Aquaculture
Organic Agriculture
Plant Breeding and Genomics
Sheep
Small and Backyard Flocks
Small Meat Processors
Sustainable Marine Fisheries
Wood Products

Health and Nutrition
Community Nutrition Education
Families, Food and Fitness
Healthy Food Choices in Schools

Lawn and Garden
Extension Master Gardener
Gardens & Landscapes
The Garden Professors
Water Conservation for Lawn and Landscape

Pest Management
Ant Pests
Feral Hogs
Imported Fire Ants
Invasive Species
Pest Management In and Around Structures
Wildlife Damage Management

Youth
Ag Zone
Science for Youth

Table II. Institutions of the Initial Leadership Members of the Goat Industry Community of Practice

Institution	State Located
Alabama A & M University	AL
Alcorn State University	MS
Cooperative Extension Program at Prairie View	TX
Delaware State University	DE
Florida A & M University	FL
Lincoln University	MO
Langston University	OK

Table III. Institution of Goat Industry Members

<u>1890 Institutions</u>
Alabama A & M University
Alcorn State University
Cooperative Extension Program at Prairie View
Delaware State University
Florida A & M University
Fort Valley State University
Kentucky State University
Langston University
Lincoln University of Missouri
North Carolina A & T State University
Tennessee State University
Tuskegee University
University of Maryland- Eastern Shore
Virginia State University
West Virginia State University

<u>1862 Institutions</u>
Auburn University
Clemson University
Colorado State University
Cornell University
Kansas State University
Louisiana State University
Michigan State University
North Carolina State University
Oklahoma State University
Oregon State University
Penn State University
Purdue University
Rutgers, State University of New Jersey
South Dakota State University
Texas Agri Life Extension Service
The Ohio State University
University of Arkansas
University of California

<u>Other Institutions and Agencies</u>
University of Delaware
University of Florida
University of Georgia
University of Kentucky
University of Maine
University of Maryland
University of Minnesota
University of Missouri
University of Nevada Reno
University of Tennessee
University of the Virgin Islands
University of Wisconsin
University of Wyoming
Utah State University
Virginia Polytechnic Institute and State University
Washington State University

Missouri State University
USDA

Table IV. Number of Times Top Ten Content Viewed on Goat Industry Website During the Eight Years*

Top Content Viewed	Number of Times Pages Viewed	Percent of Total Time Pages Viewed (2,162,962)
Goat Puberty Sexual & Maturity	189,764	9%
Goat Webpage	71,437	3%
Goat Vaccination Program	69,684	3%
Goat Parturition/Kidding	51,630	2%
Goat Reproduction	31,562	1%
How to Do Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis	31,432	1%
What are Some Diseases Goats can Transmit to Humans?	31,368	1%
Goat Breeds	27,796	1%
Goat Pastures & Forages	24,354	1%
Newborn Goat Kids	21,301	1%

* A total of 1,999 pages viewed 2,162,962 times during the eight years.

Putting Precision Agriculture to Work for the Goat Industry

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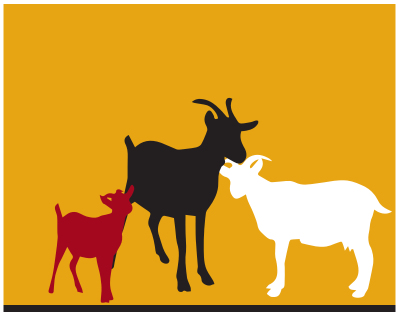
Precision livestock farming is the use of advanced technologies to optimize the contributions of an individual animal. Although the goat industry is a viable enterprise in the US, new technologies must be developed and adopted to increase the economic value and impact of goats, as the industry is in its infancy. Traditionally, livestock improvement has been achieved through the use of conventional methods of selection, natural mating, and/or artificial insemination. Genetic improvements resulting from these practices are usually slow. Biotechnological innovations now permit the rapid propagation of superior genes and offer the opportunity to enhance existing and develop new assisted reproductive technologies (ART) that may result in animals that meet the demands of the goat industry and accommodate environmental challenges. Numerous ARTs have already resulted in goats with more desirable phenotypes and significant market potential. Further, bioengineering of the goat has potential for developing new products of high quality, as reflected by reports of improved meat goat quality, production of pharmaceutical proteins in milk, enhanced parasite resistance, and improved fertility and fiber quality. However, many of these technologies remain inefficient and are accompanied by growing consumer concerns. To enhance the practical utility of many of these technologies, it is necessary to understand the molecular mechanisms of gonadal function, such as the testis, particularly those associated with the development of germline stem cells. Currently, molecular tools required for such studies of livestock species, particularly goats, are limited. Here we will explore the potential of these technologies and touch on related consumer concerns.

Keywords: Goat, Precision Agriculture, Molecular Mechanisms, Assisted Reproductive Technologies



SECTION THREE

ANIMAL SELECTION, REPRODUCTION AND BIOTECHNOLOGY

Reproductive Technologies Used to Make Goats more Efficient

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With the introduction of Boer and Kiko breeds for meat goat production in the United States, more emphasis is being placed on the reproductive management to increase the number of offspring's born and weaned and the frequency with which they are produced. It is also desirable to produce out of season kids to take advantage of a market premium for milk and meat. Reproductive manipulations, commercial Artificial Insemination (AI) programs using fresh or frozen semen, and Embryo Transfer (ET) have been developed and are in use most commonly in goats for reproductive efficiency.

NORMAL ESTROUS CYCLE AND BREEDING SEASON:

Goats in a temperate region are polyestrus and breed efficiently when daylight lengths are short (August-March) with a peak breeding season of October through December. The transitional periods are approximately two months before and after breeding season, with deepest anestrus period in April and May. In tropical areas near the equator, native breeds show less seasonality and breed year-around. There is variation between, and within seasonality which allows for selection of out-of- season breeders. For example, pygmy and Tennessee stiff legged breeds of meat goats breed year-around in the United States and Nubian, Spanish meat goats, Boer and Kiko are less seasonal. This seasonality can be used to the producer's advantage by introducing males during the summer transitional period to "shock" the female into cycling. This will not occur when males are run year-round with the females. The length of estrus cycle in the doe is 18-21 days; short cycles of 5 to 7 days are more common at the beginning and end of the breeding season. Estrus varies from 24-72 hours duration, with most females showing estrus for 30 hours. Does in estrus are restless, show tail wagging, vocalize, have a swollen vulva with clear discharge which changes to cloudy toward the end of estrus. These behaviors may be pronounced in the presence of a male.

REPRODUCTIVE MANIPULATION:

Male effect during the transitional period: Introduction of a buck or ram into a group of transitional does (after having no contact with a male for at least 3 weeks) will induce a hormone surge and subsequent ovulation within a few days. Teaser males can be introduced to the females several weeks before the first desired breeding, and then a fertile male can be substituted when breeding is desired. Similarly, fence line contact introduced males can be used to achieve a male effect for hand mating. The response to male stimulation can be quite variable and is influenced by breed, prior isolation, and depth of anestrus, nutrition and stage of postpartum. This technique can be used in combination with some drugs for out-of-season breeding manipulation.

Synchronization of estrus during the breeding season: Synchronization of estrus in cycling does can be accomplished using either prostaglandin or progestins.

Prostaglandins: Goats must be in luteal phase for prostaglandin (PG) to be effective. Adequate nutrition, heat detection capabilities, and adequate sire or insemination capabilities are essential prior to a synchronization program. Prostaglandin $F2\alpha$ 10-15 mg (Lutalyse®) or Cloprostenol, 125 mcg (Estrumate®) will induce estrus in 36-72 hrs (48 hrs. average). Two doses of prostaglandins given 9 to 11 days apart will synchronize the majority of cycling females. An alternative is to observe the flock actively for 4 days, breed all females that come into heat, administer PG on the fourth day, and breed all females that come into estrus during the next 3 days. This should result in most females being bred within a 7-day period. Producers should ensure that none of these ewes or does is pregnant at the time of PG administration because abortion may be induced.

Progestins: Exogenous progestins can be used during the breeding season to artificially control the length and termination of the luteal phase. This is the most common method of estrus synchronization in goats for AI or Embryo Transfers (ET). Intravaginal devices, such as Controlled Intravaginal Drug Release device (CIDR), are also available in US that contain 300mg of progesterone impregnated in silicone (EAZI-BREED). All of these require removal of progestins after12 to 14 days from the doe. Estrus occur 24-36 hrs after removal of the progestin source. Prostaglandins 24 hrs. before progestin removal or small dose of Pregnant Mare Serum Gonadotropin (PMSG, (eCG) either 24-48 hrs. before or at time of progestin removal (250IU) could be used during the breeding season. From our experience, progestins produced better synchronization than prostaglandins.

Synchronization of estrus or induction of estrus for out-of-breeding season: Prostaglandins are not effective for estrus synchronization out-of-season. The most commonly used program for out-of-season breeding is a combination of progestins andPMSG (eCG). CIDR is inserted, the same manner described before for synchronization during the breeding season, for approximately 14 days and a gonadatropin, either FSH orPMSG, is administered 48 hrs. prior to progestin removal. PMSG is most commonly used because of the need to give only one single injection. The dose ofPMSG is 400 IU. BecausePMSG is not commercially available in the United States, a product containing both HCG andPMSG (PG 600®), that is labeled for use in gilts, has been used for goats successfully in the United States. The dose of PG 600 is 5ml.

Control Lighting: Artificial lighting, either by itself or in conjunction with male effect, can be used for effective manipulation of the breeding season. Artificial lighting is mostly employed for a long day simulation. In winter, long days (19-20 hrs. of light) are simulated for two months and then stopped on March 1, to allow normal lighting. After six weeks, males are introduced, and a fertile estrus occurs around 10-20 days later. These females have a short breeding season of around 60 days. Males may also benefit from this treatment to increase libido and quality of semen. Some producers combine hormone and lighting for out-of-season breeding. The lighting manipulation is used in many dairy goat operations successfully.

Estrus cycle manipulation summary:

1. **Breeding season:**

- Progestins (Oral or CIDR) for 14 days
- Progestins (Oral or CIDR) for 14 days, + 4ml PG 600, 24-48 hrs. before or at time of progestin removal
  Prostaglandins (single or double injection)

2. **Transitional period:**

- Male effect
  Progestins (Oral or CIDR) for 14 days + 5ml PG 600, 48 hrs before progestin removal

3. **Out-of-Breeding Season:**

- Progestins (Oral or CIDR) for 14 days + 5ml PG 600, 48 hrs before progestin removal
- Lighting program

ARTIFICIAL INSEMINATION:

Transcervical insemination: Vaginal and cervical inseminations have low conception rates and are easier to perform. Transcervical insemination is a more invasive method to place semen directly into the uterus and is relatively common procedure and one can easily master it with some practice. The necessary speculum, light sources, and insemination equipment are readily available in goat supply data catalogues. Cattle insemination guns and sheaths can be used since they are the same standard size compared to goat guns, but a bit longer which give an advantage for better handling. In dairy goats, animals could be observed for heat and inseminated accordingly. Because length of estrus varies between does and ovulation occurs late in estrus, optimal timing of insemination is best determined by changes in cervical mucus. However, the standard AM-PM insemination guidelines can be used together with changes in cervical mucus. As estrus progresses, the mucus turns from clear and thin to cloudy and stringy. Insemination is recommended before mucus turns cloudy, usually 12-15 hrs. after onset of estrus. A teaser buck or an intact buck in an adjacent pen could help detection of animals in standing estrus. In meat goats, does are usually synchronized for estrus for artificial insemination. Dairy goats can be inseminated on milking stands. Meat goats are usually not cooperative on stands and need to be restrained by an assistant. After proper preparation, the cervix is visualized through a clear vaginal speculum, the insemination gun is manipulated through cervix by gentle rotation and forward movement, and semen is deposited in the anterior cervix or uterine body. Conception rate of 50-85% is reported, which depends on skill of the operator and quality of the semen used. Fresh diluted semen or frozen semen can be used for insemination. The desired number of motile sperm per insemination for fresh liquid semen is 150 million and 200 million for frozen semen. It is advisable that both fresh and frozen semen be evaluated before insemination for quality.

Laparoscopic Insemination: Laparoscopic artificial insemination is the most common AI technique used for ewe. This procedure is also used for goats in ET programs and for valuable sperm of meat goats since less sperm is needed for laparoscopic insemination. Females are synchronized for estrus and detected as described for transcervical insemination. Fresh or frozen semen could be used for insemination. Females are fasted for 36 hrs prior to laparoscopic AI. They are sedated and are positioned in dorsal recumbency with the head tilted down at 45-degree angles or more. Two trocar-cannulas are inserted into the peritoneal cavity, at the sites in front of the udder away from the midline. The peritoneal cavity is inflated with CO^2 gas. A 10mm laparoscope is inserted through the appropriate cannula, and the uterus is visualized through the laparoscope. The insemination gun fitted with an insemination needle is inserted through the other cannula into the abdomen and the semen is injected into each uterine horn. The laparoscope and cannula are removed, and the puncture sites are covered by an antibiotic ointment. Animals are moved to a recovery area and left undisturbed for 1-2 hours after insemination.

MULTIPLE OVULATION AND EMBRYO TRANSFER:

Traditional crossbreeding program using artificial insemination focuses on the male for availability of superior offspring. Whereas, through multiple ovulation and Embryo Transfer, genetically superior females can contribute to this genetic diversity. The limited economic value of most goats precludes the widespread use of ET for the average production unit. Also, the invasive methods needed make ET less practical in sheep and goats than in cattle. Importation of South African Boer and New Zealand Kiko goats for meat production made ET more widespread in goats. A successful ET Program requires advanced planning and lots of attention to details in donors and recipient selection, superovulation, synchronization of donors and recipients, and successful recovery and transfer of high quality embryos. ET can be carried out in or out-of-season, but the best response is attained during the breeding season when donors and recipients are cycling normally.

Estrus synchronization and superovulation: Most ET Programs rely on exogenous hormones to induce and synchronize estrus in donors and recipients. Synchronization is commonly achieved using progestin sponges or CI-Accurate detection of estrus is needed by use of a teaser male. The method of estrus synchronization is the same for both the donors and the recipients, with the exception that progestin implants should be removed from recipients 12 hrs. prior to removal from donors, since donors show estrus sooner than the recipients due to super ovulatory drugs they receive. Super-ovulation of the donor is accomplished by injection of PMSG, also called eCG, and pituitary extracts of Porcine Follicular Stimulating Hormone (FSH-P or Folltropin-V).PMSG has a longer half-life of FSH activity (about 72 hrs.) and contains more LH.PMSG is associated with over stimulation of ovaries, resulting in large numbers of ovulation with increased proportion of unfertilized embryos and poorer quality embryos. 1000-1500 IU of PMSG is administered in a single dose 48 hrs prior to pessary removal for superovulation. FSH has a half-life of about 6 hrs. and requires twice a day injection for several days. FSH is superior to PMSG in ovulation and fertilization rates and in production of good quality embryos. We use FSH in our research program for super-ovulation of the donors in the following manner:

Sample Program:

Day	*Treatment*	
-16	Donors and recipients receive CIDR	
	AM	Donors 4 mg FSH
-4	PM	Donors 4 mg FSH
	AM	Donors 3 mg FSH
-3	PM	Donors 3 mg FSH
-2 (AM- Remove CIDR from recipients)	AM	Donors 2 mg FSH
	PM	Donors 2 mg FSH (and Remove CDIR from donors)
	AM	Donors 1 mg FSH
-1	PM	Donors 1 mg FSH
0	Estrus, AI or natural breeding, two services at 12 hrs. interval until end-of-estrus.	
5-6	Embryo recovery	

Recipients should get 400 IU of PMSG at the time of the implant removal for out-of-season embryo transfer. In donors having more than 10-12 ovulations, fertilization is reduced due to reduced transport of sperm through the cervix. Laparoscopic deposition of the semen directly into the uterine horn can correct this problem especially when frozen semen is to be used.

Embryo Collection: embryos are usually recovered from the donor's uterus on days 5-6 following breeding.

Surgical Collection: Surgical collection of embryo is the most used technique in the goats. Does and ewes require general anesthesia and are positioned in dorsal recumbency with hind quarters elevated on surgical table. The uterus and ovaries are exposed through a small caudal ventral midline laparotomy. Ovaries are examined to determine response to superovulation. This can also be accomplished with laparoscopy prior to laparotomy to prevent handling of the ovaries. A 20-gauge Teflon IV catheter is inserted into the tip of the uterus near the utero-tubal junction. The tip of a small pair of artery forceps is used to puncture a small hole through the uterine wall for the insertion of a 10 French Foley catheter at the base of the uterine horn. The cuff is inflated with 5 ccs of air, 20 ml of flushing media is injected through the IV catheter and the fluid is collected from the Foley catheter into a collecting bowl or Petri dish. The procedure is repeated on the opposite uterine horn. There is no need to suture the puncture sites in the uterus. Sterile warm saline should be used to keep the uterus moist during the procedure and large amounts should be poured into the peritoneal cavity as peritoneal lavage prior to routine abdominal closure. Antibiotics and prostaglandin should be administered post operatively.

Non-surgical Collection: While research into transcervical collection of embryos continues, there is no practical technique yet that can be recommended for field use.

Laparoscopic Embryo Collection: Laparoscopic assisted collection can be performed to exteriorize the tip of the uterine horn and then flushing is done in the same manner described for surgical collection. This can reduce the severity of adhesions that result from handling of the uterus from the surgical procedure. Laparoscopy is also used for collection of the embryos within the abdomen without performing laparotomy. This technique requires considerable skill and is not practical for routine field use.

Transfer of Embryos: Nonsurgical, Laparoscopic, Laparoscopic assisted and surgical methods for embryo transfer have been described. While the Laparoscopic collection of embryos requires considerable expertise, Laparoscopic transfer of embryos is relatively easy and is recommended for especially large ET Programs. However, Laparoscopic assisted transfer and surgical transfer is the techniques used the most for transfer of embryos in goats.

Laparoscopic Assisted Transfer: A Laparoscope is used to examine the ovaries. The uterus is identified and grasped by grasping forceps through a 2cm midline stab, about 10 cm cranial to the udder. The tip of the uterine horn, ipsilateral to CL, is punctured using a blunted needle and embryos are introduced through a tom cat catheter into the uterine horn. The catheter should be inspected under the microscope, to ensure embryos are not retained in the catheter, prior to closure of the abdominal incision.

Surgical Transfer: Most transfers are done surgically. The tip of the uterine horn is exposed as described under surgical collection and the embryos are introduced into the uterus through a puncture at the tip of the horn ipsilateral to the ovary with CL.

EXPECTED RESULTS:

Many factors can affect the success of an ET Program. It is difficult to predict the outcome. An average of 8-10 transferable embryos can be expected per donor with pregnancy rate of 60-80 percent for the transfer of 2 fresh embryos per recipient. Pregnancy resulted from frozen embryos transferred is much lower.

IN VITRO FERTILIZATION:

In Vitro fertilization (IVF) and culture technology offers the advantage of producing embryos from animals when production of embryos might be more difficult or impossible. In addition, efficient IVF procedure is important for development of biotechnologies such as embryo sexing, nuclear transfer and gene transfer. Recent progress in embryo biotechnologies has resulted in increased efforts in practical and commercial application of IVF for ET industry. Goat oocytes can now be successfully matured during the breeding and non-breeding seasons and have been transferred to produce live young kids.

Optimizing Reproductive Performance in the Goat Herd

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ABSTRACT: Reproductive efficiency has a direct impact on pregnancy rates, the kidding/lambing frequency and the number of offspring available to market each year, and is a major factor affecting profitability. In order to enhance reproductive performance, one has to consider breed, selection, nutrition and health and have a basic understanding of female and male reproduction. The importance of a good nutrition plan cannot be overstated. Proper ration formulation and feeding promotes reproductive function and females with an ideal body condition score (2.5 – 3.0) ovulate more eggs and therefore have more offspring. Selecting the highest performing females while culling unproductive ones will increase herd reproductive rates. There are numerous diseases that can affect reproduction as well as survival of kids. Therefore, it is important to adopt a disease prevention strategy that includes routine vaccinations and a deworming protocol that promotes good herd health. Having an understanding of male and female reproduction is critical in managing puberty, minimizing the effects of seasonality on reproduction, and using advanced reproductive techniques for genetic improvement. Finally, 5% of bucks can be sterile or sub-sterile and all breeding males should be evaluated by conducting a standard breeding soundness exam 1 month prior to breeding. Male libido/sex drive should also be evaluated in breeding males. In conclusion, if the factors above are considered, enhanced reproductive performance can be achieved and this will not only optimize production but also promote profitability.

Keywords: reproduction, kidding, puberty, does, bucks.

I. INTRODUCTION

Small ruminants are important for limited resource farmers who manage their animals for multiple purposes including meat and milk. The most recent National Agriculture Statistics Services (NASS) data reported that U.S goats totaled 2.62 million head (NASS, 2018). Demand for goat meat appears to be very strong in the U.S as demonstrated by the increasing total number of goat meat imports and the number of goats slaughtered under federal and non-federal inspection (NASS, 2011). Therefore, market opportunities abound for small acreage producers to raise goats to meet this demand. In addition, there are opportunities to sell value added meat products for direct sale to local niche markets (roadside markets, farmers markets, community supported agriculture, online sales, buying clubs, regional food hubs). Although these opportunities exist for producers in the goat industry, many factors impact forward progress in production and marketing which must be adequately addressed through extension and research activities. A critical factor that many producers face is failure to take advantage of the relatively short gestation period (pregnancy) in goats and to manage their herd adequately for optimum reproductive efficiency. Factors such as breed, maintaining a good nutrition and health program and efficiently utilizing reproductive technology to minimize seasonal impacts are critical for increasing production and profitability in herds.

II. BREED SELECTION

Breed selection can have an enormous influence on reproductive performance. The characteristics generally impacted most by breed are age to puberty and prolificacy (litter size), and seasonality. Goat breeds are diverse in their reproductive traits and this makes it more important that breed is considered seriously before starting a flock/herd if one wants to optimize reproductive efficiency.

Maternal breeds of small ruminants should possess specific traits such as being fertile, prolific, have easy birthing and good mothering ability, good milk production and the ability to breed out of season. In the U.S, the most popular breeds of meat goats include Boer, Spanish, and Kiko breeds. Of these three breeds, research has indicated that Spanish and Kiko breeds were superior in all survival and reproductive traits measured (Browning et al., 2010). Under a semi-intensive pasture management system, litter size, litter weight per doe exposed, and the number of does weaning at least 1 kid were all consistently lower in Boer does. In addition, a significant proportion of Boer does experienced reproductive failure compared to the other breeds in the study (Browning et al., 2010). Different breeds perform best under specific environmental conditions and the decision on which breed to choose depends on your reason for raising goats and how well they perform in your environment and farm.

Sire breed selection is also important in optimizing reproductive traits. Good terminal sire breeds excel in traits such as growth and carcass yield. In the Browning et al. (2010) study, data indicated that Boer bucks excelled in these traits compared to Kiko and Spanish bucks. Boer sires used in this study generally produced heavier birth weights and carcasses with heavier muscling (Browning et al., 2010).

III. **NUTRITION**

Herd nutrition has a direct influence on reproductive performance. Of all the issues discussed, this is the one factor that the producer has the most control over. Strategic use of nutritional supplements is known to improve a number of reproductive traits including boosting sperm production before mating, maximizing ovulation rate to increase litter size, reducing early embryo loss and maximizing postnatal survival and development (Martin et al., 2004). A good plane of nutrition can also decrease the length of the post-partum interval (time between kidding and re-breeding).

All animals, including males, should be evaluated for adequate body condition scores (BCS) two months prior to the breeding season and their feet trimmed as necessary. Flushing is the technique of increasing nutrition prior to breeding to increase body weights or condition and increase the number of ovulations per female. Flushing should begin 3 - 4 weeks before breeding and be continued through to the first 3 weeks of breeding. Generally, results from flushing vary and it is seen to be most beneficial if used early in the breeding season and when there are a significant number of thin females. Every producer should be familiar with how to assess BCS. Langston University has a great reference on how to correctly do BCS in goats (http://www.luresext.edu/?q=content/body-condition-scoring).

During the first 90 days of pregnancy, adequate nutrition is important, especially for placental development. However, only a small increase relative to what is required for maintenance is needed. Inadequate feeding can result in reduced survival rates at birth and all pregnant females should be fed to maintain a BCS of 2.5 - 3 during early gestation and onwards. If this cannot be maintained on pasture or moderate-quality hay, supplemental grain might be required, especially during winter-associated increases in feed requirements.

Excess losses in bodyweight can place females at risk for developing pregnancy toxemia. Nutrition during the last 4 - 6 weeks is extremely important as approximately 70% of fetal growth occurs during this period. During this time, most of the female's mammary (udder) development is occurring as well, and under-feeding can affect subsequent colostrum and milk production. Inadequate nutrition can also result in abortions, low birth weights in kids and increased death loss. On the other hand, overfeeding results in obesity, contributing to dystocia and again increased risk in pregnancy toxemia risk. Therefore, it is very important that feeding regimes minimize the energy being supplied by body fat reserves and strive to maintain the flock at an optimum BCS. Grain supplementation is usually necessary to meet increased energy demands, especially when forage quality is low and when you have high producing females. The amount of grain supplementation needed will depend on quantity and quality of available forage, breed, the number of fetuses, doe size and age.

Because adequate nutrition is critical, it is important to ensure sufficient feed bunk space for pregnant and lactating does. Some females, especially small/young ones, might not get enough to eat and it might be necessary to feed them separately. Feeding on the ground should always be avoided due to potential spread of infectious abortive diseases. Higher producing females should be fed higher quality feed, especially does nursing twins and triplets. During pregnancy and lactation, free choice minerals might not ensure adequate intake, especially of calcium. Calcium requirements generally increase during early and late gestation and peaks during lactation. Calcium requirements are highest for females carrying multiple fetuses and those producing more milk making adequate mineral supplementation more important.

IV. HEALTH

The overall objective of a good health management plan that enhances reproductive efficiency is the successful completion of pregnancy, birth of healthy, strong offspring, optimal birth and weaning weights, and optimum milk production (Fthenakis et al., 2012). A good health management plan for does should include nutrition, udder health, and internal parasite management, vaccinations and the prevention of abortive and metabolic disorders (pregnancy toxemia and hypocalcemia).

Effective udder health management includes careful examination by palpation for any hardness, abscesses, or nodules. It has been documented that mammary infections increase during the weeks following the cessation of lactation (Barkema et al., 1998). Evaluating the mammary glands at this time will help to identify any females with abnormalities that should be culled, especially since kids from does with mammary gland abnormalities tend not to thrive as well as those from dams with healthy udders.

Heavy infections with internal parasites can reduce the BCS of breeding females and may reduce reproductive performance in the herd. To minimize any negative effects, a regular parasite control program has to be implemented. Goat producers should be utilizing tools such as the FAMACHA© system and Five Point Check® in a targeted selective treatment approach. This is especially important around the time of kidding when females experience a decline in their normal immunity to internal parasites (peri-parturient rise in fecal egg counts). This then becomes the primary source of parasite infection for new offspring who are highly susceptible to infections due to their naïve immune systems. As expected, kidding on pasture, spring and winter kidding, and younger females increases this risk. Selective deworming, utilizing FAMACHA© and the Five Point Check©, 2 - 4 weeks prior to kidding helps to kill parasites and reduce pasture infestation. The suppression of the peri-parturient rise in fecal egg counts depends on the effectiveness of the anthelmintic/dewormer used. Finally, the impact of good nutrition, especially protein and trace minerals needed to support a strong immune response should never be underestimated in an effective parasite control program. Research has shown that ewes receiving higher levels of protein for 6 weeks prior to lambing have significantly lower fecal egg counts (Donaldson et al., 1997).

A good health management plan should also aim to ensure health of pregnant females as well as their offspring. Vaccination against Clostridial diseases, including enterotoxemia (over-eating disease or pulpy kidney disease; Type D), bloody scours (Type C) and Tetanus (lockjaw; Type D), are generally effective and all females should be vaccinated 2 - 4 weeks prior to giving birth. This allows dams to provide passive immunity to their offspring through colostrum. The antibodies from colostrum can only be absorbed within the first 24 hrs after birth and it is critical that kids nurse soon after being born so that they are protected against these diseases.

Small ruminants are also susceptible to infectious abortive diseases such as Chlamydia, Toxoplasmosis, Brucellosis, Listeriosis, Q fever, and a host of others. A few of these have vaccinations available and if there is a history of abortions and/or weak small kids born in your herd the cause should be diagnosed. Detailed history, blood tests and/or isolation of bacteria from placenta or fetal tissue can be used to accurately diagnose an infectious abortive disease in your herd. If a vaccination was not carried out or is not available, feeding (chlorotetracycline (aureomycin) at a rate of 80 mg/hd/day during last 6 weeks of gestation) or administering injections of antibiotics (LA-200; oxytetracycline) at 2 week intervals during last 6 weeks of gestation has been shown to be effective in preventing abortions. Abortions due to toxoplasmosis can be prevented by feeding a coccidiostat in the feed 6 weeks before lambing/kidding. Pregnant women should never handle aborted material due to the risks to her own pregnancy. For instance, *Clamydia abortus*, the agent responsible for causing Chlamydia, is zoonotic (spread from animals to humans) and can cause serious health problems in pregnant women.

V. MALE AND FEMALE REPRODUCTION

A. Puberty

From a practical point of view, puberty in females is not only when she reaches sexual maturity and exhibits estrus (6 – 8 months of age) but is the age at which she can successfully support pregnancy to term (Senger, 2003). Similarly, in males, puberty is not only the age when the ram's reproductive organs become functional and his secondary sexual characteristics develop, but rather the age when the ejaculate contains a threshold number of spermatozoa adequate for successful fertilization (Senger, 2003). There are a number of factors that affect the onset of puberty and these include breed, geographic location, social structure, and photoperiod. It is recommended that replacement females first be bred when a target weight of 60 - 70% of mature adult weight for that breed is reached. Replacement females born earlier in the season generally reach puberty earlier because of their age and weight while those born later tend to breed later. In addition, replacements that kid earlier will breed back earlier in the season and this increases the productive life of the animal.

B. Estrous cycle

The estrous cycle is defined as the period between one estrus (standing heat/period of time when the female is receptive to the male) to the next. The average duration of the estrous cycle can vary by breed, and environment. The estrous cycle is divided into 2 main phases, namely the follicular phase (follicular growth, secretion of estrogen; short - 25% of cycle) and the luteal phase (following ovulation, corpus luteum produces progesterone; long – 75% of cycle). The average duration of standing heat varies by breed, age, season and presence or absence of a male (Senger, 2003). Estrus detection is based on behavior/signs and typically includes, bleating, mucus discharge, interest in bucks, tail wagging, swollen vulva, and standing for mounting in does. During anestrous, the normal cycle stops and this could be due to any stressor such as under-nutrition, disease, gestation, lactation and season. Please see Table I for a list of normal reproductive traits of goats.

Table I. Normal Reproductive Traits of Goats.

Characteristic	Goats
Age at puberty	
Male	4 – 6 mos.
Female	5 – 8 mos.
Estrous cycle length	21 days (18 – 22)
Duration of estrus	12 – 36 hrs.
Ovulation	12 – 36 hrs. after estrus onset
Length of pregnancy	146 - 155 days

C. **Seasonality of reproduction**

As stated previously, during anestrous, the normal cycle stops and this can be due to many factors including increasing day length. Small ruminants are generally considered to be short day breeders (breeding season: September – February, but varies among breeds.

The pineal gland secretes a hormone melatonin, which is produced in the dark. Increased secretion of this hormone is needed to trigger the hypothalamus to produce gonadotropin-releasing hormone (stimulates egg and sperm production). During the longer days of the year (spring and summer), daylight entering the eye inhibits the production and secretion of melatonin in some breeds and leads to a period of anestrous. However, estrus and ovulation can be induced in females experiencing seasonal anestrous by treatment with natural progesterone, synthetic derivatives of progesterone (progestogens; ex. melengestrol acetate), and other hormone treatment protocols.

D. **Estrus synchronization/induction**

Estrus synchronization allows for parturition at appropriate times to take advantage of niche markets, feed supplies, labor, and increasing price trends. Methods of synchronization in goats include hormonal treatments (ex. natural progesterone, progestogens and prostaglandin), and manipulation of social inputs (i.e., the buck effect). In efforts to synchronize estrus, various forms of progestogens and different methods of administration have been used in cycling females, as well as in seasonally anestrus ones (Wildeus, 1999). Although alternative methods are available during the breeding season, it is commonly accepted that natural progesterone or a progestogen is required for induction or synchronization outside of the normal breeding season. Administration tricks the body into thinking its pregnant and its removal results in the doe demonstrating estrus in a predictable timeframe (within 24 - 72 hrs). Currently, there is a controlled internal drug-releasing device (CIDR), in the form of a silicone intravaginal natural progesterone insert, approved for use in sheep, and available for purchase in the U.S. (Eazi-breed™ CIDR; FDA approval granted for sheep, but pending for goats). This product has become especially important in the development of effective synchronization protocols for artificial insemination (AI) protocols in goats and is usually inserted for 9 – 21 days. Progestogen administration can be used with or without supplementary treatments such as gonadotropins (hormones that promote follicle growth and ovulation/release of egg) or prostaglandin (lyse an active corpus luteum).

D.1. Progestogen

Previously, progestogen sponges containing fluorogestone acetate and methyl acetoxy progesterone were used in the synchronization and induction of estrus (Whitley and Jackson, 2002). Routine synchronization protocols typically combined vaginal sponges inserted for approximately 11 days, together with a prostaglandin (such as dinoprost tromethamine; Lutalyse®) and equine chorionic gonadotropin (eCG; extra-label drug use in the form of PG-600 to promote follicular growth and ovulation) injections 2 days before sponge removal (Leboeuf et al., 2000). The additional use of prostaglandin and gonadatropins assist in further tightening synchronization. This technique and others have been demonstrated to efficiently induce and synchronize estrus and ovulation during the breeding as well as the non-breeding seasons. The CIDR was equally effective in synchronizing and inducing estrus compared to fluorogestone acetate and methyl acetoxy progesterone sponges in studies (Motlomeo et al., 2002).

An alternative, maybe more practical method of administering progestogens, can be through oral dosing in feeds. Melengestrol acetate (MGA) is a synthetic progestogen that was first used in the dairy industry to suppress heat in heifers. The use of MGA to induce estrus in seasonally anestrus ewes (Wildeus, 1999; Whitley et al., 2003) and does (Jackson et al., 2002) has been well documented and proven to be effective. MGA is usually fed at a rate of 0.25 mg per doe per day for 8 – 14 days alone or in combination with the male effect. Similar to the use of other progestogens, the use of gonadatropins and prostaglandin analogs may assist in further tightening synchronization The major issue with this method appears to be administering the feed since group feeding has the possibility of some females getting more or less of the required dose to synchronize/induce estrus. Individual feeding or ensuring that there is sufficient feeder bunk space should prevent this from occurring.

D.2. Prostaglandin

Prostaglandin has been shown to be effective in synchronizing cycling females and offers a flexible, economical method to shorten the breeding season in a natural mating situation. A typical prostaglandin protocol includes two injections 11 days apart. This is necessary because in order for prostaglandin to be effective it requires an active corpus luteum present on the ovary. Therefore, the second injection ensures an increased chance of lysing the corpus luteum and allowing the doe to return to estrus faster. The most commonly available prostaglandin is dinoprost tromethamine (Lutalyse; Pharmacia and Upjohn Co.,Kalamazoo, MI) but cloprostenal (Estrumate) is also available. It should be noted that prostaglandin might cause abortions if administered to a pregnant female.

D.3. Male effect

Exposure to males after a period of isolation can be used for estrus synchronization during the breeding season without additional treatments. Research has shown that sudden introduction of the buck to females separated from the male for several weeks (>3 weeks) will result in a surge in luteinizing hormone (responsible for ovulation/egg release) and a rise in progesterone concentrations allowing a proportion of females to come into heat within a predictable time-frame. It has been suggested that pheromones from the male leads to the increase in these hormone secretions, thereby inducing estrus or ovulation in goats during the breeding season (Over et al., 1990). However, during the non-breeding season, the male effect is less likely to work on its own and is more effective in conjunction with a natural progesterone or progestogen.

E. **Advanced Reproductive techniques**

E.1. Artificial Insemination (AI)

Advanced reproductive techniques, such as artificial insemination (AI), provide a means by which genetic material can be transferred between locations. In addition, it also eliminates health concerns associated with the movement of live animals from one farm to the next, especially with increased concerns with internal parasite resistance. During AI, semen is deposited into the female reproductive tract via artificial techniques rather than by natural means. The primary advantage of this technique is that it permits the extensive use of outstanding sires to maximize genetic improvement. In addition, once you have the necessary equipment, frozen semen might be much less expensive than paying a breeding fee or buying expensive males. Semen is now more readily available from many high quality males, in some breeds more than others, and it's more possible now more than ever to quickly improve the quality of your herd using such techniques. However, the success of the actual insemination depends to a large degree on the appropriate timing in relation to estrus and ovulation (Wildeus, 2003). The success of AI is also dependent on the ability to efficiently collect and cryopreserve spermatozoa from quality males for use on females from generation to generation.

The beef and dairy cattle industries almost completely rely on timed AI (TAI) reproductive protocols and this has led to many improvements in genetics and consistency in the market. Similar results can be achieved if this technology becomes mainstream in the small ruminant industry. Two AI methods are currently used in the small ruminant industry. Cervical insemination (common in goats) involves deposition of sperm in the cervix while the second method, laparoscopic insemination (less common in goats), involves the use of a laparoscope and manipulating probe to aid in depositing fresh or frozen-thawed sperm directly into the uterine horns. Conception rates using cervical and laparoscopic AI ranges from 40 to 80% during both the breeding and nonbreeding season. To accommodate AI, females are generally synchronized, using techniques described above, and bred according to the AM/PM rule. That is, a female is inseminated 12 hrs. after first being observed in estrus. However, North Carolina State University has developed a novel ovulation synchronization technique, NC-Synch, which does not require the use of progesterone and allows for all females to be bred at the same time without the need for heat/estrus checks. This protocol, NCSynch-TAI, uses a treatment combination of prostaglandin and gonadotropin releasing hormone to induce a synchronized ovulation for TAI (Bowdridge et al., 2013).

Interestingly, there is current research at Virginia State University on the development of a simple vaginal AI (shot-in-the-dark) procedure for small ruminants, using fresh chilled semen, which provides acceptable pregnancy rates. This has the potential to expand the use of AI in small farm settings and allow for the increase in genetic potential on many farms. Additional research is looking at optimizing the protocol, especially semen extension in goats and minimal concentration (both species) needed for increased pregnancy rates on farm.

F. **Reproductive failure of the female**

There are instances where females may fail to mate, or mate and not become pregnant or even not be able to maintain a pregnancy. The reasons for reproductive failure in females are difficult to determine and the possibilities are endless. For instance, a female might fail to mate because she is already pregnant, in seasonal or lactational anestrous, experiences nutrition and mineral deficiency, stress, poor health, or it could be some pathology of the reproductive tract to name a few. Reasons for failure to mate, become pregnant or maintain a pregnancy should be evaluated by a veterinarian and efforts made to correct the issue if possible so that she can be bred. However, if the exact reason cannot be determined and a female has failed to conceive in consecutive cycles, it is recommended that this female be culled from the herd.

G. **Reproductive failure of the male**

Reproductive failure also occurs in males. Bucks might also fail to mate or mate and pregnancy does not occur. As with females, there are a number of reasons for reproductive failure in males and they should be evaluated for any health or other stressors that could be responsible for this failure. To correctly evaluate if a male is breeding or not, a marking harness or raddle powder is recommended. If a male is not mating, then he could be too ill, too thin, and too old or the weather might simply be too hot. Possible disease to check include pizzle rot, contagious ecthyma (sore mouth) of the penis or prepuce, or lameness and overgrown hooves making it difficult to mount comfortably. Experience of the male should also be considered. An inexperienced male could be dominated by bigger/older females or males in the breeding group and be reluctant to breed. The male to female ratio used during breeding might also be an issue, especially if a synchronization protocol is being followed. The typical ratio recommended during a normal breeding season is 1 male: 30-50 females while in a synchronized mating the ratio should be 1 male to every 15-20 females. It should be noted that younger males can serve no more than 20 females during the normal breeding season.

To help diagnose possible issues due to infertility, all bucks should be evaluated by a veterinarian for breeding soundness at least 1 month prior to the start of the mating season. A BSE evaluation usually includes a physical examination, scrotal circumference measurement, and semen evaluation. The physical examination is to ensure that the male can move around freely without issues of lameness or overgrown hoofs and have adequate BCS to do an effective job during the breeding season. The male should also be free from diseases such as pizzle rot and internal parasites. Measurement of the scrotal circumference is a very helpful tool in determining fertility and breeding ability in males. There are a number of research studies that have indicated that scrotal circumference is highly correlated with sperm concentration, motility and viability. In a mature buck (older than 14 months), the scrotal circumference should be > 25 cm (Merck Manual). The testicles should be palpated for firmness, symmetry and any abnormalities. Season can adversely affect scrotal circumference, with testicles being smaller during the non-breeding season and injury or infection (such as epididymitis) could result in asymmetry or changes in testicular firmness. Finally, a semen evaluation should be conducted. A good quality semen sample will be milky in appearance and free from contaminants including pus, blood or urine. When examined under a microscope there should be a good wave motion indicating sperm motility. Table II has the normal semen parameters for breeding bucks.

Table II. Normal semen parameters for breeding bucks and rams

Parameters	Buck
Volume (ml)	0.5 – 1.0
Sperm concentration (billion/ml)	2 – 5 (2.5)
Motility* (%)	70 - 90 (80)
Normal Morphology* (%)	75 – 95 (90)

Motility – percentage of sperm in progressive motion
Morphology – sperm shape

VI. CONCLUSION

In conclusion, if not included in your overall management plan, any one of the factors described above can have an effect on your breeding program and reduce the reproductive efficiency in your herd. Since reproductive efficiency has a direct impact on pregnancy rates and the number of offspring available to market each year, all factors discussed should be given adequate consideration for optimizing reproductive performance. If these factors above are considered, enhanced reproductive performance can be achieved and this will not only optimize production but also promote profitability.

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CENTRAL PERFORMANCE TESTING: PURPOSE, BENEFITS, IMPACTS, AND TRENDS

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ABSTRACT

The central performance test is a selection tool that could be utilized to move a population under selection in a desirable direction. The premise of the central performance test is simple: differences in performance of young animals raised in a common environment are largely attributed to genetics; however, this can be confounded by differences in pre-test environments. It is assumed top-ranking individuals have the best set of genes for the trait(s) in question, given that particular environment. This genetic advantage is a permanent change transferable to the next generation. Yet, the popularity of central performance tests has waxed and waned over the past decades. A strengths-weaknesses-opportunities-threats analysis indicates factors influencing producer participation can include cost, time, geographical coverage, alignment with industry, association support, and relevancy. A second generation of central performance tests with innovative and targeted approaches is needed to face the challenges of the goat industry. An example of such an approach is the incorporation of internal parasite resistance and resilience into the traits measured; however, there are equivocal results concerning natural versus artificial challenges. One of the greatest challenges to central performance tests is genomics. Genomics has the potential to impact all aspects of the livestock industry, and central performance testing is no exception. However, the building of a reference population large enough to yield meaningful genomic estimated breeding value (GEBV) will take time, especially in a minor species such as the goat. The future of central performance test remains a question mark.

Keywords: central performance test, selection, evaluation, production, SWOT

I. INTRODUCTION

The basic definition of a central performance test (CPT) is thus: animals, generally young, growing males, from different herds or flocks are gathered into one central location and performance is measured and recorded on each individual. The fundamental principle of a CPT is the observed differences in performance are primarily due to genetic differences and those animals with better performances posses a better set of genes or breeding value (BV) for the production trait under question. Those genes are passed onto offspring, which is the foundation for permanent change in the trait, as compared to environmental effects, which are not.

II. History of CPT for Meat Goats

The Angelo State CPT was the first CPT for meat goats in the U.S. Boer goat breeders started it in 1996 shortly after the advent of the Boer goats to the U.S. The management basis of the Angelo State CPT was confinement, basically a feedlot environment. Proponents of this CPT system purport to accurately assess a production trait like growth, nutrition must not be a limiting factor. The Angelo State CPT was able to calculate intake on a pen basis but not on an individual animal basis. The second CPT established was by Fort Valley State University, which was a forage-based CPT. Proponents of this CPT system argue the predominant management system for meat goat producers is a forage-based system and the CPT environment should mimic the production environment as closely as possible. In addition, proponents argue resistance to internal parasites can be assessed on a forage-based CPT. A third CPT was established by Langston University. The unique aspect of the Langston CPT was the use of Calan gate feeders, which allowed measurement of individual feed intake and subsequently measure of residual feed intake. In the mid-2000s, interest in CPT was high and several new CPTs were established by the University of

Maryland (Western Maryland), Kerr Center/Eastern Oklahoma State College (EOSC), Pennsylvania Department of Agriculture (PA Dept. of Ag), and Western Illinois University. The former two CPT are forage-based CPTs and the latter two are confinement CPTs. Most recently, West Virginia University has established a confinement CPT for meat goats. The Pennsylvania Department of Agriculture, Western Illinois University, and West Virginia University CPTs also utilized the testing facilities for rams. Western Maryland, Kerr Center/Eastern Oklahoma State College, Pennsylvania Department of Agriculture, and West Virginia University CPTs are still active; the others have been terminated or have been suspended for an indefinite time. Western Maryland recently announced "The Western Maryland Pasture-Based Meat Goat Performance Test will not be held in 2017. After 11 years of the test and 13 years of small ruminant grazing, the test site will be rested. … The present test has run its course. High levels of parasite infection, coupled with lack of efficacy of the anthelmintics (dewormers) has resulted in too many goats being unable to adapt to test conditions. A new test will be considered for 2018 (source: http://mdgoattest.blogspot.com/ for Tuesday, October 11, 2016 and **http://mdgoattest.blogspot.com/**2017/ 08/a-new-era.html)." A timeline for CPTs is presented in Figure 1 and they are categorized by management system and location in Table 1.

Table 1. Types of meat goat CPTs by management system and location.

Confinement (Feedlot)	**Forage (Pasture)**
Angelo State University	Kerr Center/Eastern Oklahoma State College
Langston University	Fort Valley State University
PA Dept. of Ag.	Western Maryland
West Virginia University	
Western Illinois University	

CPTs for meat goats are like any other enterprise and have internal and external factors affecting them. The internal factors are the strengths and weaknesses of enterprise and the external factors are generally opportunities and threats.

III. SWOT Analysis

A SWOT (strengths, weaknesses, opportunities, and threats) analysis is a powerful tool in assessing the viability of an enterprise (Piercy and Giles, 1989) and has been used often in evaluating livestock enterprises (Shrestha et al., 2004; Wasike et al., 2011; Martín-Collado et al., 2013). This paper will not conduct a classical SWOT analysis (Ghazinoory et al., 2011), which is based upon survey data, but will utilize personal conversations with breeders and extension specialists and principles of SWOT.

IV. Factor Affecting CPT

Cost

Generally, CPTs operate as a service of the managing entities and operate at cost, excluding CPT personnel. For the confinement CPT, producers have often stated that cost of a CPT is approximately equal to their cost if they would have kept the bucks on their ranch/farm and maintained them for the same timeframe and they add the care and attention given the bucks is probably better than if the bucks were maintained at home. Therefore, cost is definitely a strength for the CPT and one often overlooked when marketing them to breeders.

Time

Time is a precious commodity and can be split into two periods; the time immediately before and after the CPT and the length of the CPT itself. The former is a commitment by breeders to transport their bucks to and from the CPT. This time commitment is directly related to the distance a breeder is from the CPT. Unless completely committed to a CPT, breeders farther from a CPT are disincentivized from participating. This time factor can be confounded with geographical coverage. One solution for this time issue is to provide a pick-up service for breeders distant from the CPT for CPT enrollment, when it is less critical for breeders to be present. At the end of the CPT, when reports and awards are given or a sale of bucks is held, the presence of participating breeders is more important. The Langston CPT utilized this approach.

Generally, CPTs have elected for a long test duration—the standard is 84 days—to ensure accurate and reliable measures are obtained. However, as CPT length increases, expenses in feeding and management inevitably increase. In recent years, optimizing the duration of performance tests for growth rate which is generally measured as average daily gain (ADG), feed intake, and feed efficiency as assessed by average daily gain ADG:feed intake ratio and residual feed intake (RFI) has been studied in Boer goats on the Langston University CPT over a 10-year span (Hu et al., 2012)but minimum test duration has not been ascertained to assess accurately performance traits. This study was conducted to determine the minimum length of time required for accurate evaluation of growing Boer bucks for ADG, dry matter intake (DMI. Therefore, the duration of confinement CPT could be decreased from the standard 84 to 63 days with little loss in accuracy (Hu et al., 2012)but minimum test duration has not been ascertained to assess accurately performance traits. This study was conducted to determine the minimum length of time required for accurate evaluation of growing Boer bucks for ADG, dry matter intake (DMI, which would result in cost savings for an already cost-efficient system. These findings are similar to those in beef cattle (Archer et al., 1997; Archer and Bergh, 2000; Wang et al., 2006), where the duration of performance testing could be shortened by varying extents to lengths of 63–84 days compared with original lengths of 91 days or longer. Also, duration of performance testing for growing pigs could be shortened from 56 to 35 days (Arthur et al., 2008). The optimal length of a forage-based CPT is unknown but opportunity exists for data analysis and appropriate recommendations. Time is probably a weakness of the CPT but an opportunity exists to assist breeders with transport, especially transporting bucks to the CPT. An opportunity also exists for various CPTs to provide a uniform set of standard operating procedures that would reduce variation between CPTs.

Pre-test environment

Studies on the pre-test environment are lacking in meat goats but findings from beef cattle and sheep have shown various pre-test factors affect performance while on CPT. In performance-tested ram lambs, ADG is affected by numerous environmental factors including diet, management practice, facility characteristics, initial body weight and age of animals on test, etc. (Waldron et al., 1990; Snowder and Van Vleck, 2002). In beef cattle, the pre-test environment is often questioned as to its effect upon performance-test results (Dalton and Morris, 1978). Herd of origin, which is confounded with sire and pre-test management, was found to have the greatest effect (Simm et al., 1985; Liu and Makarechian, 1993; Schenkel et al., 2004; Nephawe et al., 2006), while initial age or weight on-test had minimal or no effect (Patterson et al., 1950; Tong, 1982). Consequently, modifying the initial age or weight at the start of the CPT might not have any effect upon the final results. Evidence from other beef cattle findings (Archer and Bergh, 2000) suggested that there is no need for different test lengths for different breeds or biological types in spite of differences in feeding patterns and growth rates. The failure to account for pre-test differences is a weakness of the CPT but presents an opportunity for study.

Geographical coverage

Outside the northeastern U.S. (Figure 2), meat goat breeders have limited access to a CPT unless they are extremely dedicated to the concept of performance testing. Breeders in the Northeast can choose between two confinement CPTs or one forage-based CPT. Breeders in the Midwest have a single forage-based CPT. Figure 2 has circles with a radius of 250 miles around each CPT, which represent a manageable day's round-trip drive from the CPTs. Reports of the 2016 test results indicated breeders from Alabama, Delaware, Georgia, Illinois, Indiana, Kansas, Kentucky, Maryland, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Vermont, Virginia, and West Virginia consigned bucks to the Western Maryland CPT and breeders from Alabama, Georgia, Kansas, Mississippi, Missouri, Oklahoma, Texas consigned bucks to the EOSC CPT. Thus, 63% of the states for Western Maryland CPT and 43% for EOSC CPT were outside of the 250-mile radius. Conversely, for the confinement CPTs, almost all their consigned bucks came from within the 250-mile radius. It is not known exactly how the limited geographical availability affects CPT participation but evidence from the forage-based CPTs indicates it is probably minimal. Geographical coverage appears to be a strength for the forage-based CPTs and a weakness for the confinement CPTs. An opportunity exists for a CPT to be established in the Western U.S. Several years ago, a California university discussed the possibility of establishing a CPT but it never materialized.

Alignment with Industry/Relevancy

There has been debate whether CPTs give producers what they want, that is, does the buck's performance on test relate to anything important? A study conducted in the early years of CPT for meat goats concluded CPT results did not accurately predict progeny performance due to pre-test factors biasing sires' CPT performance (Waldron et al., 2002). From that study, the authors encouraged breeders to consider testing several sons from each sire rather than only one or two sons from each sire. This would result in the CPT becoming a variation of a progeny test. The rationale was the pre-test environment would be virtually identical for all buckings born within the same year from the same herd and when performance from half-sibs is added to the sire's performance, a more accurate genetic evaluation of the sires is obtained. Those authors also encouraged breeders to record performance measures such as birth weight, weaning weight, post-weaning ADG, and doe efficiency on their own ranch/farm because at that time, most goats were raised under extensive management systems and little performance data was collected on ranches/farms. Meat goats are still raised under extensive conditions but record-keeping is becoming more prevalent. Both Kentucky State University and Tennessee State University offer producer services for analyzing on-farm performance data. Thus, predicting progeny performance from sires' performance on CPT is a weakness for confinement CPT; however, this may be a weakness for forage-based CPTs, too.

A possible relevancy issue for forage-based CPTs is one of parasite resistance. Forage-based CPT have advertised their advantage over confinement CPTS in being able to measure parasite resistance via fecal egg counts (FEC) and FAMACHA© scores. Grazing animals have been known to avoid foraging in areas that are contaminated by parasites, to select diets that increase their resistance to parasites, and to select diets containing anti-parasitic compounds (Hutchings et al., 2008). Studies in sheep have shown sheep will avoid grazing areas heavily contaminated with feces (Hutchings et al., 1998) and will select diets containing tannins for a self-cure (Villalba et al., 2010). Therefore, the assessment of parasite resistance using FEC on a forage-based CPT is confounded with animals' grazing behavior. Eventually, an extremely infected pasture will overwhelm even the most grazing-averse goat and it will succumb to internal parasites. The assessment of resistance to internal parasites, which is confounded with grazing behavior, for forage-based CPT is neither a strength nor a weakness but could be transformed into a strength with the addition of a single or repeated artificial challenge (Gaba et al., 2006).

Association support

Generally the various goat associations are very supportive of CPT. The major breed associations for Boers and Kikos recognize achievements made by bucks on a CPT. For example, under the American Boer Goat Association rules for Ennoblement and Sire of Merit Award, bucks can earn points based upon CPT performance (ennoblement) or their sons' performance (Sire of Merit). However, points can be earned based on a buck's show ring performance(s) and that of his progeny. It is not clear what percentage of points earned for ennoblement or Sire of Merit are earned via a CPT. For a buck or his progeny to earn points via CPT, the average ADG for all bucks entered in the CPT must be ≥0.30. According to the rules, Sire of Merit appears to be more production oriented than Ennoblement. Perhaps this is apparent from Figure 3, which indicates many more animals receive ennoblement each year compared to Sire of Merit. Obviously, only males can be Sires of Merit, whereas males and females can be ennobled—an examination of the ennobled records for the last few years indicates an approximate 50:50 split between males and females.

The Kiko associations appear to be supportive of CPT, as indicated by the popularity of the Western Maryland and EOSC CPTs, which include Kiko bucks almost exclusively. The dedication of the Kiko breeders distant from those CPTs to transport their bucks long distances is evidence of the support of those breeders. In addition, the American Kiko Goat Association (AKGA) has a Performance Test Program (PTP) that awards bucks solely upon CPT performance. However, the PTP has been suspended indefinitely to encourage AKGA breeders to utilize the on-farm performance data analysis offered by Kentucky State University and Tennessee State University. In brief, eligible bucks must be registered with the AKGA and their pedigree must be confirmed by DNA testing. Then PTP awards a Performance Buck ID based on the buck's CPT performances in ADG, fecal egg count (FEC), rib or loin eye area (REA LEA). An example of a Buck ID would be: 13K101GGG01 BLUE HORNS O' FIRE FO555. The 13K101GGG01 BLUE HORNS O' FIRE is the registration number and name of the buck, respectively. The designation of FO555 indicates the buck earned a score of 5 (i.e. finished in the 50 - 59% percentile) for ADG, earned a score of 5 for FEC, and a score of 5 for REA or LEA, on a forage only (FO) CPT. Other designation for CPT are FS for forage supplemented and FL for feedlot/confined (http://www.kikogoats.com/index. php/akga-information/akga-performance-program/). A buck with the designation of FS999 would have performed in the top 10% for ADG, FEC, and REA on a forage supplemented CPT. A buck with a FL1N1 would have finished in the bottom 20% for ADG and REA on a confinement CPT. The "N" designation indicates that FEC was not evaluated. In addition, AKGA has a Performance Program Breed Points System, which awards breed points based on CPT performance of progeny/siblings. This program is also on hiatus. Unlike the PTP, which is a single record, the Breed Points program changes with additional data from relatives. Association support of CPT is a strength; however, not all associations are equally supportive.

Genomics

Genomic selection (GS) is a quickly evolving field and one that may soon revolutionize selection of individuals for breeding purposes (Goddard and Hayes, 2007; Goddard, 2009). According to Meuwissen et al. (2016), GS involves the estimation of genetic merit of an individual based upon its DNA—actually its single nucleotide polymorphisms (SNP). The SNPs of an individual must be compared to a reference population, that is, a group of animals that have been genotyped and have production records for the trait under selection. The size of the reference population depends upon the heritability of the trait and upon the desired accuracy (Goddard, 2009). The size of the reference population is illustrated in Figure 4. Using ADG in Boer as an example, the heritability of ADG is 0.17 (Schoeman et al., 1997). From Figure 4, a reference population of ~4,000 is required for an accuracy of 0.60, which is slightly greater than the estimated breeding value (EBV) accuracy of the buck's single record on CPT. If 9-month weight is used, then a reference population of ~3,000 is required for the same accuracy. This is because the heritability of 9-month weight is 0.40 (Schoeman et al., 1997). Evidently, a higher desired accuracy will result in a larger required reference population as can be seen by ~15,000 and ~8,000 for an accuracy of 0.80 for ADG and 9-month weight, respectively. Obviously, this reference population does not exist in meat goats as it does for dairy cattle (Wiggans et al., 2012), swine (Knol et al., 2016), and poultry (Wolc et al., 2016), and is being constructed for beef cattle (Silva et al., 2016) and for dairy goats (Carillier et al., 2013). Eventually a reference population will be constructed for simply measured traits and then for more complex traits, such as residual feed intake or carcass traits. Genomic selection is a threat to CPT and it could overtake it, especially as on-farm performance data analysis as offered by Kentucky State University and Tennessee State University grows.

V. CONCLUSIONS

Central performance testing allows selection for genetic improvement that is permanent and cumulative. However, CPTs have strengths, weakness, opportunities, and threats that must be addressed if they are to remain a functional and useful tool for meat goat breeders.

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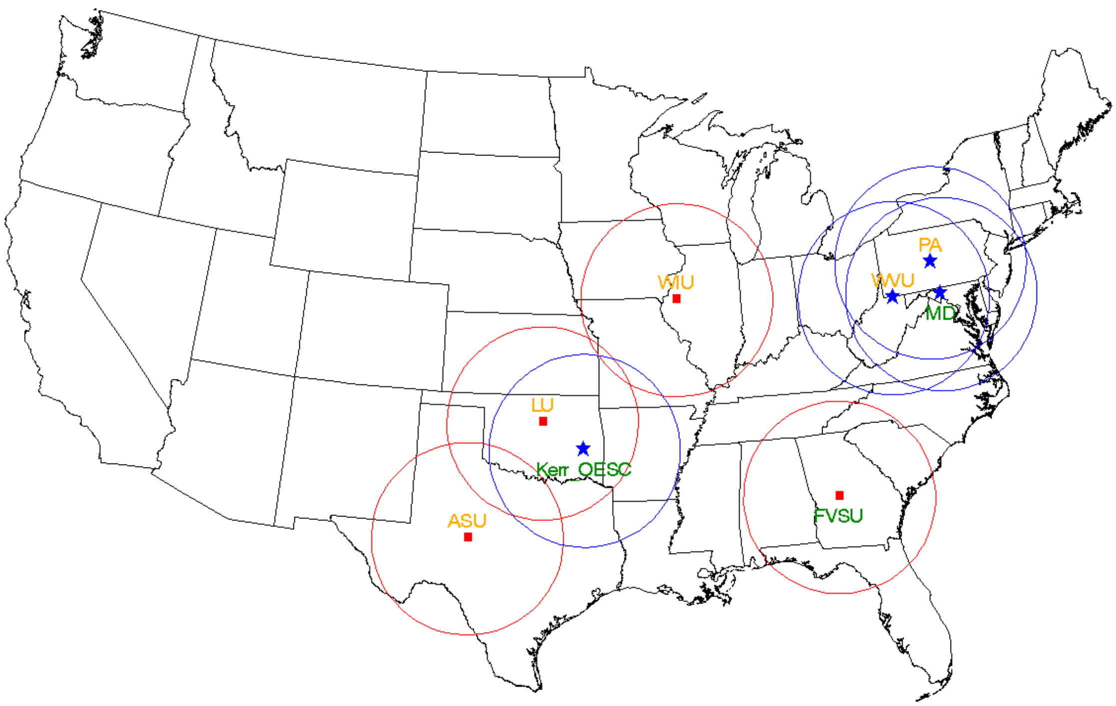

Figure 2. Geographical location of various CPTs. Red squares indicate a CPT that is discontinued and blue stars indicated an ongoing CPT. Orange lettering indicates a confinement CPT and green lettering indicates a forage-based CPT. Circle indicate a 250 mile radius.

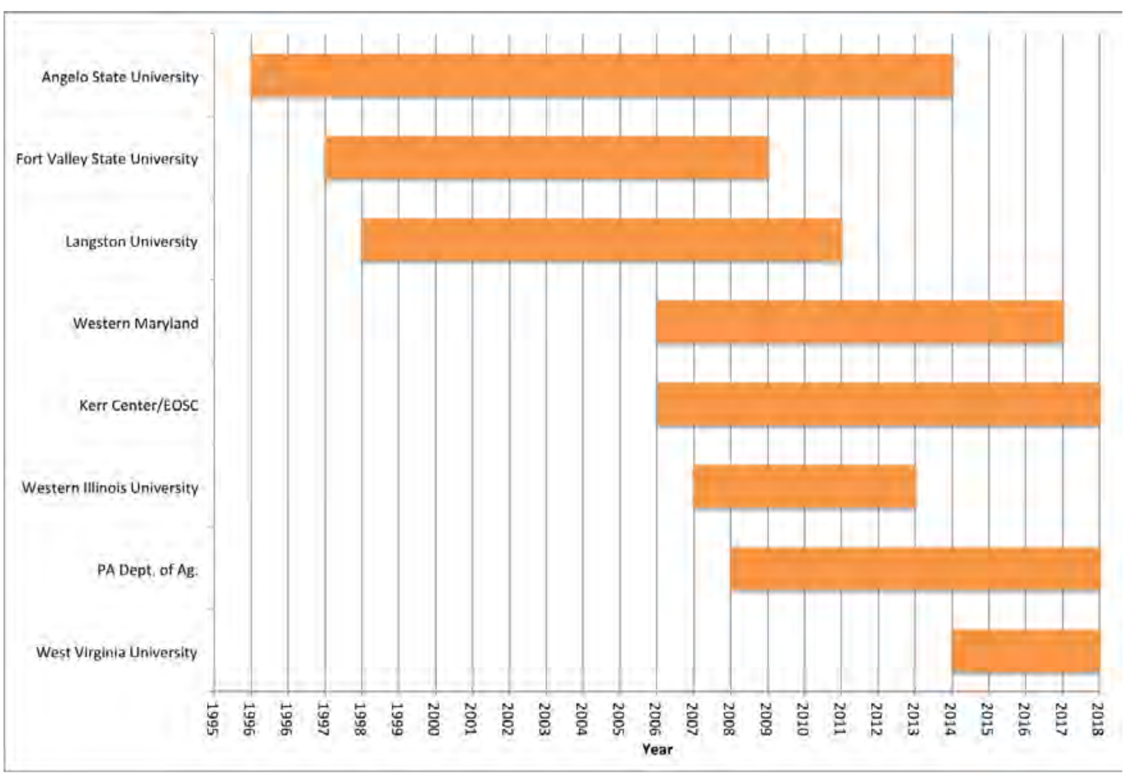

Figure 6. Establishment and duration of various CPTs for meat goats.

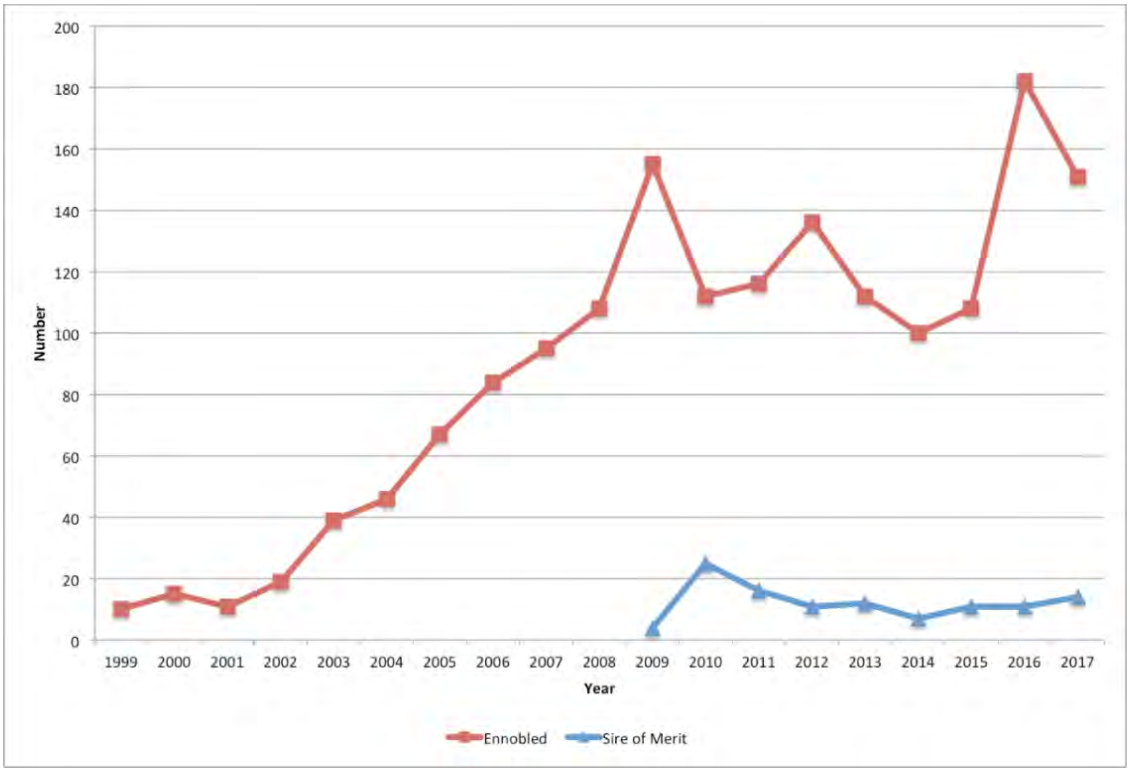

Figure 3. Number of Ennobled animals and Sire of Merit bucks for the American Boer Goat Association by year.

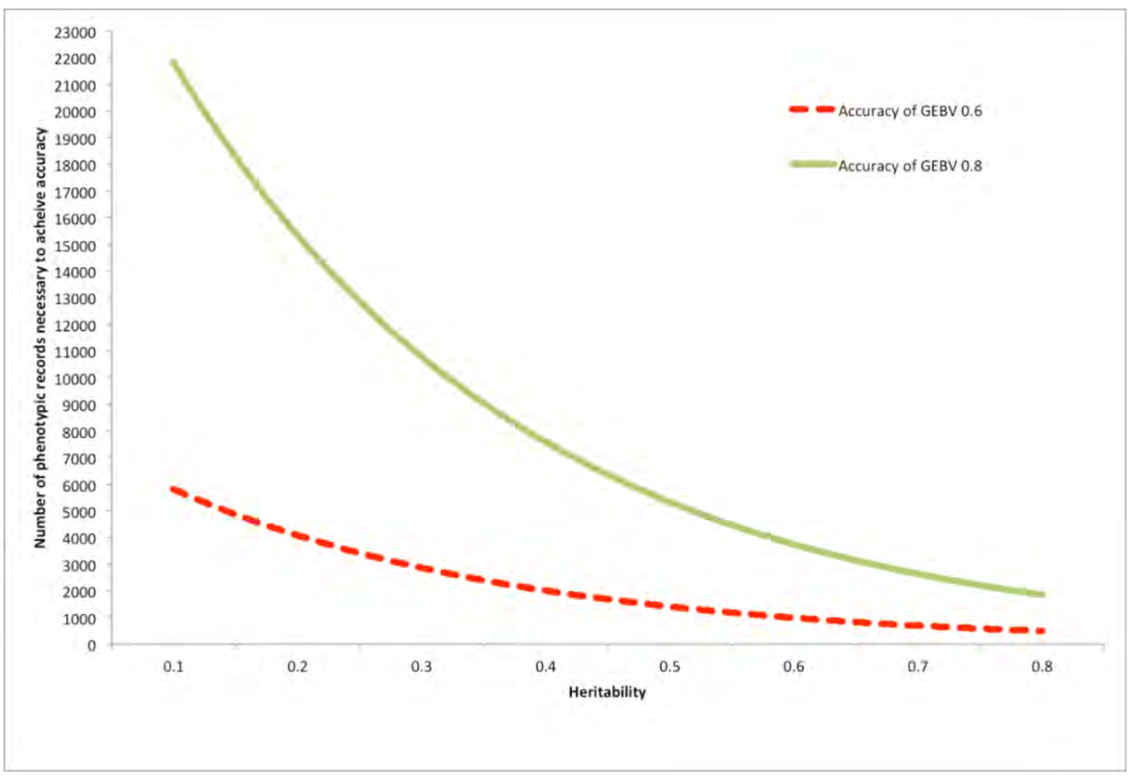

Figure 4. Number of animals in the reference population (phenotyped and genotyped) for GEBV accuracy [(Goddard, 2009) as cited by (Hayes et al., 2009)

SUITABLE BREED AND ANIMAL SELECTION FOR PRODUCTION EFFICIENCY

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ABSTRACT

There are several goat breeds available in the United States. Selection of the breed for a farm should be conducted with the farm goals (business, hobby, etc.), production systems, markets and resources in mind. Breed and animal selection will depend on the type of production desired. Meat, milk, fiber or dual purpose systems may require different breeds for profitable production efficiency. Animal selection for breeding stock production and marketing, especially registered or show stock needs to focus on breed characteristics, animal conformation, show winnings and perhaps even animal pedigrees. Resources to evaluate prior to breed and animal selection include those already owned as well as the capital (funding) to purchase those that will be needed. Establishing at least one consistent market to include in a business/marketing plan prior that will result in farm profitability prior to animal purchase is critical.

Once breed (or breeds for crossbreeding systems) is determined, animal selection will be critical, including choosing sellers (i.e. avoid sale barns), productive males and females with performance records, possible show animals (with winning records) and animals with parasite resistance. For many farms, purchasing healthy, productive animals from sellers raising animals in a similar manner and similar environment (i.e. location) as the buyer will help ensure animal production efficiency and thus farm profitability. Overall, breed and animal selection research should start well before investments are made in a farm to help support overall productivity and profitability and should consider goals, production system, markets and resources.

Keywords: selection, healthy, breeding, records, production

I. INTRODUCTION

There are several goat breeds available in the United States, though not nearly as many as there are sheep breeds. Determination of a breed to raise on a farm should include consideration of the farm goals, production systems, markets and resources. Different farms have goals that should fit the owner. Is it a hobby or homestead enterprise, mostly for enjoyment and perhaps some products for use by the family? Is it a business that needs to support itself only, support up to one salary or support the whole family? Breeds or crossbreeds used may change based on the answer to those questions as well as the access to markets willing and able to purchase animals or products at a price that will be profitable based on the farm goals.

Goats with guardian dog; photo by Susan Schoenian

II. PRODUCTION SYSTEMS

It is easy to understand how the production system could impact breed selection. Goats were bred over many years to yield primarily milk, fiber or meat, though there are some breeds or breed types considered dual purpose (i.e. cashmere and meat, milk and meat), and animals not meeting requirements for one part of a system, even if not a dual-purpose breed, would eventually become part of the food system. For example, animals not producing enough milk or that do not have the fiber quality required to maintain profitability would not be kept or sold for breeding. Outside of a pet market (which is very small), most of these animals would then be marketed as part of the meat industry.

Most production systems would allow for sales of some breeding stock if animal quality and performance are high, but if breeding stock is going to be the market focus, additional selection criteria would apply. Selling registered (papered) animals would require not only being able to choose animals with the good conformation (how the animal is put together; judging/grading criteria) and performance, but also making sure that purchased animals meet the criteria for registration for that breed (i.e. coat color, horn style, teat numbers, etc.) and possibly checking for popular pedigrees. It often takes intense marketing efforts, including possibly showing in breed shows (and winning) or traveling with animals or pictures of animals to breed-related events to become well-known and profitable in the breeding stock industry. Sales of commercial (non-registered) or crossbred quality breeding stock would be possible with less marketing effort if the breed is popular and the farm has a good reputation as a responsible seller with healthy animals.

Purchase and marketing of show animals is the most resource-intense production system. Understanding of conformation and what the judge is looking for in the show ring (which often changes with time and location) would be critical to buying animals that would be suited for marketing offspring. Animals with winning, or just popular, pedigrees will be expensive and selling of show stock often requires showing and winning which is time and capital (money) intensive. In addition, show animals or expensive breeding stock may require special housing and hauling equipment to avoid animal injury or loss.

Goat show; photo by Niki Whitley.

III. RESOURCES

Resources to evaluate prior to breed and animal selection include those already owned as well as the capital (funding) to purchase those that will be needed. If the goal is to sell milk products for human consumption, most states require Grade A dairy licensing (some states may allow Grade B for some products). The resources to start a Grade A dairy should be researched, working with the State Department of Agriculture's Dairy Division to determine regulations required by State and Federal law. As with any enterprise, the market for the products should be researched to determine if it will be profitable enough to sustain the system and if the labor requirements are acceptable. Even with a meat production system, some breeds require more labor, housing or feed resources than others or are more expensive to purchase and may be difficult to market. For fiber production – understanding the harvesting and processing labor and costs compared to what you may get from the product at market is critical as well.

IV. MARKETING

Establishing at least one consistent market to include in a business/marketing plan that will result in farm profitability prior to animal purchase is critical. Understanding what local markets require is important to deciding if the market is appropriate. If the farm owner loves production but does not enjoy negotiating prices, providing convincing sales pitches or hosting potential buyers on the farm, direct sales, though often more profitable, should not be considered unless someone else involved in the operation is willing to take on the chore of marketing. If the closest profitable market for a meat production system is two hours away and requires processing of animals into meat products, the cost of travel, animal processing and permit requirements for selling meat should be considered in the marketing plan.

V. BREEDS

The primary fiber production breed of goats is the Angora, but many goats have a thick, downy undercoat of cashmere produced in the greatest amounts in the winter. Goats with a large amount of high quality cashmere are selected and bred for this luxurious fiber. Though there is not a specific cashmere goat breed, there are guidelines for the overall color, quality and length of fiber marketed as cashmere (Cashmere Goat Association, 2018). Angora goats are not known for meat production (Oman et al., 2000) and cashmere goats are also not chosen for muscling, but animals being used for fiber might be crossbred to a breed selected for meat to increase muscling and expand marketing opportunities. Proper feeding is required to fiber quality and yield, including protein and energy supplementation (Jia et al., 1995; McGregor, 1988).

For milk production, farm goals also play a large role in breed selection. Nigerian (West African) Dwarf goats are small, so require fewer resources and may be easier to handle, but animals specifically selected for milk production can provide up to a quart a day of high milk/butter fat (6-10%) over a 305-day lactation (Storey, 2018) and some research has shown parasite resistance in their native county (Chiejina and Behnke, 2011; Chiejina et al., 2015). Selection for moderate milk production in this breed or in the Nubian might allow for the female to raise her offpsring with some milk left over for human use if twice daily milking or high volumes of milk are not desired. This would be difficult with high producing breeds.

Nubians are considered a dual purpose (milk and meat) breed with lower milk volume in general but higher butterfat (nearly 5%). The higher producing breeds generally have lower butterfat (3-4%) and include the Saanen (most common in large commercial dairies, highest average milk yield), French Alpine, Lamancha (very small, almost non-existent ears) and Toggenburg. For more detailed information about dairy goat breeds and production, contact the American Dairy Goat Association (adga.org; see also Storey, 2018 reference).

There are very few purebred meat goat breeds in the United States. The Boer goat, with the traditional white body and red head is likely the most recognized today. It was developed for muscling and growth and often excels in the show ring. The high genetic potential for growth generally means higher nutrient requirements (high amounts of quality feedstuff), and because the breed was developed in a dry, arid region of South Africa, it often experiences parasite (worm) issues in the warm, wet areas of the United States. The Savanna goat breed was developed in the same region of South Africa in a similar manner, also for muscling and growth.

Boer crossbred females; photo by Susan Schoenian.

The Kiko meat goat breed was developed in New Zealand for low input traits and since has been selected for growth by some people. As such, this breed may do well in a pasture-based system. Although not a recognized breed, the Spanish goat, often considered a lower input breed, is tracked for relative purity by the Spanish Goat Association and consists of several 'lines', some of which are better adapted to warm, humid (parasite-abundant) climates than others. A smaller breed, the Myotonic, Fainting or Tennessee Fainting Goat has heavy muscling (only if it 'faints', or stiffens which builds the muscles like weight lifting), and may offer some entertainment (or frustration) when handling animals.

Although developed originally as a meat goat, due to its small size, the Pygmy goat breed is often raised as pets or for showing. Past breeding for a small size may result in an increased number of birthing problems. For example, Pygmy goats represented the greatest number of goat breeds in those requiring a C-section in a 2004 report (Brounts et al.) so care should be taken, and questions related to birthing ease asked of the seller if this breed is selected. There are a few other breeds available and more information may be found at Oklahoma State University's livestock breeds website, a site that includes goat breeds both in and outside of the United States (www.ansi.okstate.edu/breeds/goats).

VI. ANIMAL SELECTION

Once breed (or breeds for crossbreeding systems) is determined, animal selection will be critical, including choosing sellers (i.e. avoid sale barns), productive males and females with performance records, possible show animals (with winning records) and animals with parasite resistance. For many farms, purchasing healthy, productive animals from sellers raising animals in a similar manner and similar environment (i.e. location) as the buyer will help ensure animal production efficiency and thus farm profitability. To find sources of animals, specific breed associations may host websites with member information and classified ads, farm websites may be available, general classified ad websites, agricultural journals, and social media sites may provide information about possible sellers.

Sale (auction) barns group animals from many different sources in a crowded environment (exposing them to potential diseases) and are often the places that owners take animals that are not suitable for breeding due to injuries, age, disease, poor genetics, low performance or other reasons. It is much better to find a reputable breeder of quality animals from which to buy breeding stock. A sale barn may be a place to determine what the minimum sale price should be and a place to meet other breeders. The sale barn owner may be able to help you source appropriate animals for a fair commission, or fee, and some sale barns host special sales for healthy breeding stock throughout the year. All animals new to the farm should be quarantined (isolated from any contact) from all other animals for at least 30 days. If animals go through a regular livestock barn sale, a longer isolation period and/or disease testing prior to herd introduction should be considered.

When selecting individual animals for purchase, remember that males provide genetics to all offspring and impact the herd to a great extent, especially if replacement females are kept for breeding. It is therefore suggested that special attention is paid to selecting the best buck possible and that bucks are replaced regularly to make the most genetic improvement. Use of males that have been performance or genetic tested (have estimated breeding values or records of superior performance within a contemporary group on-farm or at a performance test site) is strongly recommended.

VII. SELECTION TIPS

Although there may be exceptions or additions that should be considered based on the production system (especially for dairy goats), below are general tips for choosing individual animals for a goat herd.

Select animals that:
- Were born and raised twins or better; parents were born and raised twins or better
- Had good growth rates (heavy weaning weights, good post-weaning growth)
- Have proper overall body structure (dental pad and teeth meet evenly, no extreme sway or dip in back; legs not crooked, especially if expensive show/breeding stock)
- Have two normally shaped teats; no fish/fused teats; no small, non-functioning teats
- Are apparently healthy (no abscesses/bumps, lameness, runny nose, swollen joints, scabs on face or legs, diarrhea/scours or pale eyelids)
- Do not have malformed hooves
- Do not need to be de-wormed often
- Are not aggressive towards people (intact males are more prone to this)

Select males that also:
- Have strong male features and behavior
- Have two testicles outside the body that are normally sized for age with no swellings, bumps or scar tissue
- Do not have a split scrotum over 1”
- Passed a breeding soundness exam and/or is a proven breeder

Select females that also:
- Are no more than three years old
- Birthed and raised healthy twins every year since they were two years old
- Have a well-formed and attached udder with no swellings, bumps or scar tissue
- Have normally formed teats that are not too large for newborn kids
- Were from a mother birthing and raising twins or better each year
- Never prolapsed (uterus, vagina or rectum came out of the body)
- Have a deep body for carrying kids

For more information on goat breeds, selection and production, contact your local county extension office or Land-Grant University.

Spanish yearling bucks; photo by Niki Whitley.

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COMPARISON OF PRODUCTIVITY OF DIFFERENT BREEDS OF MEAT GOATS UNDER LOW- TO MODERATE-INPUT SYSTEMS IN THE UNITED STATES

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ABSTRACT

Productivity indicators in a meat goat enterprise include doe reproductive output, kid growth rate, and carcass merit. Breed choices affect these traits and the likelihood of profit or loss. Boer and Kiko goats were imported in the 1990s to enhance productivity of the US base population meat goats consisting of predominantly Spanish-type goats. Successful breed introductions require some level of adaptation to the destination environment, particularly in low-input systems. Well-planned, low-input management is considered the best route to meat goat enterprise profitability. Reproductive output is a greater profit driver than growth and carcass traits. Goat fitness (health and reproductive attributes) is often overlooked when considering breeds. Doe fitness studies found the Boer influence was negligible to negative compared with the Kiko influence or the Spanish base effect. Significant declines in doe herd fitness suggest reduced profitability. Differences in growth or carcass traits by choice of sire breed have not consistently favor any particular breed. One trait noticeably improved by Boer genetics was visual conformation. Improved conformation scores can increase market value. However, advantages in visual appraisal have not translated to improvements in objectively measured goat carcass traits. Like with Boer and Kiko in the 1990s, current industry use of the imported Savanna in the US is preceding objective characterization. Proper selection and use of breeds, including minor heritage types like the Myotonic, in meat goat mating systems is important for profitability in low-input commercial operations. Managing to compensate for poor meat goat genetic management decisions are neither profitable nor sustainable.

Keywords: meat goat, breeds, fitness, productivity, profitability

I. INTRODUCTION

In the United States, breed choices are limited for commercial meat goat producers to consider when developing a breeding program. Although limited, it is still important for these options to be objectively evaluated to provide producers with research-based guidance on breed strengths and weaknesses for economically important traits. Commercial meat goats are typically managed in low- to moderate-input systems. These are extensive to semi-intensive, forage-based management systems with generally restricted resource inputs. Breeds should be evaluated under conditions that reflect resource-limited production environments. It is not uncommon for seed-stock herds to be managed at higher input levels than the commercial herds that the supplied seed-stock are expected to perform in. The trait with the greatest impact on profitability in a commercial meat goat enterprise is reproductive performance. Unfortunately, reproduction and survivability (both measures of fitness) have been generally neglected when evaluating breeds. Research has historically been lacking for comparing meat goat breeds for health and reproductive traits as compared with more easily measured growth traits (Shrestha and Fahmy, 2007).

Three primary breeds are represented in the US commercial meat goat herd. The Boer was developed by a breeder group in semi-arid South Africa (Casey and Van Niekerk, 1988; Campbell, 2003). Boer is arguably the predominant meat goat genotype in the US today. The Kiko was developed as a composite type through the crossing of dairy bucks to feral does by a breeder cooperative in humid New Zealand (Batten, 1987). The Spanish is a landrace type that evolved primarily in semi-arid Texas from animals brought to the western hemisphere by Spanish explorers in the 1500s (Shelton, 1978; Mason, 1981). New breeds are usually introduced to improve on real or perceived trait deficiencies of the resident production population. Boer and Kiko goats were imported by US interests in the mid-1990s to improve the meat producing attributes of resident Spanish goats. It is common to see new livestock breeds introduced to improve growth and carcass traits while ignoring the fitness traits that may be greater profit drivers in suckler herds, especially if females are retained as herd replacements. Successful new breed introductions require some level of adaptation to destination environments, particularly in low-input systems (Blackburn and Gollin, 2009).

Objective breed evaluations are important on two fronts. Genetic management decision-making can be reduced to two basic areas: selection and mating. Selection occurs among and within breeds. Selection among breeds require data on the strengths and weaknesses of the breed options available to identify those with desirable trait profiles. In commercial herds, one or more breeds may be selected for use based on available comparative data. Breed selection is half of the genetic management process. Mating decisions are also required to determine if pure breeding or crossbreeding will be implemented. Crossbreeding may be desirable in commercial herds. Thus, it is important to determine the best way to use selected breeds in a crossbreeding scheme. This provides an overview of research conducted at Tennessee State University (TSU) and other locations to evaluate meat goat breeds for fitness, growth, and carcass traits. Emphasis is placed on doe fitness.

II. DOE TRAITS

Profitability in a meat goat enterprise is tied to doe herd reproductive output. An unproductive doe herd will be unprofitable, regardless of the genetic merits for growth or carcass traits among the sires used or kids produced in the herd. Computer simulations conducted by Blackburn (1995) around the time that the first Boer goats arrived in North America predicted that Boer does would be similar to or inferior to Spanish does for reproductive output, moderate to low levels of forage nutrient resources under Oklahoma and Texas conditions. For fall breeding herds under lower forage conditions, Boer does weaned about 60% of number of kids weaned (i.e., kids sold) by Spanish does in the simulations. Blackburn (1995) concluded that the Boer doe may require a more intense level of management than typical of meat goat operations. Perhaps the more salient implication of this early work was that the Boer goat did not offer an improvement over the resident Spanish goat for doe herd performance under moderate to poor forage conditions. It is not clear if the simulations outcomes were considered part of the general outreach recommendations provided to the industry in the mid- to late-1990s or beyond.

Straight-bred does.

A series of evaluations have been conducted at TSU since 2002 comparing Boer, Kiko, and Spanish does for fitness traits. The studies are highlighted by a pair of six-year datasets (2004-2009: Phase I and 2009-2014: Phase II). Parts of these datasets have been presented in various documents (Browning et al., 2011; Pellerin and Browning, 2012; Nguluma et al., 2013; Wang, 2014; Khanal, 2016). Across the 12 years, 205 Boer, 207 Kiko, and 193 Spanish straight-bred does were managed on pasture and bred to bucks of various breeds to produce spring-born purebred and crossbred kids. Service sire breeds, doe ages and parity were balanced across the doe breeds. Does represented a diverse sampling of genetic lines within each breed. The TSU research station in Nashville is in the humid, subtropical southeastern region of the US. Does were managed on tall fescue (*Festuca arundinacea*) and bermudagrass (*Cynodon dactylon*) pastures supplemented with orchardgrass hay (*Dactylis glomerata*) for *ad libitum* consumption and limited amounts of various winter concentrate supplements. A distinction between the Phase I and Phase II evaluations was that supplementation extended as long as to 9 months per year in Phase I, whereas doe herd nutrient supplementation was never longer than 4 months in Phase II. Stocking rate was approximately 3-4 does per acre. Does were scheduled for deworming once or twice each year, including once at kidding. Kids were not creep-fed and weaned at 90 days of age. Culling of does from the research herd was based on repeated reproductive failure.

Under uniform management conditions, whole herd reproductive output was lower ($P < 0.05$) for Boer does than for Kiko and Spanish does (Table I). The doe breeds were similar among doe populations that kidded or weaned kids. However, for the more economically relevant whole herd evaluation (i.e., population of all does in the herd at fall breeding), Boer doe kid production was about half the values of their Kiko and Spanish herd mates at the spring kidding and summer weaning end points (Table I).

Doe health is an important contributor to reproductive outcomes. The single most inhibiting health challenge to efficient goat performance is arguably internal parasitism (Kaplan et al., 2004). Using breeds identified as having reduced susceptibility to internal parasites would be a large step towards improving goat herd profitability and sustainability. As anthelmintic resistance continues to rise across the industry, the selection and use of goats with inherent hardiness under chronic internal parasite exposure will become increasing important. The principal indicator trait used to assess internal parasite burdens in goats is fecal egg counts (FEC). Boer does have generally had higher ($P < 0.05$) geometric mean FEC than Kiko and Spanish does at kid weaning (Table I). This trait should receive more attention in the future for genetic improvement.

Whether it leads to reproductive failure and subsequent culling or general animal morbidity and mortality, internal parasitism likely plays a role in doe stayability and longevity. There are biological and economic implications of does exiting the herd and the need to replace them. Early exits (i.e., does leaving the herd after one or two years) can be especially burdensome. Boer does had lower ($P < 0.05$) annual survival rates that Kiko and Spanish does (Table I). In the first six-year study period it was reported that Boer does had lower ($P < 0.05$) stayability rates compared with Kiko and Spanish does (Figure 1) and lower ($P < 0.05$) cumulative kid production values after 2, 3, and 5 years of possible herd presence (Pellerin and Browning, 2012). For does with the opportunity to stay in the herd for 5 breeding years, Boer does weaned a total of 3.2 kids and 125 lbs, whereas Kiko does weaned 6.1 kids and 244 lbs and Spanish does weaned 6.2 kids and 220 lbs. Does that stay in the herd longer are more likely to have greater lifetime productivity and offset the costs associated with purchase and(or) development of replacement does.

Boer does had generally poor fitness. The separation of Spanish and Boer does in the TSU evaluations under semi-intensive management concurred with Blackburn (1995) for moderate to low forage conditions. It has become common for US producers to indicate that Boer-influenced goats lack hardiness. The semi-arid origin of Spanish does did not cause fitness problems under these experimental conditions. Unimproved goats in South Africa were reportedly more disease resistant than Boer goats (Ramsay et al., 1978; Campbell, 2003). It may be surmised that general hardiness was compromised when the Boer breed was developed under artificial selection pressures.

Crossbred does.

Crossbred does are most likely to be found in the commercial meat goat herd. The predominant genotype among commercial meat-type does is probably the Boer crossbred. While the Phase I effort at TSU focused exclusively on straight-bred does, Phase II included 245 Boer F1 (first-cross) does along with 162 Kiko and 150 Boer does (Nguluma et al., 2013; Browning et al., 2014; Khanal, 2016). The Boer F1 does were reciprocal-cross Boer x Kiko (n = 133) and Boer x Spanish (n = 112). Boer F1 does performed at levels similar to the base Kiko and Spanish does (Table II) with the only exception being fertility where the Boer F1 does had lower kidding rates ($P < 0.05$) than the straight-bred Kiko and Spanish does. Across 8 years of production in Texas, Rhone et al. (2013) observed Boer x Spanish does had reproductive levels similar to ($P > 0.05$) Spanish does in a study herd of nearly 300 breeding females. In the TSU study, it should be noted that the Boer-cross does were better ($P < 0.05$) than the limited number (n = 20) of Boer straight-bred does for the various traits. Reproductive values for the Boer does were low: 12.9% does birthing kids, 7.2% does weaning kids and 0.13 kids weaned per doe in the breeding herd.

The doe evaluation outcomes suggested that crossbred Boer does would not improve reproductive rates compared with Kiko or Spanish straight-bred does. This could have been anticipated given the relatively poor performance of the Boer genetic influence contributing to the crosses. However, it was somewhat surprising the Boer-cross does were close to the Spanish and Kiko does for the fitness indicator traits. The non-additive genetic results of crossbreeding (heterosis) were probably the reason for the Boer-cross does approaching the levels of Kiko and Spanish for doe fitness. If the use of a new breed is to improve on the resident population, then the crossing with Boer did not enhance doe fitness. Conversely, crossbreeding with Kiko or Spanish can be beneficial in herds of predominantly Boer to improve doe herd fitness.

The Kiko and Spanish does had fairly similar reproductive values across the purebred studies (Browning et al., 2011, Wang, 2014). However, the Kiko influence had better reproductive values than the Spanish influence when purebred and crossbred does were merged for evaluation (Browning et al., 2014). One advantage the Spanish have demonstrated over their Kiko herd mates is lower postpartum FEC (Table 1; Browning et al., 2011, 2014). As a heritage breed-type, the Spanish goat remains a valuable genetic resource for meat goat production with regard to female fitness.

III. PREWEANING KID TRAITS

Kid performance from birth and weaning can be affected by breed selection and mating systems. Offspring growth traits usually receive the majority of attention when breeds are compared. Often it is the sire breeds that are evaluated because they are more easily interchangeable within an established production system. Sires are also the point of selection focus because of their singular influence on genetic contributions to a broad set of offspring when compared with the potential contributions of individual breeding females. To a lesser extent, maternal breeds have been tested for offspring performance. Phase I of the TSU effort included evaluating sire and dam breed contributions to individual kid performance (Browning and Leite-Browning, 2011). This dataset included 1,547 kids born and 1,173 kids weaned. The study ran a complete three-breed diallel mating plan with all possible matings among Boer, Kiko, and Spanish breeding stock and 9 kid genotypes produced.

Kid weights.

Sire breed and dam breed interacted ($P < 0.05$) for birth weight (Figure 2). Straight-bred Boer kids were heavier ($P < 0.05$) than straight-bred Kiko and Spanish kids. Sire breed did not affect birth weight within Boer dams, but Boer-sired kids were heavier ($P < 0.05$) than Kiko- and Spanish-sired kids when born to Kiko or Spanish does. Sire breed and dam breed also interacted ($P < 0.05$) for weaning weights (Figure 3). Kiko kids were heavier ($P < 0.05$) than Boer and Spanish among straight-bred comparisons. For Boer-sired kids, Kiko does weaned heavier ($P < 0.05$) kids than Boer or Spanish dams. For Kiko-sired kids, Kiko dams weaned heavier ($P < 0.05$) kids than Spanish dams. Per main effects, sire breed did not affect 90-day weaning weights, whereas Kiko dams weaned heavier ($P < 0.01$) kids than Boer and Spanish dams (35.0 vs. 31.2 and 31.7 ± 4.4 lbs).

The direct breed effect (i.e., the effect of breeds contributing to the kid genotype) at weaning did not contribute ($P > 0.05$) to the variation in kid weaning weights (Boer = 0.77 lbs, Kiko = 1.01 lbs, Spanish = -1.78 lbs; Browning et al., 2011). The maternal breed effect (i.e., the effect of breeds contributing to the dams raising the kids) played an important role ($P < 0.05$) in kid weaning weights. Boer dams contributed a loss ($P < 0.05$) of 2.73 lbs per kid at weaning, Kiko dams added ($P < 0.05$) 2.86 lbs per kid weaned, and Spanish dams did not affect ($P > 0.05$) kid weaning weight (-0.13 lbs). The crossbreeding advantage of hybrid vigor was only significant for the Boer-Kiko matings (1.76 lbs of added weight above the combined breed average, $P < 0.05$). The Boer-Spanish and Kiko-Spanish crosses generated 0.73 lbs and 0.37 lbs, respectively in added weight relative to the combined breed averages; these hybrid vigor levels not being significant (Browning and Leite-Browning, 2011).

Boer sires generated heavier kids at birth. However, dam breed had a greater effect on weaning weights than sire breed with Kiko dams yielding heavier weaning weights than the other dam breeds. Goodenwardene et al. (1998) also reported that the weight advantage of Boer-sired kids at birth was not maintained through weaning. Boer sires increased weaning weights compared with other sire breeds in some reports (Haas, 1978; Merlos-Brito et al., 2008), but not in others (Goonewardene et al., 1998; Rhone, 2005; Oliveira, 2006; Menezes et al., 2007). Steinbach (1988) and Martinez-Rojero et al. (2014) reported that Boer sires increased weaning weights when compared with local sires when mated local does but Boer sires and imported dairy breed sires were similar for crossbred kid weaning weights. Enhancing kid weaning weights by crossbreeding with Boer sires in limited-input meat goat production systems in the US is possible, but not automatic. It may be dependent on the quality of the sires and alternative sire breeds under consideration as well as other genetic and environmental considerations. There was a clear advantage for Kiko does compared with the other doe breeds for kid weaning weights. This is a trait where the Kiko introduction showed improvement over the resident Spanish doe base.

Figure 3 illustrates how proper use of breeds when is as influential as proper selection of breeds for a crossbreeding program. Viewing the two kid genotypes resulting from the crossing of Boer and Kiko. Kids produced from matings of Boer sires to Kiko dams had a significant advantage ($P < 0.05$) of 4 lbs over kids produced from matings of Kiko sires to Boer dams. The proper use of selected breeds is important to enhancing doe-kid performance in a planned crossbreeding scheme.

Kid survival.

Sire breed did not affect preweaning kid survival. Kid survival from birth to weaning was affected ($P < 0.05$) by dam breed (Browning et al., 2011). Boer dams raised a lower ($P < 0.05$) percentage of their kids to weaning (68.7 ± 6.2%) than Kiko (84.1 ± 4.1%) and Spanish dams (87.2 ± 3.6%). In their native southern Africa, Boer does also had reduced preweaning kid survival rates compared with Nguni does (87 vs. 66%; Lehloenya et al., 2005), unimproved Veld does (86 vs. 24% in Year 1 and 90 vs. 70% in Year 2; Casey and Van Niekerk, 1988) and Tswana does (91 vs. 75%; Senyatso and Masilo, 1996). Observations of reduced kid survival for Boer dams mirror the narrative of Boer does having reduced fitness compared to other maternal breed options. In a low- to moderate-input management system, the expectation is that does in the breeding program can deliver and raise kids unassisted to weaning. There is little room in such commercial systems for orphans (bottle babies) or excessive feeding or management to overcome deficiencies in maternal merit if profit is an objective.

IV. POSTWEANING KID TRAITS

Kid performance after weaning is important for developing market kids and replacement doelings. Most male kids are destined for harvest, so weight gain until harvest is important as well as carcass yield. In the US, there are no official systems of quality or yield grading for marketed meat goat carcasses. Yield estimates are loosely based on an unofficial live animal and carcass conformation scoring system (McMillin and Pinkerton, 2008; Chisley and Phelps, 2010). Offspring growth traits usually receive the majority of attention when breeds are compared for performance. In terminal sire breeding programs, doelings would also be grown out for harvest. among the various production traits, carcass merit is probably least important as a driver of meat goat enterprise profitability.

Doelings in seed-stock and commercial herds are expected to develop to the point that they successfully enter the breeding herd. Few weaned buckings should be expected to merit further developed as herd sire prospects with most coming from seed-stock herds, not commercial herds. Market kid and replacement stock development both depend on post-weaning growth and survival to the pertinent end-points.

Carcass traits.

Phase I of the TSU evaluation effort included 3 years of harvested buck kids (n = 275) representing the nine kid genotypes (Browning et al., 2012). Sire breed affected ($P < 0.05$) live grade and dressing percent and dam breed affected ($P < 0.05$) live grade, live weight, carcass weight and dressing percent (Table III). Live grade is used to help assign market value to kids. The mean grades suggested that the market kids of Boer sires or dams would be higher valued and with higher yielding carcasses compared to Kiko sires and Spanish dams, respectively. However, Boer-influenced progeny produced lighter carcasses, lower dressing percentages, and no differences in measured lean:bone ratios when compared with the Kiko and Spanish influences (Table III; Browning et al., 2012). Sire breed was also a non-factor ($P > 0.05$) for ribeye area. Consistent with the preweaning data, dam breed had a greater influence on carcass yield traits than sire breed.

Although the Boer influence (sire or dam) looked subjectively to have enhanced carcass yield, objective measurements indicated that the Boer effect was negative or non-existent for the carcass traits recorded compared with Kiko and Spanish. Boer sires have been well studied for their potential to improve carcass yield traits as reviewed by Browning et al. (2012). The majority of studies reviewed in the scientific literature indicated that Boer sires did not improve carcass weight or dressing percent over alternative sire breeds. For carcass weight comparisons of Boer-sired F1 kids compared to straight-bred kids of base doe breeds, Merlos-Brito et al. (2008) reported Boer sires increased carcass weights, whereas five other studies found no crossbreeding advantage (Goonewardene et al., 1998; Dhanda et al., 2003; Menezes et al., 2009; Rodrigues et al., 2009; Martins et al., 2014). For carcass weight comparisons of Boer-sired F1 kids compared to F1 kids of other sire breeds, four studies found no sire breed effects (Dhanda et al., 1999, 2003; Rodrigues et al., 2009; Merlos-Brito et al., 2008), whereas a fifth (Goonewardene et al., 1998) indicated Alpine sires produced heavier carcasses than Boer sires. For dressing percentage, Boer sires did not differ from other sire breeds in five reviewed studies (Goonewardene et al., 1998; Dhanda et al., 2003; Merlos-Brito et al., 2008; Menezes et al., 2009; Rodrigues et al., 2009), while a sixth report indicated that Saanen-sired F1 kid generated higher dressing percentages than Boer-sired F1 kids (Dhanda et al., 1999). The findings of three smaller-scaled US carcass studies were also reviewed. Oman et al. (1999) in Texas indicated that under feedlot conditions, using Boer sires to cross with Spanish does increased live and carcass weights, but the crossing with Boer did change ribeye area or percent lean yield; the weight advantages were not evident for 24 kids under range conditions. Cameron et al. (2001) in Oklahoma found no difference between Boer x Spanish and straight-bred Spanish kid carcasses for live or carcass weight, dressing percent, ribeye area, or percent lean tissue. In Alabama, Solaiman et al. (2012) reported that purebred Boer kids were heavier than Kiko kids for live weight, the two breeds were similar for carcass weight, dressing percent, and ribeye area, and the Kiko kids yielded a higher lean tissue percentage than the Boer kids. The scientific evidence generally suggested that Boer genetics can be expected to improve carcass yield traits with a high degree of certainty.

Doeling development.

Replacement doeling development is a management task that can impact the future performance of a herd. Replacement doelings carry the improved genetics that a manager has selected and bred for. Replacement doelings are expected to enhance future herd performance or generate revenue if sold to enhance the future performance of other herds. Raising replacement doelings is not a cost-free endeavor. Doeling development has probably received the least amount of attention as an area of meat goat research.

A study was conducted to evaluate different aspects of doeling selection and development (Khanal, 2016; Khanal et al., 2016). Doelings weaned across Phase I and II evaluations were used to assess, in part, how kid breed affected doeling development from weaning through their first year in the breeding herd. Records were used for Boer (n = 60), Kiko (n = 102), Spanish (n = 96), and Boer-cross (n = 138) doelings. In the TSU herd, first mating occurs in the second fall breeding season when replacement does are approximately 18-20 months of age. A sample of traits are provided in Table IV. The consistent observation was that straight-bred Boer doelings were less fit compared with Kiko, Spanish, and Boer-cross does across the group of developmental traits tested. Deficiencies noted for Boer does within the management system of the research herd were evident as early as the yearling measurement date. Equally apparent was that the fitness of Boer-cross doelings was similar to the Kiko and Spanish straight-bred doelings, mirroring observations in the main doe herd (Table II).

V. GENERAL COMMENTS

The general implications from the series of trials conducted at TSU along with related studies at other research locations are that the Boer goat is not the singular breed to improve meat goat production in the US and the Spanish goat should not be discounted as representing a goat population lacking in commercial production value. Each of the three breeds reviewed here can contribute positively to a commercial system if properly used. There are other breeds that may also contribute to commercial meat goat production systems. Two breeds in particular are the Myotonic and Savanna. To date, these two breeds have received little to no research attention under a comprehensive breed evaluation protocol. They have been added to the TSU evaluation effort with early Savanna results starting to emerge (Goolsby et al., 2016; Hayes et al., 2016). Dairy breeds should not be overlooked. Several of the studies reviewed indicated that Alpine, Nubian, and Saanen sires performed equal to or better than Boer sires for slaughter kid production. The Kiko goat is the product of these dairy sire breeds. Selection and use of meat goat breeds may be driven in part by production objectives, marketing interests, and available resources.

Relative breed performance may vary somewhat by environment and management system. However, breed differences should not be ignored or discounted. There is an often echoed concept stated in one form or another that there is more variation within breeds than between breeds. This may be true but there is ample variation between breed averages for some economically important traits, especially fitness traits, that poor breed selection and(or) use can prove costly, especially in resource-limited meat goat production systems. A comprehensive economic analysis of the Phase I dataset was conducted that incorporated most variable and fixed production costs and various income streams based on herd performance data and relevant market price data. Annual returns over variable and total costs resulted in net losses for Boer does, but net profits for Kiko and Spanish does. Additional economic assessments of the dataset revealed that applying market 'premiums' for Boer-influenced kids did little to alter the 'per doe' economic return estimates. Recall that voluntary doe culling pressure has historically been relaxed in the research herd. Widespread use of breeds without knowing breed strengths and weaknesses can prove financially detrimental. Newer meat goat breed may increase industry popularity, but not necessarily profitability.

Semi-intensive pasture and extensive range management environments are dynamic and often less than ideal. They require a maternal goat type that can perform under diverse, suboptimal conditions with limited inputs. The part-time nature of most goat managers also dictate that the doe herd not require constant hands-on management and intervention. In the current project, the Boer breed generally performed poorly across the range of performance traits measured when compared to the Kiko and foundation Spanish breeds. The latter two exhibited general hardiness and appeared better suited as maternal breeds for commercial meat goat production on humid, subtropical pasture. Reducing stock rates is a common means of controlling internal parasitism. This can be taken to a counterproductive extreme if dealing with an unfit doe population. Consider the assessment of herd productivity using an acre of land at the production unit instead of the individual doe as the production unit. It is likely that does better able to handle an internal parasite challenge could be managed at a higher stocking rate than does more apt to become debilitated by internal parasites. Thus, 'per acre' herd productivity would benefit from genetically improved doe fitness in addition to 'per doe' herd productivity.

The Boer is better suited as a terminal sire breed with the avoidance of Boer influence on the maternal side. A terminal sire plan was the reason for the initial transfer of Boer goats from South Africa to New Zealand and was recommended by Blackburn (1995) in response to the simulation results. Terminal sire use either did not become part of general outreach information transfer or was ignored by industry participants. Little benefit was shown in crossbreeding with Boer sires for replacement doeling production compared with maintaining straight-bred Kiko or Spanish base doe populations (or perhaps a crossing of the latter two). In a commercial doe herd, Boer sires may be a preferred choice if the objective is to produce market kids for harvest, taking advantage of possibly enhance kid growth and improved visual conformation. Kiko or Spanish sires may be more appropriate if replacement doeling production is the primary objective; the buck kids will still be suitable for the harvest market as the carcass research demonstrated. There isAMple opportunity to change trait values for any of the breeds through good performance recording, proper within-breed animal selection, consistency, and patience. Crossbreeding may be a faster way to alter performance levels with proper breed selection. In any case, start with good breed selection decisions because trying to manage around poor breed choices, especially on the maternal side, is likely unprofitable and unsustainable.

ACKNOWLEDGMENT

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Table I. Effect of doe breed on fitness traits for straight-bred does.

	Breed of doe			
Trait	Boer	Kiko	Spanish	SE
Does, n	205	207	193	
Litter size born, kids	1.80	1.76	1.74	0.08
Litter size weaned, kids	1.38	1.46	1.61	0.10
Per doe in fall breeding herd				
Does birthing kids, %	48.8 [b]	83.7 [a]	81.4 [a]	4.3
Does weaning kids, %	30.5 [b]	71.5 [a]	71.0 [a]	5.9
Litter size weaned, kids	0.43 [b]	1.07 [a]	1.12 [a]	0.12
Fecal egg counts, eggs/g [1]	1226 [a]	718 [b]	589 [c]	-
Annual survival rate, % [2]	53.5 [b]	86.5 [a]	84.5 [a]	4.4

[ab]Means with different letters differ significantly ($P < 0.05$).

[1]Collected from does at kid weaning at 90 days.

[2]Surviving does included those that avoided death or culling.

Table II. Effect of doe breed on fitness traits for crossbred does.

	Breed of doe				
Trait	Kiko	Boer x Kiko	Spanish	Boer x Spanish	SE
Doe, n	162	133	150	112	
Litter size born, kids	1.62	1.65	1.50	1.54	0.08
Litter size weaned, kids	1.45	1.45	1.38	1.32	0.08
Per doe in fall breeding herd					
Does birthing kids, %	74.0 [a]	61.5 [b]	72.3 [a]	57.4 [b]	8.1
Does weaning kids, %	54.9	46.4	59.9	45.8	6.6
Litter size weaned, kids	0.79	0.68	0.79	0.61	0.1
Fecal egg counts, eggs/g [1]	740	775	758	561	-
Annual survival rate, % [2]	83.0	75.8	79.4	77.9	3.7

[ab]Means with different letters differ significantly ($P < 0.05$).

[1]Collected from does at kid weaning at 90 days.

[2]Surviving does included those that avoided death or culling.

Table III. Effect of sire and dam breeds on meat goat carcass traits.

	Breed			
Trait	Boer	Kiko	Spanish	SE
Per sire breed				
Live conformation grade[1]	2.81 [a]	2.60 [b]	2.69 [a]	0.11
Live body weight, lbs	55.2	57.2	55.0	3.3
Cold carcass weight, lbs	23.4	24.8	24.3	2.0
Cold dress-out, %	40.1 [b]	41.4 [a]	41.7 [a]	1.0
Per dam breed				
Live conformation grade[1]	2.76 [a]	2.68 [a]	2.66 [b]	0.11
Live body weight, lbs	53.9 [b]	58.5 [a]	54.8 [b]	3.3
Cold carcass weight, lbs	23.1 [b]	25.7 [a]	23.7 [ab]	2.0
Cold dress-out, %	40.2 [b]	41.9 [a]	41.1 [ab]	1.0

[ab]Means with different letters differ significantly ($P < 0.05$).

[1]Muscle conformation improves subjectively as grades increase from 2.0 to 2.9.

Table IV. Effect of doe breed on replacement doeling fitness traits post-weaning.[1,2]

	Breed of doe				
Trait	Boer	Boer-F1	Kiko	Spanish	SE
Doelings weaned, n	60	138	102	96	
Survival to yearling age, %	66 [b]	88 [a]	91 [a]	91 [a]	5
Survival to 1st breeding, %	52 [b]	87 [a]	90 [a]	90 [a]	5
1st year kidding rate, %	37 [b]	77 [a]	83 [a]	89 [a]	10
1st year weaning rate, %	20 [b]	57 [a]	71 [a]	74 [a]	10

[ab]Means with different letters differ significantly ($P < 0.05$).

[1]Khanal, 2016.

[2]Doelings were weaned at 3 months of age and first bred at 18 months of age.

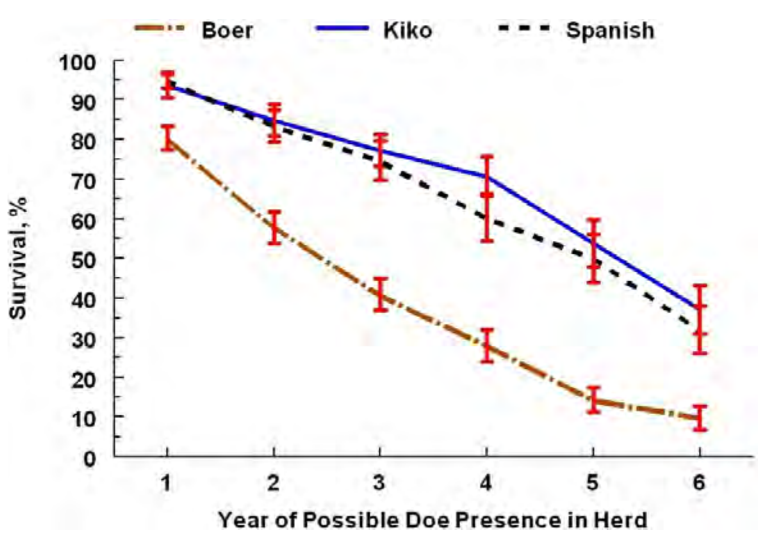

Figure 1. Doe survival estimates (± SE) for doe breeds using the culling protocol of removal after second reproductive failure. Boer does differed ($P < 0.05$) from Kiko and Spanish does for the survival curve over 6 years of production and for doe stayability rate at each year of possible presence in the herd. Does in Year 1 were approximately 2–3 years of age. Does reaching Year 6 would have been approximately 7–8 years of age. (Pellerin and Browning, 2012).

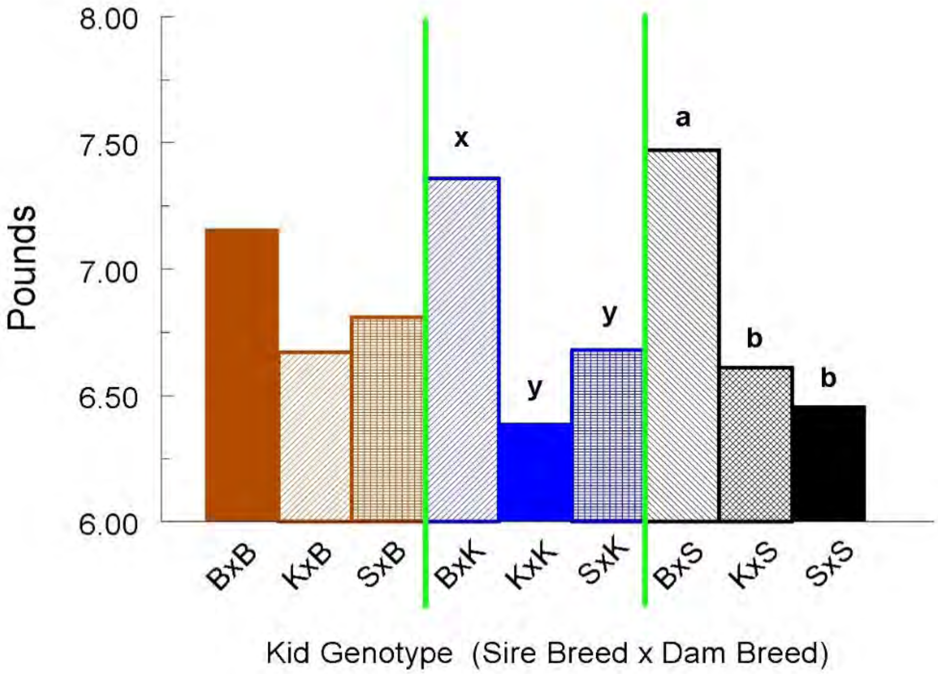

Figure 2. Kid birth weight (LSM ± 0.28 lbs) from Boer (B), Kiko (K), and Spanish (S) parental stock. First and second letters of kid genotype are the sire and dam breeds, respectively. [ab]Within S dam group, B-sired kids were heavier ($P < 0.05$) than K- or S-sired kids. [xy]Within K dam group, B-sired kids were heavier ($P < 0.05$) than K- or S-sired kids. Straight-bred B kids were heavier ($P < 0.05$) than straight-bred K and S kids (BB vs. KK, SS).

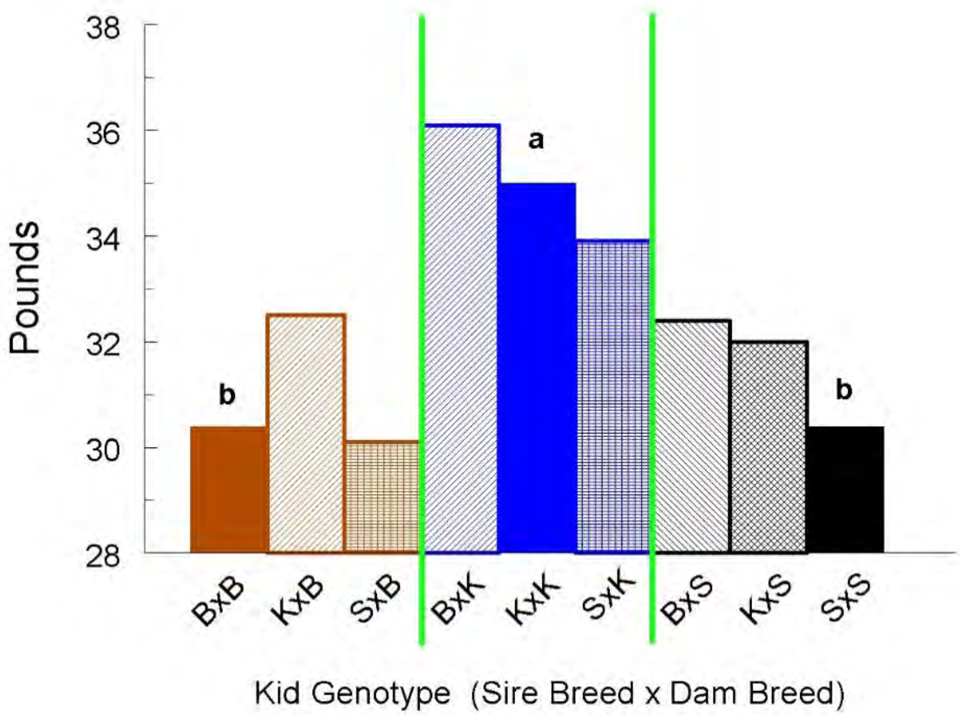

Figure 3. Kid weaning weight (90-day adjusted; LSM ± 1.3 lbs) from Boer (B), Kiko (K), and Spanish (S) parental stock. First and second letters of kid genotype are sire and dam breeds, respectively. [ab] Straight-bred K kids were heavier ($P < 0.05$) than B or S straight-bred kids. Weights were heavier ($P < 0.05$) kids raised by K dams than by B and S dams within B-sired (BK vs. BB, BS) and S-sired (SK vs. SB, SS) groups.

SECTION FOUR

DISEASE AND HERD HEALTH

BUYING HEALTHY GOATS AND KEEPING THEM THAT WAY

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ABSTRACT

Starting a goat herd with a healthy foundation of animals will prevent years of expense and effort to eliminate serious infectious diseases. Pre-purchase testing and examinations are well worth their cost because of the savings realized through fewer animal illnesses, increased production, lower medication costs, and reduced culling. Key management practices such as hoof trimming, vaccinating, body condition scoring, and assessing parasite loads are needed to maintain herd health. Biosecurity practices must become routine to prevent the introduction and/or spread of contagious diseases. Several goat diseases are also contagious to humans, so biosecurity measures must address this concern as well. Excellent record keeping will help producers monitor health and production trends, document treatments, make breeding vs. culling decisions, and produce food products without illegal residues. Starting with healthy animals, reducing exposure to contagious diseases, providing excellent nutrition, reducing stress, practicing required management tasks in a timely fashion, selecting for healthy animals, and monitoring all animals daily should result in a goat herd consisting of animals rarely needing medical intervention—an important factor in a goat enterprise's long-term financial, social, and environmental sustainability.

Keywords: biosecurity, herd health, prevention

I. INTRODUCTION

Unless you have unlimited money, time, and ability to tolerate animal illness and death, you will want to prevent as many goat diseases in your herd as possible. Resources devoted to disease prevention are well worth the investment. Disease prevention is also the foundational concept of animal welfare.

II. ASSEMBLING A HERD

When establishing a herd, consult a local veterinarian familiar with breeders and diseases in your area. Instead of the high-risk approaches of purchasing animals from sale yards, feed store fliers, or classified ads, ask your veterinarian where he/she would recommend obtaining breeding stock, then work directly with that breeder. Reputable breeders of high quality, lower-risk animals will be forthcoming about illnesses, treatments, pedigrees, production, and other details about individual animals. Many have expended considerable time and money to free their herd from specific diseases; expect to pay more for these animals but realize they are worth their added value.

From a biosecurity standpoint, it is best to assemble a herd from one source. If animals will be acquired from multiple sources, keep animals from each source with each other but quarantine away from other goats by at least 10 feet (Rowe, 2018) for at least 30 days, monitoring closely for evidence of illness. Use separate equipment and feeders for each group; wash hands and change clothing and footwear between groups during the quarantine period.

A. Pre-purchase Physical Examination

A pre-purchase examination of a prospective herd addition should include a detailed history of the individual's health status, including all illnesses, vaccinations, dewormings, and treatments. Breeding and kidding records should also be examined. A comprehensive physical examination should be conducted on all prospects, of course. Considerations such as conformation, docility, blemishes, faults, hornedness, etc. will be of greater or lesser importance depending on the animal's purpose. For example, if assembling a herd of wethers for commercial brush clearing, one may not care about an animal's temperament, faults, etc. However, conformation and temperament are important considerations for breeding stock.

B. **Pre-purchase Laboratory Testing**

Going more in depth with laboratory work, a breeding soundness evaluation should be conducted on potential herd sires—even proven sires—because previous fertility does not guarantee future fertility. Those purchasing does in milk may decide to have milk cultures done to look for contagious forms of mastitis such as *Streptococcus agalactiae*, *Staphylococcus aureus*, and *Mycoplasma* species. A fecal examination to determine parasite loads would be valuable, as would a fecal egg count 10 to 14 days after deworming to determine the presence of dewormer-resistant parasites (Coles et al., 1992). When purchasing animals, you are also purchasing their bacteria, viruses, and parasites.

C. **Pre-purchase Biosecurity Screening**

Additional pre-purchase biosecurity screening tests can be conducted for caseous lymphadenitis (CL), the caprine arthritis and encephalitis virus (CAE and/or caprine lentivirus), Johne's disease, brucellosis, tuberculosis, Q fever, and others. A veterinarian should be consulted to help interpret test results. Although most laboratory test results are accurate, tests differ in their sensitivity (ability to detect true positives) and specificity (ability to detect true negatives). Results in question should be confirmed by re-testing.

It is critical to appreciate laboratory test results on individual animals are not as meaningful as the disease status of the entire herd of origin. Johne's disease testing in goats is particularly challenging: infected and clinically ill goats may test negative on all Johne's tests, yet succumb to the disease and be diagnosed positive at necropsy. A positive Johne's test is meaningful, but false negative results abound. Screening tests are snapshots of one animal's disease status at a particular time; they may not be able to identify animals recently exposed to a pathogen and in the early phase of disease development.

Laboratory tests are designed to identify antibodies produced against a specific disease-causing agent or detect the agent itself. For example, the screening test for CL checks for antibodies to the causative organism (*Corynebacterium pseudotuberculosis*), which are generated if and when an animal is exposed to the agent. However, antibodies are also generated if an animal is vaccinated against CL, so consult a veterinarian for help interpreting CL test results. A discussion with the breeder about an animal's vaccination history and historical presence or absence of CL in the herd should help with interpretation of test results; findings from a comprehensive physical examination may help clarify laboratory test results, as well.

CAE antibody tests are accurate after an animal is six months old; prior to that, a kid's CAE test results could reflect its dam's CAE status. A positive test indicates an animal has been exposed to and is infected with the CAE virus and has generated antibodies against it. Many positive animals will lead long and healthy lives, never showing signs of illness. However, they can transmit the virus vertically to their offspring through milk and colostrum and horizontally to herd mates (Rowe, 2018). Because the virus is contained in white blood cells, anything causing exchange of infected cells between animals (breeding, infected needles, infected discharges, etc.) has the potential to transmit the CAE virus between goats. Herd-wide CAE testing enables creation of positive and negative sub-herds on a farm, which will facilitate transition to a herd-negative status after management changes have been enacted (Nord et al., 1998).

Scrapie is a fatal transmissible spongiform encephalopathy of sheep and goats; the U.S. is trying to eradicate this disease from the country. Previously, tests were only possible on brain samples from dead or euthanized animals. However, testing can now be conducted on rectal biopsy samples from live animals to detect infected but subclinical animals (Dennis et al., 2009). Scrapie is another example of the value of knowing herd status vs. individual status: purchasing a goat from a premise on which a case of scrapie has never been diagnosed and healthy animals live to become elderly would be a low-risk venture regarding scrapie. Animals could be tested using the rectal biopsy test to further reduce the risk of purchasing an infected animal.

III. ROUTINE CARE

A. Hoof Trimming

After assembling a healthy herd, several routine practices will be needed to keep them healthy. Firstly, all goats' feet should be examined regularly to assess the need for hoof trimming. Hooves may need to be trimmed every 4 to 12 weeks, depending on environmental and individual factors. The typical sign of the need to trim is a long toe and wall that has grown over the sole (Photo 1). Trim hooves to resemble a parallelogram with the front and rear surfaces parallel and the top and bottom surfaces parallel. Disinfect hoof trimmers between goats to prevent the spread of foot rot and other diseases.

B. Body Condition Scoring

Body condition scoring (BCS) should be done on all animals at least monthly and more often during critical times such as winter, lactation, and pregnancy. BCS is a hand-on assessment of the muscle and fat cover over an animal's skeleton. A five-point scale is used for goats, with '1' indicating emaciation and '5' indicating obesity. A BCS of three is desirable for most animals, but heavy milkers may drop body condition to '2' or even lower during peak production. Also, pregnant does may gain some condition during their dry period, but scores above four are not desirable. Villaquiran et al. (2007) produced an excellent training resource about BCS.

C. Vaccinating

Developing a herd vaccination program is another example of when it would be advantageous to work directly with a local veterinarian. She or he will be knowledgeable about local diseases and pathogen strains and able to make practical recommendations regarding vaccinating to reduce disease risk.

At a minimum, goats need protection from *Clostridium perfringens* types C and D and tetanus; properly using a three-way "CDT" vaccine will protect goats from these diseases. Vaccinate kids at six, nine, and 12 weeks of age; booster at six months, then every six months thereafter. Booster pregnant does one month before kidding so they produce and incorporate high levels of protective antibodies in their colostrum—this will provide passive protective immunity to their kids until the latter develop active immunity through vaccination. In some areas, it will be advisable to use a seven- or eight-way clostridial vaccine due to local disease risk. If using a seven- or eight-way vaccine, be sure it includes CDT protection.

Some farms will need to use the sore mouth vaccine in kids annually if the virus is present on the farm and/or kids will go to shows. This vaccine is modified live and causes a milder form of the disease. Protection is usually lifelong after initial vaccination and does pass on some protective antibodies to kids via colostrum. The advantage of vaccination is timing: kids can be vaccinated after they have a good start instead of experiencing a more severe natural case of sore mouth when they are very young. Care should be taken when using this vaccine because humans can contract sore mouth.

A bacterial vaccine called *Mannheimia haemolytica-Pasteurella multocida* bacterin is licensed for use in goats to prevent outbreaks of Pasteurella pneumonia. The need for this vaccine will be much higher in large herds primarily housed indoors vs. smaller herds with significant access to pasture, and with herds going to shows and adding new animals vs. closed herds.

If needed, vaccines against additional diseases such as rabies, CL, enzootic abortion, foot rot, vibriosis, etc. will require use of vaccines not licensed for use in goats. Such use is legal only with the recommendation and guidance of a licensed veterinarian with whom the producer has a legal veterinary-client-patient relationship. All goats are considered food animals, so their medications and vaccines are regulated by the U.S. Food and Drug Administration (FDA). It is a violation of federal FDA regulations to use a product in a food animal in any way not specified on the label (extra-label drug use) unless in certain circumstances and with veterinary oversight.

D. Controlling Parasites

Most goat breeds developed in environments and/or under management systems that did not expose them to high loads of internal parasite larvae. Consequently, there was little genetic selection pressure on them to develop resistance to parasites. However, conditions in many parts of the U.S. are ideal for parasite survival. Goat caretakers must constantly assess all animals for signs of parasitism and practice specific pasture management techniques to minimize the intake of problematic parasite larvae. Assessment of internal parasite loads involves body condition scoring; FAMACHA© scoring of ocular mucous membrane color; monitoring of manure color and consistency; assessing production levels and rates of gain; observing appetite, hair coat quality, hind quarter cleanliness, and alertness; and checking for bottle jaw (fluid accumulation under the jaw due to low blood protein levels). Advanced monitoring involves comprehensive or targeted use of fecal egg counts to determine internal parasite loads.

When individuals animals have clinical signs of parasitism (thin, poor coat, anemia, diarrhea, bottle jaw, potbelly, poor appetite, dull, weak, etc.), they should be treated with an effective dewormer. However, owners are not obligated to keep these animals beyond the dewormer's meat/milk withdrawal period nor are they obligated to breed animals that need treatment. Each producer must determine how strongly he or she will cull animals based on how often deworming is needed. Retaining and breeding only the most resistant animals will help producers eventually develop a herd in which only individual animals occasionally need deworming. However, all animals will need a lifetime of frequent monitoring to quickly identify and treat animals in need.

Controlling parasites in goats also involves following best management practices for pastures. These practices include never allowing animals to graze lower than three inches; rotating animals through grazing cells; never leaving animals in a grazing cell longer than four days; not returning to a grazing cell sooner than six weeks; providing as much browse as possible; and drylotting animals if needed to allow time for pasture regrowth or larval death.

IV. BIOSECURITY PRACTICES

Biosecurity practices help keep diseases off farms and help contain the spread of pathogens already on a farm. Pathogens are microscopic and no alarms sound when they are transmitted, so it is easy to become complacent about biosecurity measures. Biosecurity procedures should be developed with the guidance of a herd veterinarian and then strictly followed every day by everyone (Photo 2). Farms interested in educating the public via farm tours yet desirous of reducing the risk of disease introduction need to develop pre-event biosecurity protocols (Kerr, 2017).

In addition to the above-mentioned healthy animal selection criteria, general biosecurity recommendations include:

- Isolate sick animals
- Quarantine herd additions or returns
- Avoid livestock shows and sales
- Separate animals by age after weaning
- Practice excellent sanitation
- Feed animals above floors
- Remove and compost manure
- Cull chronic cases
- Wear disinfected boots and clean coveralls
- Change boots and clothing between groups of animals
- Vaccinate against relevant diseases

- Use effective cleaning and disinfection protocols
- Restrict farm visitors
- Wash hands after animal contact
- Do not borrow or loan equipment
- Separate feed and manure-handling equipment
- Restrict vehicle and foot traffic

V. ZOONOTIC DISEASE POTENTIAL

A significant number of diseases can be transmitted and shared between goats and humans (Table I). The biosecurity and personal hygiene practices recommended above can mitigate the risk of contracting most of these diseases. Personal protective equipment such as disposable gloves, hair/beard net, eye protection, and nose/mouth mask will further reduce the risk of exposure. Goats of particular concern as sources of zoonotic diseases include those with diarrhea, contagious abscesses, skin lesions, neurologic signs, oral sores and ulcers, and miscarriages. Contact with aborting goats is such an elevated risk of zoonotic disease exposure pregnant women should have no contact with them whatsoever.

Handwashing, washing and cooking food thoroughly, and pasteurizing dairy products will reduce the risk of many zoonotic and/or foodborne illnesses. Laboratory testing of sick animals should identify the pathogen involved and alert the owner of its zoonotic potential. An exception is Q fever: many healthy-appearing sheep, goats, and cattle shed this zoonotic pathogen sporadically. Q fever testing does not always identify infected animals, and infected animals do not always shed the organism (Van Den Brom et al., 2015). The disease is more serious in humans than livestock, as well. Consequently, food safety recommendations regarding pasteurization of dairy products should be followed. Raw milk is a potential source of Q fever and several other diseases.

VI. RECORD KEEPING ESSENTIAL

Accurate records are essential on all farms for many reasons. As examples, they help identify problematic animals and family lines, document treatments and medication withholding periods, note breeding dates, and make doing farm taxes easier. Commercial software is available for both farm management and financial record keeping, or producers can create their own spreadsheets. Even hard copy record keeping is valuable. Items to document include, but are not limited to:

- Animal identification
- Sire and dam
- Birth date
- Birth weight
- Weaning weight
- Rate of gain
- Kidding ease
- Grafting details
- Number kids born
- Number kids weaned
- Pounds of kids weaned
- Milk production
- Dates of procedures
- Illnesses
- Treatment details
- Reason culled
- Necropsy results
- Where sold

- Fertility test results
- Carcass characteristics
- Breeding dates
- Pre- and post-treatment fecal egg counts
- FAMACHA scores
- Body condition scores
- Fleece weight & quality
- Somatic cell counts
- Test results
- Linear appraisal score
- Serial and lot numbers of vaccines and medications
- Medication withholding times
- Quality assurance actions

VII. SUMMARY

Starting with healthy animals, practicing routine management tasks, and enacting effective biosecurity protocols will go a long way toward reducing the occurrence of diseases on goat farms. When combined with a balanced nutrition program and a low-stress environment, these steps should allow goat owners to spend enjoyable time observing and monitoring animals instead of treating them for illness.

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Photo 1. Overgrown goat hoof with left claw partially trimmed. Note complete coverage of sole of right claw with overgrown hoof wall.

Photo 2. A keystone of farm biosecurity: thorough soap-and-water cleaning of footwear followed by required contact time of an effective disinfectant.

Table I. Diseases transmissible between goats and humans. Adapted from CDC information.

Disease	Cause	Transmission route	Livestock species involved	Notes
Campylobacteriosis	*Campylobacter jejuni* and other species	Oral (ingesting contaminated food or water)	Primarily chickens, cattle, birds, dogs, cats	Reduce risk through pasteurization, washing fruits and vegetables, disinfecting drinking water
Caseous lymphadenitis	*Corynebacterium pseudotuberculosis*	Breaks in skin	Goats and sheep	Risk significantly reduced by use of gloves and handwashing
Colibacillosis and Hemolytic Uremic Syndrome	*Escherichia coli* O157:H7	Oral (contaminated food or water; direct contact with infected animals)	Cattle, goats, sheep, deer	Young children, elderly, and immune-compromised are at elevated risk
Cryptosporidiosis	*Cryptosporidium parvum* and other species	Oral (ingesting contaminated water or food; contacting contaminated surfaces)	All domestic and wild mammals	Organism is very hardy in environment and resistant to many disinfectants
Echinocccosis	*Echinococcus granulosus*	Oral (ingesting food, water, or soil contaminated with infected dog feces; contact with contaminated dog hair)	Dogs, (definitive host) and sheep, cattle, goats, and pigs	Dogs are definitive host; other species are intermediate hosts
Erysipeloid	*Erysipelothrix rhusiopathiae*	Breaks in skin	Domestic and wild mammals, fish, birds, shellfish	Most common livestock species affected is swine
Giardiasis	*Giardia lamblia* and other species	Oral (ingesting contaminated food, water, or soil)	Domestic and wild mammals	Organism is very hardy in environment and resistant to many disinfectants
Leptospirosis	*Leptospira pomona* and other species	Oral (ingestion of water, soil, or food contaminated with urine of infected animals); direct contact (infected body fluids from infected animals); inhalation; breaks in skin; mucous membranes	Domestic and wild mammals	Risk elevated during and after flooding
Listeriosis	*Listeria monocytogenes*	Oral (ingesting contaminated water, soil, or food, particularly raw food); in utero	Poultry, cattle	Pasteurization reduces risk of transmission through dairy products
Disease	**Cause**	**Transmission route**	**Livestock species involved**	**Notes**

Q Fever	*Coxiella burnetii*	Inhalation; contact with contaminated surfaces	Goats, cattle, sheep	Risk significantly reduced by milk pasteurization; avoid contact with animals giving birth
Rabies	*Lyssavirus*	Direct contact with saliva from infected animal; inhalation and transplants (rare)	Domestic and wild mammals	Most common wildlife hosts are bats, skunks, raccoons, coyotes, and foxes
Ringworm	*Trychophyton* and *Microsporum* species	Direct contact of skin with infected animals or surfaces	All domestic mammals	Usually lifelong immunity after infection
Salmonellosis	*Salmonella typhimurium* and other species	Oral (ingesting contaminated food or water); in utero	Domestic and wild mammals; reptiles;AMphibians; poultry and birds	Poultry, turtles, and frogs pose elevated risk to children under five years old
Sore mouth	Orf poxvirus	Direct contact with livestock sores, scabs, and contaminated environment	Goats and sheep	Risk significantly reduced by use of gloves and handwashing
Toxoplasmosis	*Toxoplasma gondii*	Oral (eating contaminated and under-cooked food, ingesting contaminated water)	Potentially all	Life cycle involves cats and intermediate hosts (rodents and birds); all other affected species are accidental cases
Tuberculosis	*Mycobacterium bovis*	Inhalation; ingestion of infected dairy products; breaks in skin	Cattle, goats, sheep, deer, elk	Risk eliminated by annual testing of dairy animals and milk pasteurization
Undulant fever or Brucellosis	*Brucella abortus* and other species	Consumption of raw dairy products from infected animals; inhalation; contact with meat from infected livestock or wildlife	Many domestic and wild mammal species, particularly goats, sheep, cattle, camels bison, elk, caribou, moose, and feral swine	Risk eliminated by annual testing of dairy animals and milk pasteurization
Yersiniosis	*Yersinia enterocolitica*	Oral (ingesting contaminated water, milk, and undercooked food; contact with infected animals or humans)	Many domestic and wild mammal species	Pigs are the major animal reservoir

COMMON INFECTIOUS DISEASES OF SMALL RUMINANTS

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ABSTRACT

Keeping a herd healthy is the number one goal of every livestock producer. Any deviation from a normal state of health leads to disease. It can have more than one cause, vary in severity, and differ from one animal to another. Of the three major categories that diseases are commonly grouped in, infectious diseases make up the largest. These are caused by a disease-causing agent (e.g., bacteria, viruses, protozoa, fungi) and are capable of being transmitted from one animal to another. They can also be spread from animals to man. While each disease can have its own specific clinical signs, failure to adequately diagnose and prevent its spread can lead to catastrophic consequences to a livestock producer's herd. This paper will present information about the clinical signs, general treatments and approaches to the prevention of some of the common infectious diseases of small ruminants. Several of the important foreign animal diseases and diseases that must be reported to state officials, which affect sheep and goats, will also be discussed.

Keywords: Infectious, Diseases, Clinical signs, Prevention.

I. COMMON INFECTIOUS DISEASES

Bluetongue (sore muzzle, ovine catarrhal fever): An infectious, noncontagious viral disease, transmitted by biting flies, and other vectors

- **Clinical signs:** After an incubation period of 4–6 days, a fever of 105°–107.5°F (40.5°–42°C) develops. The common signs are a blue tongue, congestion, hemorrhage, inflammation, and necrosis with depression, rapid and extreme weight loss, red mucous membranes of the mouth which turns purple to blue, frothing, lip ulcers, discharge from the eye and nose, weakness, red bands at the top of the hooves, lameness, and wool loss. Clinical signs in young lambs are more apparent, and the mortality rate can be high (up to 30%). Approximately 2 days after onset of fever, additional clinical signs may be seen, such as edema of lips, nose, face, eyelids, and sometimes ears; congestion of mouth, nose, nasal cavities, conjunctiva, and coronary bands; and lameness and depression. The congestion of nose and nasal cavities produces what is commonly referred to as "sore muzzle." On examination of the mouth, small hemorrhages and ulcers will be seen. Some affected sheep have severe swelling of the tongue, which may become cyanotic ('blue tongue") and even stick out from the mouth. Animals walk with difficulty as a result of the inflammation of the hooves. A purple-red color is easily seen as a band at the junction of the skin and the hoof. In most affected animals, abnormal wool growth resulting from dermatitis may be seen.

- **Treatment:** There is no specific treatment for bluetongue except rest, soft food, and good husbandry. If secondary infections appear, they should be treated appropriately.

- **Prevention:** A modified-live virus vaccine is available for use in sheep in the U.S. Use of vaccines with different serotypes does not provide consistent cross-protection. Do not vaccinate ewes during the first two months of pregnancy.

Caprine arthritis encephalitis (CAE): CAE is a disease of the nervous system, caused by a virus, for which there is no vaccine or treatment. The type of virus that causes CAE is called a slow virus (retrovirus), meaning it takes a long time for the clinical signs to appear. It is transmitted (from mother to offspring) through the colostrum and milk of lactating does. It can cause an inflammation of the brain (encephalitis), or paralysis of the hind limbs in young animals, arthritis, and chronic pneumonia in older animals. With younger does, you may see hardening of the udder. It is transmitted from doe to kids early in life through infected colostrum and milk.

- **Clinical signs:** Young kids (≤5 months) develop weakness in the hind legs, stumble, and finally lay down. Otherwise, they appear normal. The rear legs atrophy, the affected kid is unable to nurse, and soon dies from malnutrition. In older goats (≥1-2 years), the condition is presented as swollen leg joints (stifle, hock) that are painful and warm. Animals will eventually be unable to walk or they will walk on their knees. Can also cause hard mammary glands.

- **Treatment:** Treating the clinical signs (anti-inflammatory drugs, extra bedding, and foot trimming) can be effective, but it is not advisable as the disease could possibly spread and persists in the herd.

- **Prevention**: A blood test can diagnose the condition (even in animals which show no clinical signs) and if an animal tests positive it should be culled from the herd. Isolating kids at birth from positive mothers and bottle-feeding may help avoid transference.

Caseous lymphadenitis (CL, cheesy gland): This condition is a highly contagious, chronic disease, spread by a bacteria (*Corynebacterium pseudotuberculosis)* that causes abscesses to form in certain lymph nodes throughout the body (under jaw, ear, flank, and udder). They are frequently seen in the nodes around the head and neck, but can be found anyplace there are lymph nodes (see Figure 1). The abscesses contain pus, which is thick, cottage cheesy-like in consistency, greenish-white to grey, or yellow. Once seen, abscesses will grow until they rupture and seep the pus onto the ground, which will contaminate the pasture. There is a higher incidence in the west and south. Infections spread through wounds caused by head butting, punctures and shearing, by ingestion, inhalation, or penetration through intact skin. Survival of the bacteria is increased by contact with wooden (rather than metal) troughs, posts, and feed bins. There can also be incidences of abscesses that appear without an apparent cause or idiopathic CL. In this case, the abscesses are found within the goat's body (lungs, digestive system, etc.) and are hard to identify. As the organism is a common soil contaminant, abscesses can appear at any time, so it is important that all new animals are quarantined for at least 30 days or longer (if possible).

- **Clinical signs:** Hard swellings around the head, leg, neck, or udders that gradually grow, become softer, and split open. In the case of idiopathic (unusual) lymphadenitis, the only clinical signs your will see may be weight loss, a chronic cough, or difficulty breathing. Once the animal dies, if you do a necropsy, you will see abscesses throughout the body. In sheep you will find the abscesses most often internally (visceral form), while in goats the superficial form is what you will come across. Sheep exhibit similar clinical signs.

- **Treatment:** When the abscess becomes soft and seems ready to burst, it can be lanced with a razor or scalpel blade and flushed out with an antiseptic or disinfectant. Lance an abscess in an area away from the primary herd and discard all materials in a sealed bag. Give a shot of a broad spectrum antibiotic to prevent secondary infections.

- **Prevention:** Once established in your herd, this condition is hard to get rid of. Culturing the blood of an animal can expose the presence of the bacteria in the herd and that animal can be culled if you desire. A vaccine is available, but it does not prevent a new infection, it only reduces the incidence and it causes side effects in goats, so it is not advisable for use.

Foot rot (hoof rot): A contagious disease of the hoof caused by two bacteria (*Dichelobacter nodosus and Fusobacterium necrophorum*) that exists in the soil. If the animal has had any injury to the hoof or has overgrown hooves, it is susceptible to contracting foot rot. A normal hoof is not red or swollen or crusty. Once established in your pen, it can be spread quickly throughout the herd. Although the animal will not usually die from foot rot, you will lose productivity of that animal, time for treatment, and materials used to treat it, so it is best to avoid foot rot. Quarantine new animals until you are sure they do not have foot rot.

- **Clinical signs:** Lameness, foul odor, redness, warm feeling and swelling on the skin between the cleft of the toes and around the coronary band, foul odor in chronic cases. Also, you may see animals spending a lot of time on their knees. The hoof may separate from the bone with extreme inflammation and involve the sole of the foot.

  - **Treatment:** After trimming the feet, there are several different formulas that can be used for a footbath below: (also see Table I for different treatment regimes).

    - o 10% zinc sulfate (8 pounds zinc: 10 gallons water), or
    - o copper sulfate (8:10) and formalin (1 gallon formaldehyde:19 gallons water) at least twice weekly (but daily is preferable) for 30-60 minutes (**Copper sulfate toxic to sheep), or
    - o copper sulfate (10%) in vinegar - 1/4 (0.25) pound in one quart vinegar, or
    - o copper sulfate in pine tar - 2 parts $CuS0_4$ in one part pine tar, or
    - o oxytetracycline solution in alcohol - one 25.69-gram package to 1/2 cup water, then add alcohol to bring solution to 2 quarts, or
    - o penicillin in alcohol - 5 million units of potassium penicillin G with 10 milliliters of water, then add to 1 quart alcohol.
    - o Apply a topical medication (Zinc sulfate (10%) - 1/4 (0.25) pound in one quart of water.

  A vaccine is available to control the condition, when all other conditions are met (trimming). Check infected animals every 3-5 days.

- **Prevention:** Never buy animals from a farm with a history of foot rot, avoid buying animals from a livestock market, quarantine new or infected animals; disinfect tools and areas that have been exposed to the disease. Run new animals through a footbath, and always disinfect transport vehicles. Vaccines for *Bacteroides nodosus* are approved for use in the U.S. They may range in effectiveness from 0-100%; most users report a 60-80% success.

Johne's (pronounced Yo-nees) disease (Wasting disease, Paratuberculosis): While rarely recognized in goats (as compared to sheep), this can have devastating effects on a herd (Ensminger, 2002). It is a silent killer, caused by a bacterium (*Mycobacterium paratuberculosis*) that is spread in feed, but there is some evidence that animals can be born with the disease or pick it up from the mother's milk. The bacterium causes the lining of the intestine to become thick, thus decreasing the animal's ability to absorb nutrients and the animal starves to death. These animals are also more susceptible to chronic parasite infection.

- **Clinical signs:** Usually in animals 3-5 years old, progressive weight loss where clinical signs do not appear until the final stages, rough hair coat, decreased milk production, anorexia, and depression. Diarrhea can develops in the last stages of life in goats but not in sheep. There are no specific signs in sheep though there is considerable variation in its course. In some animals, it progresses fast with death occurring a few months after wasting first appears, while in others, death may not occur for a long period of time (see Figure 2). Stress speeds up the progression.

- **Treatment:** None.

- **Prevention:** Test all new animals (fecal culture 40-60% effective, blood test good when animals are symptomatic), cull exposed animals, avoid fecal to oral transmission ("All manure is suspect"). Tests include culturing fecal material for the organism (takes 6 weeks to 4 months to complete and can give false negatives). Fecal tests can also tell how the organism is being shed from that animal. Blood tests are quicker but can give false positives. For every animal that tests positive, there are probably 10 or more who are infected, also shedding, but do not show any clinical signs. Lambs born to ewes diagnosed with the disease should be culled as they are probably also infected (via feces or in utero). There is a vaccine (cattle vaccine can be used in sheep), and although it does not prevent infection it can reduce the number of bacteria excreted (recognize that some vaccinated animals can shed bacteria in the feces). There is no vaccine approved for goats in the United States. In Europe and Australia a vaccine developed for sheep (Gudair®) is used in small ruminants which has been found to decrease the number of deaths in animals that develop clinical Johne's disease and reduces the amount of shedding. It does not appear to change the rate that goats get infected.

Leptospirosis: Leptospirosis is caused by a bacterium that damages the liver, kidneys and other organs of animals and humans. It is spread through the urine of infected animals. Rats, mice and other wildlife can spread the bacteria. Humans contract the bacteria from infected urine, or through contact with water, soil or food that has been contaminated.

- **Clinical signs:** Fever, anorexia, jaundice, diarrhea, abortions, stillbirth, or weak newborns.
- **Treatment:** Antibiotics and supportive care.
- **Prevention:** A vaccine is available for cattle, pigs and dogs. Isolate and treat infected animals. Fence off contaminated environments and keep wildlife from coming into contact with domestic livestock.

Listeriosis (Circling disease): Though this condition is more prevalent in cooler climates, it may occasionally crop up in our temperate area. The route of transmission of the bacteria (Listeria monocytogenes) will affect how the clinical signs appear. Main route of contamination is usually consuming silage contaminated with soil. The bacterium is hardy and can survive in soil, silage, manure, milk, urine, and drainage from the eyes and nose, so it can be inhaled, swallowed, or transmitted via the eyes. This disease is also transmitted to humans and can be deadly; has severe consequences to pregnant women (encephalitis of the newborn, or abortion). Biosecurity is vital when dealing with infected animals.

- **Clinical signs:** Rapid course with death within 24-48 hours after onset of signs. Abortion (at any stage of pregnancy), uterine infection, circling, fever, anorexia, red conjunctiva, blindness, paralysis on one side of the face, drooping ear or eyelid, convulsions (in encephalitic form), and depression.
- **Treatment:** Treatment of animals that came into contact with the affected animals may prevent further infections but the main tool is to avoid feeding of contaminated feed.
- **Prevention:** Isolate sick animals, dispose of spoiled silage.

Malignant edema (Gas gangrene): While not commonly seen, this is also a Clostridial disease, and must be differentiated from other diseases like abscesses, bruising, and other conditions caused by clostridium. It starts when a wound is infected, and the toxin produced by the bacteria (e.g., *Clostridium perfringens* type A, C, *C. septicum type* C) kills the tissue surrounding the wound. Death can occur rapidly. Human wounds can be infected with the organism.

- **Clinical signs:** Swollen or infected wound, with fever, depression, and anorexia. The infection will spread rapidly and death generally occurs within 1-2 days after initial signs. In sheep, a condition commonly known as big head occurs in rams 6 months to 2 years of age with swelling under the eyes and the whole head in addition to the wound swelling.

- **Treatment:** Aggressive antibiotic therapy early on with removal of dead and dying tissue can halt progression.

- **Prevention:** In endemic areas, vaccination may help (must be done before castration; two doses 2-3 weeks apart and then annually). Revaccination is also suggested after an injury.

Mastitis: An inflammation of the mammary gland that can appear in different ways and is caused by the invasion of several kinds of bacteria (*Staphylococcus, Streptococcus*, etc.). Whatever the invasive organism, the causes vary from unclean milking equipment to rough treatment of the udders by man or other animals. This will injure the udder and make it more susceptible to the bacteria.

- **Clinical signs:** The udder is hot, painful, and swollen. There may or may not be a color change in the milk, or the milk may contain flecks of blood, or be thick or watery. The infected udder's color can range from slightly more pink to bright red. A black, cold udder is indicative of a gangrenous mastitis, which can lead to loss of the udder (after tissue dies) and the death of the animal. With a subclinical mastitis, there may not be any clinical signs, but milk production can drop at least 25%.
- **Treatment:** Intramammary infusion of antibiotics is the first step to a cure. Always wash the teat with soap and water and wipe with alcohol before inserting anything into the udder. In serious cases, injectable antibiotics should be given. Remove any kids, but milk the udder out 3 times daily. Bathing the udder in warm water helps to reduce swelling and pain. For the most effective treatment use a drug that will attack the specific organism. The chart in Table II will give you an idea of the type of mastitis you are dealing with, but the only sure way to know is to culture some of the milk for bacterial growth.
- **Prevention:** Proper maintenance of equipment is essential (if used) as the organism can be spread from animal to animal. Goats with mastitis should be the last ones to be on a milking machine, after which it should be washed out and disinfected. If a goat has had a mastitis problem, use a dry doe treatment 2 months before she is ready to kid. Ensure that you have removed any physical hazards from your facility. The California Mastitis Test, a kit that contains all the reagents needed to test for the disease, is a good way to screen your herd and root out problems early. The only downside to this test is that the milk from healthy goats will sometimes show a reaction. It is best to cull repeaters of this disease.

Navel ill (Omphalophlebitis, Joint ill, Polyarthritis): A bacterial infection of the joints that is due to an infected navel cord. It can also be seen with an infection after castration or dehorning.

- **Clinical signs:** High fever, failure to nurse, swollen, hard and tender navel. If treatment is not given, the bacterium enters the bloodstream and localizes in the joints. The joints will be hot and painful, mild fever, failure to stand, and seizures can occur.
- **Treatment:** For animals recognized early (2 weeks or less) a broad spectrum antibiotic can be effective. If the clinical signs have been going on for one or two months, treatment may be useless.
- **Prevention:** Clean surroundings before kidding, clean hands if assisting during delivery, and dip navel cord in iodine.

Overeating Disease (Enterotoxemia, Pulpy kidney disease): This is an "auto-intoxication" of the gastrointestinal tract of goats caused by a Clostridial organism (types C and D). Type C affects adults, while type D affects younger animals. Type D is common in animals on a high grain diet or lush pasture. The overeating of feed, milk, or grass may slow down or stop the normal motility of the gut and leads to an overgrowth of the normal bacteria in the gut. These bacteria produce deadly toxins that get into the blood (Thedford, 1983).

- **Clinical signs:** Sudden death of the best-conditioned young animal should always lead you to think of *Clostridium* type D. Those that survive the first 24 hours will have a fever, be anorexic, depressed, and colicky, have a hemorrhagic diarrhea, have convulsions, and soon die. Some of those animals may have shown clinical signs of excitement, "star gazing," tooth grinding, incoordination, and convulsions. If autopsied, the gastrointestinal tract will be full of feed and the kidneys mushy. Diarrhea may or may not develop. With type C, there may also be sudden death with no clinical signs. Others will have a smelly, watery, blood-tinged diarrhea and death within a few days. Animals may also have abdominal pain, tremors and convulsions. Less severe cases recover after several days.

- **Treatment:** Intravenous injection of the antitoxin as early as possible, antibiotics and supportive care.
- **Prevention:** Two doses of the vaccine, avoid overfeeding young animals, sudden diet changes, and allowing undernourished animals to gobble down their food.

Pinkeye: This is seen as an inflammation of the eye, and can be caused by a variety of bacterial (*Mycoplasma conjunctiva* in goats and sheep) (*Chlamydia psittaci* in sheep) and viral agents. It is generally seen as a problem during the warmer, drier months, and can be readily spread with the wind, by insects or through the high grasses. It spreads quickly throughout the herd and can lead to blindness if not treated. Recovered animals can become asymptomatic carriers.

- **Clinical signs:** Watery eyes, redness of the membranes around the eyes, excessive blinking, white cloud over the cornea, or corneal ulceration. Corneal opacity (the white cloud) can lead to loss of vision. *Chlamydia psittaci* can also cause abortion and polyarthritis in sheep.
- **Treatment:** Antibiotic drops, shield animal from sunlight and isolate from the rest of the herd.
- **Prevention:** Isolate affected animals, keep insects down to a minimum (if possible), cut excessively tall grasses, and keep dust down in holding pens.

Pneumonia: Pneumonia is a general term referring to inflammation of the lung and airways. It is usually accompanied by increases in the rate and depth of respiration. There are many different causes (infectious or noninfectious), including bacteria, viruses, parasites, allergens, or fluid aspirated into the lungs after drenching. *Mannheimia haemolytica* (*Pasteurella* haemolytica) is one of the organisms that can be a direct cause in sheep. The condition can show up acutely (short term) with a quick death, or be chronic (long term). Other conditions in sheep, Ovine progressive pneumonia (OPP) and maedi-visna are caused by a virus. There is also a very serious respiratory disease in goats that is a reportable foreign animal disease (see below).

- **Clinical signs:** Fever, runny nose, dry or wet coughs, rapid or labored breathing, anorexia, breathing through the mouth, grunting when breathing. Stress and poor ventilation in the goat house can make the clinical signs worse. In many cases signs are not noticed and the animal is found dead. OPP is seen mostly in sheep over 4 years old. Signs are respiratory distress and chronic wasting.
- **Treatment:** Symptomatic care, antibiotics, proper ventilation, fresh food and water. There is a vaccine.

Q-Fever: Although Q-Fever is more of a problem in sheep, the bacteria (*Coxiella burnetii*) can infect goats. Its importance is in its ability to transfer from goats to humans. Cattle, cats, pigs, and dogs may be non-symptomatic carriers. Wild birds, rodents, and rabbits may also be carriers. Ticks may harbor the bacteria and then infect wild animals. In sheep and goats the predominant sign of an infection is abortion (in the last week of pregnancy), and birth of stillborn and weak, live offspring. Humans contract the bacteria by coming into contact with birthing fluids of infected animals, from the air, or by drinking contaminated milk. Stress can exacerbate the condition and should be avoided (www.sheepandgoat.com).

- **Treatment:** Antibiotics for 2-4 weeks. In known infected herds, segregating pregnant animals indoors, burning or burying reproductive offal, or administering tetracycline prophylactically in the water before parturition may reduce spread of the organism.
- **Prevention:** Minimize contact with infected animals and practice biosecurity: 1) proper sanitation – good hygiene, especially when working with animals giving birth; 2) segregated kidding/lambing areas; 3) removal; 4) manure management; 5) control of ticks on livestock; and 6) restricting the movement of animals that have just given birth off the farm.

Scours (Diarrhea, Colibacillosis, Salmonellosis, White scours, Black scours): More than likely due to a bacterial (*E. coli*), or viral infection, seen in very young animals (<2 weeks of age) where environmental conditions are not ideal, they missed their colostrum, were overfed, had a vitamin A deficiency, or were heavily parasitized. It can lead to death within the first 30 days of life, and mortality can be as high as 50%. Black scours (Bloody scours) is caused by *Salmonella,* and can be shed by carrier animals without clinical signs. With this type of scours, you must be careful when handling the animal because it can be transmitted to humans.

- **Clinical signs:** Watery diarrhea, rapid dehydration, depression, weight loss, anorexia, the skin is cold and clammy. With Salmonellosis, there will be blood-streaked or black tar-like diarrhea, and is most common in young kids. They will have a high fever and may pass a stringy-like material. Several types of the *Salmonella* group have been associated with death and abortion in sheep. Deaths in neonates may also occur with a few signs in lambs over 1 week old.
- **Treatment:** Treatment should be tackled on three fronts: 1) replace fluids, 2) correct the electrolyte imbalance, and 3) kill the organism. Replace milk with a fluid formulated to replenish the animal's electrolytes (at a level of 10% of body weight for daily usage plus the amount lost due to dehydration), and give an oral antibiotic. Clean and disinfect the environment to kill the organism. Treatment for a Salmonella infection will follow the same course.
    - Example of a fluid replacement solution: give the percentage of fluid lost plus 10% of the body weight per day. For example, if a 10 lb. kid has 10% dehydration, it needs at least 500 ml. of fluid just to replace the amount lost. To give 10% of its weight in fluids each day, it needs 1 liter per day. A quick solution to make is 10 grams of salt and 10 grams of baking soda in 2.5 liters of water.
- **Prevention:** Good sanitary practices, isolation of sick animals, colostrum, a good vaccination program.

Sore mouth (Orf, Contagious ecthyma, Contagious pustular dermatitis (CPD): A viral disease that affects the lips, gums, and udders of young animals (less than one year). Older animals can be affected but lesions are mostly seen on the udder. This condition is contagious to man, gloves should be worn when working with infected animals. There have been cases in dogs that have eaten the carcass of infected animals. It is common in the late summer, fall, and winter.

- **Clinical signs:** The lesions begin as small bumps (papules) that progress into blisters, and pustules, before they burst and scab. They are usually seen on the gums and lips but may also be seen on the hairless areas on the udders or on the feet (between the toes). Udder lesions are painful and if the doe will not allow the kid to nurse it may lead to mastitis. Kids may show lesions on the rear legs. A venereal form has been seen after rams are turned out with lesions on the skin-vaginal mucosa junction and the preputial orifice. The disease is self-limiting, i.e., it lasts 1-4 weeks. When the scabs have fallen off and healed, the animal will be fine and have developed immunity.
- **Treatment:** Softening ointment on the lesions may help but treatment is usually ineffective. Antibiotics can be effective in treating secondary infections.

- **Prevention:** A live virus vaccine is available but should be used cautiously because of the possibility of vaccine "breaks" and the possible contamination of uninfected areas. Isolate vaccinated animals from the herd until inoculation scabs have fallen off.

Tetanus: Poisons produced by another Clostridial bacterium also cause lockjaw; it affects the nervous system and can lead to death. The bacteria enters living tissue from a wound that closes up quickly and seals in the infection.

- **Clinical signs:** Appear 7-14 days after infection, stiffness, soreness, hardness of muscles. Twenty-four to 48 hours later, the animal is totally stiff. If it can stand, it assumes a "sawhorse" stance, the neck and head are extended, and the tail is erect. If disturbed, the animal will go into violent convulsions, nostrils will flare, eyes open wide, and the third eyelid (from the middle of the eye) will protrude across the eye. Eventually, the animal will not be able to stand and will die (with 4-7 days).

- **Treatment:** Usually unsuccessful. Administer large doses of penicillin (injected into the muscle), and sedatives.

- **Prevention:** Two doses of tetanus toxoid (30 days apart), and a yearly booster. If the animal is wounded, give a booster. Tetanus antitoxin can also be given if wounded (1,500 IU – 30 day protection).

Warts (Papillomatosis): In sheep and goats, the wart virus affects different areas of the skin. It is a self-limiting disease, i.e., clinical signs eventually subside with no ill effects for the animal. Warts are spread by direct contact from animal to animal. They can also be spread when contaminated equipment such as shearing, ear tagging, or tattooing instruments are not cleaned properly between animals.

- **Clinical signs:** Warts can be found on the head, neck, teats, ears, and penis. The lesions are white to grey, firm and raised. These lesions are harmless in almost all situations, except where mastitis or pain is involved and are most common in animals under 2 years of age.
- **Treatments:** Many of the warts found in sheep and goats are often left alone. Treatments have had a varying degree of success; this is also true of vaccines (as the virus that causes the lesions is species specific). If the lesion is offensive it can be removed surgically, but this should be done after it has stopped growing or it may come back. This can take many months.
- **Prevention:** When an animal has a wart infection, it should be isolated from other animals. Any infected animal should also be kept from rubbing on feeders and posts that may be used by other animals. Good biosecurity as with all diseases must be carried out. That includes cleaning, shearing, tagging, and tattooing equipment with a broad spectrum antiseptic/disinfectant like chlorhexidine.

A. **REPORTABLE INFECTIOUS DISEASES**

Reportable diseases are those designated dangerous and transmissible that can seriously impact animals and sometimes people. Outbreaks of these diseases can in many cases have major economic and public health consequences so surveillance programs have been established so that any incidence of the disease can be eradicated quickly. Some of the diseases do not exist in the U.S. but with the increase in animal imports and international travel everyone must be diligent in keeping foreign animal diseases out of the country. All citizens are responsible for reporting cases of a suspected disease to a State or Federal Health Official. While these diseases are seldom (or never) seen in a normal, healthy herd, a producer should be familiar with the clinical signs indicative of an outbreak.

Anthrax: Caused by a bacterium (*Bacillus anthracis*), this old but deadly disease can destroy a herd and can be transmitted to man. The spores of the anthrax bacilla are very difficult to kill and can survive in the soil for years. They are spread from animal to animal, through contaminated feed, grazing on contaminated land, drinking contaminated water, eating animal by-products, or poorly cooked meat. It can kill an animal in 2-6 hours or take up to 48 hours after clinical signs appear. In man, there is the skin form (malignant carbuncle or pustule), the pneumonic form (from inhaling spores), and the intestinal form (from eating infected meat). If you suspect anthrax, contact your veterinarian and state health officials.

- **Clinical signs:** High fever (107º), depression, dark red-purple lining of the mouth and eyes, bloody diarrhea, rapid breathing (shallow), and a rapid and weak heartbeat. The milk or urine is blood-tinged, the tongue, throat, flanks, and area around the anus and vulva are swollen. If the animal dies, you will see blood seeping from the body openings and a lack of stiffness to the carcass.

- **Treatment:** None.

- **Prevention:** If this is prevalent in your area, you may consider vaccination. Vaccination after an outbreak is the only way to stop the spread. Consult your veterinarian. Also consult your state health officials to determine the best way to dispose of carcasses, but **NEVER OPEN A CARCASS IF YOU SUSPECT ANTHRAX.**

Brucellosis (Bangs disease, contagious abortion): Most species of Brucella are primarily associated host-specific though infections can also occur in other species, particularly when they are kept in close contact. The species that causes this disease in sheep and goats is *Brucella melitensis*. Most breeds of goats are readily infected, but the susceptibility in sheep breeds varies greatly. *B. melitensis* infections have also been reported occasionally in cattle, camels and dogs, and rarely in horses and pigs. Transmission is through contaminated feed or aborted fetuses or uteri, and infections can spill over into wild ruminants. When seen in humans, Brucellosis has been traced back to drinking unprocessed goat milk or milk products.

- **Clinical signs:** The clinical signs can be silent (mastitis, lameness, slightly loose stool), or there can be an abortion in the final stages of pregnancy (4-6 weeks before kidding). Animals that abort may retain the placenta. Sheep and goats usually abort only once, but reinvasion of the uterus and shedding of organisms can occur during later pregnancies. Some infected animals carry the pregnancy to term, but shed the organism. Milk yield is drastically reduced in animals that abort, as well as in animals whose udder becomes infected after a normal birth. However, clinical signs of mastitis are rare. The male may have swollen joints or testicles (see Figure 3) which can result in infertility. Arthritis is seen occasionally in both sexes. Many non pregnant sheep and goats remain asymptomatic.

- **Treatment:** None.

- **Prevention**: Check new animals, a blood test can diagnose the condition. Vaccinations, though relatively new, have proven effective in goats; however, they have not been approved for use in the U.S.

Contagious Caprine Pleuropneumonia (CCPP): This is one of the most severe diseases of goats. This disease, which affects the respiratory tract, is extremely contagious and frequently fatal, with mortality rates reaching 100%. It causes major economic losses in Africa, Asia and the Middle East, where it is endemic. It is caused by a bacterium (*Mycoplasma capricolum*).

- **Clinical signs:** Death can occur acutely with no signs within 1-3 days. Animals may have a fever (106º-109ºF), be lethargic, anorexic, have a cough and labored breathing. When the animal is close to death, it will not be able to move and show the familiar signs of pneumonia. Pregnant animals may abort.

Most animals die within a week to 10 days. Some animals can be chronic carriers.

- **Treatment:** If given early, antibiotics can be effective but that animal may continue to be a carrier.
- **Prevention:** Quick response in an outbreak prevents further infection. Infected animals must be quarantined. A vaccine does exist.

Foot and Mouth disease (FMD): FMD occurs worldwide, and while not seen in the United States in over 70 years, this disease is of major risk to the livestock industry. You are required to report any suspicious condition that may be FMD to your local veterinarian and state animal health officials. It is caused by a virus that can be spread from animal to animal, in feed, on your shoes and clothes, or carried by the wind.

- **Clinical signs:** Goats are depressed, have a fever, and small blisters will break out on the mouth and tongue. When these blisters pop, they will leave small ulcers. Blisters will also appear between the toes and on the feet. Those turn pale and peel off, leaving erosions and sores. The animal will be lame; they will secrete excess saliva and stop eating. You should differentiate FMD from Goat Pox (not common in the United States), and sore mouth. Signs are generally mild in adult sheep with the first sign observed is lameness. The most common site for erosions is on the dental pad. In the early signs, milk production decreases.
- **Treatment:** None.
- **Prevention:** All exposed animals should be immediately destroyed and strict biosecurity precautions taken. There is one vaccine approved for use in the U.S. but it requires approval from state or federal authorities.

Peste des Pestis Ruminants (PPR, Pseudorinderpest of Small Ruminants): This is a foreign animal disease (mostly West Africa) caused by a virus that is transmitted by direct contact with sick animals.

- **Clinical signs:** Sudden rise in temperature with restlessness. The muzzle is dry but has a clear discharge and reddening around the eyes. Diarrhea, dehydration, and anorexia sometimes are seen. Pneumonia develops; most animals die within 10 days.
- **Treatment:** None.
- **Prevention:** A vaccine is available for cattle, but is not used in the United States. This disease is reportable in the United States.

Pseudorabies (Aujeszky's disease, mad itch): Pseudorabies is a highly contagious disease of pigs. Other species may be infected when they come in contact with infected pigs (especially feral pigs), resulting in a fatal CNS disease. Clinical signs in pigs may vary depending on the age of animal affected. Piglets usually have a fever, stop eating, and show neurological signs (seizures, paralysis), dying within 24-36 hours. Older pigs may show similar symptoms, but may often have respiratory signs (coughing, sneezing, difficulty breathing) and vomiting, are less likely to die and generally recover in 5-10 days. Pregnant sows can abort or give birth to weak, trembling piglets. Feral pigs can be asymptomatic carriers of the virus and transmit it to other animal species.

- **Clinical signs:** In cattle and sheep, the disease is almost always fatal within a few days. The first symptom is intense itching concentrated in a patch of skin; this is usually manifested as severe licking, rubbing or gnawing. Self–mutilation is common. Affected animals become progressively weaker. Convulsions, bellowing, teeth grinding, cardiac irregularities and rapid, shallow breathing are common.

- **Treatment:** None.
- **Prevention:** Control feral pig access to livestock.

Rabies (Hydrophobia): It is important to list this condition, because it can be transmitted to your goats from domestic animals or wildlife. It is caused by a virus and can affect all warm-blooded mammals and man. It can be contracted through a bite or by saliva from an infected animal by entering an open wound.

- **Clinical signs:** Confusion, depression, loss of milk production, loss of appetite, chewing on foreign objects, inability to swallow, drooling, excessive bleating, and dilated pupils.
- **Treatment:** None
- **Prevention:** While there are no vaccines available specifically for goats, there are some vaccines for other animals that have been shown to be effective. Consult your veterinarian.

Scrapie: A chronic, fatal disease of the nervous system that is more common in sheep than goats. A unique organism called a prion causes Scrapie. It can take up to two years (after infection) for clinical signs to appear. While similar disease conditions exist in humans and other animals (see Table III), no link has been shown between eating meat from Scrapie-affected animals and similar diseases in humans. With that said, it is still recommended that the meat from positive animals not be used for human consumption. Clinical signs of Scrapie may mimic other nervous conditions (fine tremors, head pressing, and stargazing).

- **Clinical signs:** The early clinical signs are of a nervous animal with muscle tremors and a wobbly gait. Animals will bite at their legs, smack their lips, wobble or stumble, shake and jump at normal sounds, press its head on things for a long time, stare up at the sky, cannot get up, and eat but stay thin, constantly itch, pull out their wool, bunny hop, step high with their front feet, sway in back, rub on things a lot. Goats differ from sheep in that the classic sign of intense itching is not as prevalent. It takes a long time for clinical signs to appear (up to five years), and 1-6 months for them to progress to the point where the animals eventually lay down and die.
- **Treatment:** None.
- **Prevention:** Many farmers will have their herds tested so that they can be assured that they are Scrapie free. The disease may occur in "families," so siblings and parents of an infected animal should be tested.

Sheep and Goat Pox: This is an acute and chronic foreign animal disease, endemic in Africa, the Middle East, India and Asia, that is characterized by pox lesions throughout the skin and mucus membranes. Signs also include a persistent fever, enlarged lymph nodes, (sometimes) and pneumonia. A virus causes it and cattle can be carriers (but show no signs) (www.vet.uga.edu, 2004).

- **Clinical signs:** Clinical cases vary from severe to subclinical. Initially, there may be fever, depression, and inflammation of the conjunctiva, tearing, and inflammation of the nasal cavity. After a few days, pox lesions appear (they feel like a nodule), mostly on the hair-free parts of the body. These lesions start out as small, reddened papules, with the center becoming depressed and gray (necrosis). Within a month of the appearance of the first signs, the lesions dry up and a scab forms. Secondary infections, like pneumonia, may occur. With this disease, there can be up to an 80% occurrence in the herd, with 50% mortality.
- **Treatment:** None.
- **Prevention:** In endemic areas, vaccination is the only effective means of prevention. Control is through

confirmation and quarantine, and culling of affected animals, followed by disinfection of the premises.

Tuberculosis: Though not talked about much anymore, Tuberculosis, a chronic respiratory disease, does exist in animals and can occur in goats, though it is rare in sheep. *Mycobacterium bovis* (the cattle species) is the species that causes progressive disease in most warm-blooded vertebrates, including people. M. *caprae*, an organism closely related to the cattle species has been isolated from people, goats, cattle, and several other species in Europe. Transmission is through inhalation of infected droplets expelled from the lungs (from manure, urine, bedding), although ingestion, particularly via contaminated milk or water, also occurs. Transmission to humans can occur from the drinking of raw milk or other dairy products (made from unpasteurized milk) by inhaling bacteria shed by infected animals, or from contamination of unprotected cuts on the skin while handling infected animals.

- **Clinical signs:** Signs are not specific; there can be a loss of appetite, reduced milk yield, or respiratory signs (such as a chronic cough). Lesions, similar to those seen in cattle, can be seen in the lungs and lymph nodes of sheep and goats and these may be the only indications of a herd infection.
- **Treatment:** None
- **Prevention:** The intradermal skin test is commonly used for diagnosis. The responses should be observed at 48 and 72 hours for hardening and swelling. Test and slaughter and good biosecurity measures in the event of an infection are the best methods to control the disease.

West Nile Virus: West Nile virus (WNV) is an infectious disease that first appeared in the United States in 1999. Infected mosquitoes spread the virus that causes it. Birds contract the virus initially; mosquitoes become infected when they feed on infected birds. When the mosquito bites an animal or human they can then transmit the West Nile virus. If you have had dead birds in your area and your goats are exhibiting clinical signs related to encephalitis check with your local veterinarian just to differentiate it from other diseases (e.g., Polioencephalomalacia, Listeriosis, and Rabies).

- **Clinical signs:** Affected goats, sheep, alpacas, reindeer and white-tailed deer may show neurological signs.
- **Treatment:** Supported care.
- **Prevention:** A vaccine is available for horses and alligators. Mosquito control is important on the farm.

NOTE: While general treatments have been pointed out in this paper, animals with any of the conditions listed above should be under the care of a veterinarian as a lot of the treatment regimes need drugs that are not approved for use in small ruminants and would have to be used off-label.

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Table 1. Effectiveness of different treatments for foot rot

Study One		
	Treatment	%Cure
Group 1	Soak	38.9%
Group 2	Soak and feed antibiotic	36.3%
Group 3	Vaccinate	36.5%
Group 4	Vaccinate and soak	62.5%
Study Two		
	Treatment	% Cure
Group 1	Soak and pare	85.5%
Group 2	Footbath and pare	66.5%
Group 3	Vaccinate and pare	94.0%
Group 4	Vaccinate, pare, and clean	100.0%
As presented by W. Dee Whittier, Virginia Cooperative Extension, 2009		

Table II: Mastitis causes and treatment.

Organism	Clinical signs	Drug of Choice
Hemolytic *Staphylococcus aureus*	Gangrenous mastitis and blood-tinged fluid.	Penicillin, Ampicillin
Non-hemolytic *Staph. aureus*	Usually non clinical. Hard lumps in udder.	Penicillin, Ampicillin, cloxicillin
Streptococcus agalactiae	Swelling, tenderness, normal-looking milk or small white flecks, watery.	Penicillin, Ampicillin, tetracycline
Corynebacterium pyogenes	Large lump in groin area above udder, swollen, thick, foul-smelling milk, abscesses may develop in udder, decreased milk that is watery.	Penicillin, tetracycline
Klebsiella species (Coliform mastitis)	Udder is extremely hot, red and swollen, clear to yellow-brown fluid from udder. Fever is also a sign, and milk secretion may stop in one gland only. Animal will also be depressed, stop eating, have diarrhea, and lose weight.	Several antibiotics (penicillin-streptomycin combination, Oxytetracycline, Ampicillin) are effective but may be useless because of toxins produced from the dead bacteria and the damage done to the udder may kill the goat. Prolonged nursing care required. If the animal survives, the udder tissue returns to normal.

Table III: Scrapie like diseases in other species

Scrapie	Sheep, goat
Chronic wasting disease (CWD)	Deer (white tailed, mule), Elk
Bovine spongiform encephalopathy (BSE)	Cattle, bison, kudu, oryx, eland
Transmissible mink encephalopathy (TME)	Farmed mink
Feline spongiform encephalopathy (FSE)	Domestic cat, puma, cheetah, lion, panther, ocelot
Kuru	Man
Creutzfeldt-Jakob disease (CJD)	Man

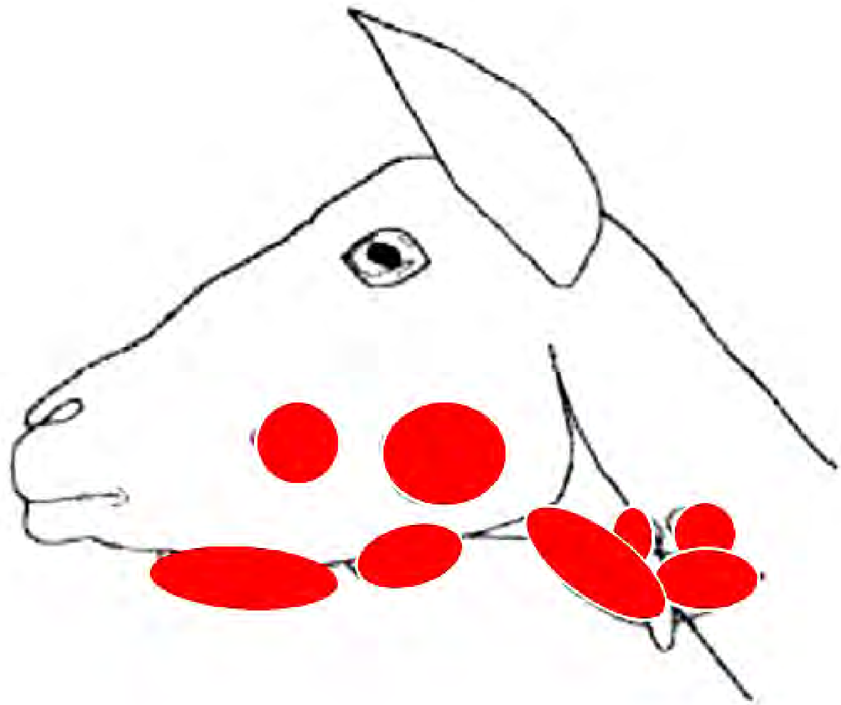


Figure 1: Frequent sites of Caseouus lymphadentis abscesses.

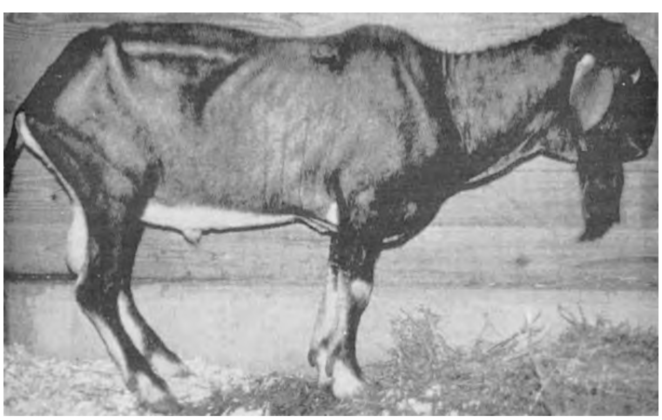
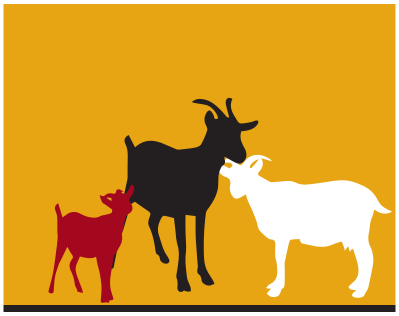


Figure 2: An emaciated goat diagnosed with John's disease.

Figure 3: Sheep testicle swollen from



SECTION FIVE

NUTRITION, FORAGE AND GRAZING SYSTEMS

Grazing System and Management for Goat Production

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Abstract

The objective of grazing system management is to supply cheap, but adequate nutrition for the goat enterprise. This involves managing forages to facilitate dry matter production and managing grazing so that forage quality is adequate and harvest efficiency is high while avoiding the consumption of internal parasite larvae. Since nutrient costs are greatest for winter, the grazing system should be planned so as to provide some degree of grazing during winter, whether by stockpiling forage, using cool-season perennials or overseeding cool-season annual forages for grazing or a combination. Having high quality forages available during the cool-season can reduce the purchase of protein supplements. Excess spring forage production can be utilized by baling hay or using stocker animals. The forage system should be managed to provide the greatest proportion of nutrients possible during kidding and lactation since this is the time of greatest nutrient demand. The base forage species can be overseeded with cool-season or leguminous species to improve forage production, quality or the seasonal distribution of forage production. A well-managed rotational grazing system can improve forage harvest efficiency (reduce trampling), reduce consumption of internal parasite larvae and improve animal tameness. Animals are exposed to positive human contact each time pastures are rotated and animal health and well-being can be regularly monitored. Good pasture management requires gathering information, planning and compromising to attain forage production objectives and the flexibility to cope with changes in the weather.

Keywords: Grazing, Forages, Pasture, Nutrition

I. INTRODUCTION

The goal for grazing system management is to provide as much of the nutrients required by the animal from economical forage sources. This implies that nutrients from forages under some conditions may not be the cheapest, depending on the forage system. Well managed pastures can be one of the cheapest sources of nutrients. It is difficult for small goat producers (<10 head which accounts for 52% of goat producers; USDA, 2011) to utilize the advantages of improved grazing systems because of the limitations of capital and scale. There is little information available in the literature on goat pasture management in contrast to beef cattle. We often can extrapolate from cattle realizing that goats have different dietary preferences, generally do not like Bermuda-grass and eat little of most clovers except for berseem clover. Also, managing the pasture for avoidance of parasites is more important than managing pastures for maximal production. Generalized recommendations are given in this paper and local extension expertise should be consulted prior to application of principles outlined in this paper. This subject has been reviewed by Luginbuhl and Mosley (2015).

II. NUTRIENT REQUIREMENTS OF THE ANIMAL

We are most interested in supplying nutrients to the doe during the dry period, gestation and lactation as shown in Figure 1. Under some conditions, we are interested in supplying nutrients to stocker animals. Stocker animals would be expected to have an intake of 4.5% of bodyweight per day for animals under 50 lbs and 3.5% of their bodyweight for animals over 50 lbs. Forage quality is very important for stocker animal gains. For the former, the chief determinant of nutrient requirement for the doe during the year is the day of kidding since nutrient requirements increase exponentially 6 weeks before kidding and are elevated during lactation after kidding and reduced abruptly at weaning. Although many kids are weaned at 90-100 days, kids may remain with the doe for 150 days until they are sold. Meat goats produce little milk after 80 days and a doe with kids at this time has nutrient requirements only slightly elevated above a dry doe. Many factors affect choice of kidding date, such as weather, parasites, forage availability, tradition and market, but forage production is often not considered in the decision. Two-thirds of the total annual nutrient requirements of the doe occur from 6 weeks before kidding to 12 weeks after kidding due to the high nutrient requirements in late gestation and during lactation. Profitability can be increased by supplying more of these nutrients from grazed forage and less from stored or purchased feed.

III. FORAGE PRODUCTION FROM BASE FORAGE

A healthy forage stand requires sunlight, warmth, moisture and plant nutrients to produce forage. Warmth and under some conditions, sunlight may be limiting for growth. The producer can provide plant nutrients, but often moisture is limiting. There are several strategies for overcoming moisture (rain) limitations. Irrigation is the most obvious, but expensive and exacerbates parasite problems. Good fertility improves water use efficiency. Some forage species are more efficient at utilizing soil moisture and some forage species can extract more soil moisture than others. A pound of forage produced during the cool season is worth two pounds of warm season forage because forage is much scarcer during the cool season and hay, the alternative, is more expensive. The relative production across the year is shown for cool and warm season forages in Fig. 2. The base forage is the forage in your pasture presently. It is generally not economic to change your base forage since it usually costs in excess of $200. per acre to till and plant a new forage species due to the high cost of multiple tillage passes, high cost of seeds from improved varieties and high fertility costs necessary for seed establishment.

IV. BRUSH AS A BASE FORAGE

In some cases, brush and weeds may be the base forage for the goat enterprise. Goats will control many species of brush and weeds while returning a profit to the manager. Some major species of browse controlled are shown in table 1. Goats will control many broadleaf weedy species, but tend to do little for western ragweed (*Ambrosia psilostachya*), common mullein (*Verbascum thapsus*) and a few other weeds. It is difficult to predict what goats will eat because of soil and climate effects on brush and weed preferences. In addition, goats often prefer a plant only when it is at a certain growth stage. It may appear that goats are not controlling a weed and the weed will disappear when it reaches the proper growth stage for goat consumption. Goat grazing restores biodiversity and the consumption of small brush will reduce fine fuel load, reducing fire hazard. Goats are often set stocked for brush and weed control, but could be rotated with cattle in a co-species grazing type of system. It is good to have an alternate pasture so that when goats have consumed most of the available biomass, they can be moved to another area. Goats generally do not consume more than 50% of their diet as browse due to the toxins that have to be detoxified. There should be other herbaceous forage available for consumption. Most browse species drop their leaves before or at frost and the goats will need other forage. Sometimes there are other species that are green during the cool season such as honeysuckle and wild rye. A more extensive discussion of using goats for vegetation management is available (Hart and Kott, 2015).

V. FILLING FORAGE DEFICIT PERIODS

Forage production of cool and warm-season grasses is graphed in figure 2 and if figure 1 is superimposed on it with your kidding date, the periods of forage deficiency should be evident. Forage deficit periods require supplemental nutrition to maintain animal productivity. Moving the kidding date will affect your forage deficit periods. The goal of forage management should be to provide as much forage as possible from grazing during the deficient times of the year. Ideas to help provide forage during these deficit periods are outlined below. An excellent reference on forages for pasture is Southern Forages by Ball et al. (2002).

The base forage can be overseeded to add forage production during times of the year when the base forage production is low. Cool season annuals could be overseeded into a warm-season perennial pasture to add grazing during the cool season time of the year, adding protein which is often limiting in the cool season as well as forage production. This may provide forage for early kidding. Cool season annual species that are suitable include rye, ryegrass, wheat, oats, etc. Cool season forages can reduce spring growth of a warm season pasture substantially if not grazed off in the spring. Legumes may also be overseeded into warm season perennial pastures with other annuals. Berseem clover, annual lespedeza and sericea lespedeza seem to be preferred by the goat to other clovers. Berseem clover grows at a time between cool season forages senescing and warm season forages initiating production and therefore fills a valuable gap. The lespedezas do have anthelmintic properties (Min et al., 2004 and Min et al., 2005) and would be a valuable addition to goat pastures. In addition, they suppress coccidia. (Burke et al., 2013) and would be useful at weaning when kids are most susceptible to coccidian. Lespedezas provide forage during the late summer when forage production and quality often decline. Cool season forages have a period of limited forage production during the mid and late summer period. Overseeding summer annuals such as sudangrass, sorghum x sudangrass, lespedezas and cowpeas may be desirable.

A. Overseeding Cool-Season Grasses

Many cool season grasses can be overseeded into a base forage. The most common ones are rye, ryegrass, wheat, triticale and oats (may freeze in cold temperatures). A legume such as berseem clover (one clover that goats relish) may also be included. Local extension expertise can help in selection of forages, establishment methods and production. Rye and triticale are the most cold tolerant species of this group. Nothing will produce more forage than well-fertilized ryegrass in the late spring when the temperature is warm enough for its growth. The forage is high quality and tolerates close, continuous grazing and it often reseeds itself. It is especially useful for kidding ~~on~~ in the spring before warm season grasses emerge. Some forages such as ryegrass do better than most other forages when broadcast whereas drilling with a no-till drill is the most reliable method to get a satisfactory stand. The base forage should be near dormancy and closely clipped or grazed prior to seeding. Do not fertilize until the base forage goes into winter dormancy and you have an adequate stand to respond to fertilizer addition.

B. Overseeding Legumes

Choose legumes that goats will consume as well as providing forage. Goats tend to consume little clover except for Berseem clover although it may differ with different groups of goats. Birdsfoot trefoil may be consumed by goats. There are other cool season legumes than clover, but little is known about their usefulness for the goat. It is worthwhile to ask your goat friends what their goats consume before you plant something your goats don't like. Annual lespedeza can often be broadcast or drilled. Soybeans or cowpeas are excellent for providing late summer grazing during the dry time of the year. Sun hemp is another warm season legume that produces an abundance of forage. Soybeans, cowpeas and sun hemp produce better when grown on clean tillage alone instead of overseeded into a pasture. They grow tall enough that animals do not graze close to the ground and pick up infective parasite larvae.

C. Overseeding Woody Legumes

There is interest in utilizing woody legumes for goats since browse is beneficial to goats. Lucaena (*Leucaena leucocephala)* has been widely used in Australia, but for cattle. It is not frost tolerant. Potential species that could be used in the U.S. include mimosa (*Albizia julibrissin*), tagasaste (*Cytisus proliferus*; does not survive below 15^{o}F), bristly locust (*Robinia hispida*), shrub lespedeza (*Lespedeza bicolor* which is often used for deer food plots), false indigo bush clover (*Amorpha fructicosa*), Russian olive (*Elaegunus augustifolia*) and four-wing saltbush (*Atriplex canescens*). A little work has been done on several species in the US, including mimosa, shrub lespedeza, false indigo bush and honey locust (*Gleditsia triacanthos*). Luginbuhl and Mueller (2000) evaluated four trees fodder trees for goats. There were problems with persistence (and none were grazed) for some species and one species had poor DM production. Honey locust and black locust trees have been proposed as browse species, but due to the goat's high preference for the bark, persistence would likely be very poor. There is much research left yet to be done to identify suitable browse species to cultivate for goats.

D. Stockpiling Forage

Warm season forages may be stockpiled for grazing in the winter and cool season forages may also be stockpiled for grazing in the summer or winter when they are dormant. Stockpiling is intentional and requires specific management. Stockpiled forage is best utilized by strip grazing or much of the valuable forage can be lost due to trampling. To stockpile cool-season forages such as fescue, clip them in late summer to encourage new growth high in quality. Fertilize prior to Labor Day with 50-60 pounds of N. Fescue holds its quality well in winter as compared to other cool season species (brome, orchardgrass and timothy) and can be grazed during winter dormancy in December through February. Other cool season grasses can be stockpiled, but will weather more severely and should be utilized sooner than fescue. Weathering is increased by high rainfall and warm temperatures and stockpiled forages will deteriorate faster in those environments and therefore needs to be utilized quicker.

Native range can be effectively stockpiled by deferring grazing after July 1. It can be grazed after frost into early winter, but usually a protein supplement is required. Native range weathers less than most other warm season grasses. Bermuda grass can be stockpiled for cool season grazing. Pastures should be clipped to 2" height in August and 50 lbs of N per acre applied. Grazing should be deferred until after frost. Stockpiled Bermuda grass should be utilized early in the season because of its susceptibility to weathering.

E. Supplemental Pastures

Research has been done with supplemental pastures in the Southern Great Plains to provide forage when warm season pastures are dormant or low in quality. Sims (1994) planted 12% of the native range to cool season annuals (rye and wheat) which was double cropped with hybrid pearl millet. This enabled stocking rate to be increased by 40% and net returns per acre were almost doubled (Gillen and Sims, 1998). A similar pasture system has been investigated by Dalrymple (1999) in which cool season annuals are overseeded with crabgrass for high quality summer forage. The crabgrass can be managed to reseed, eliminating seed and planting costs in subsequent years. These pasturing systems can have applicability to goats. Cool season pasture use can be extended by limit grazing. Animals can acquire their supplemental protein needs in only two hours of grazing per day. This can be implemented as an alternate day grazing and removing animals when they get full and lie down 3-4 hours). Animals will become trained and come off the pasture when they get full, minimizing labor requirements.

F. Providing Hay or Preserved Forage

Hay may be utilized to provide forage for forage deficit periods, but the cost of forage is generally tripled as compared to grazing when the cost of cutting and baling, hauling, storage, feeding and harvest, storage and feeding losses (nearly 30%) are taken into consideration. Goats will generously waste hay depending on how it is fed. If feeding from a round bale on its side, 30-50% of the bale may be wasted. There is much less waste if the hay is fed in an elevated feeder that cradles the hay bale or if the round bale is rolled out on the ground. The latter is a good choice if cattle and goats are being fed together.

VI. GRAZING MANAGEMENT

Grazing management is how forage is utilized. Continuous grazing systems are the most common because they require little management. Forage distribution, production and utilization can be improved with improved grazing management. Harvest efficiency (% of grazeable forage that is consumed and not trampled) is only 40-50% under continuous grazing, increases to 50-60% with a 4 paddock rotational grazing system, 60-70% with a 6-8 paddock rotational grazing system and 70-80% with strip grazing where animals graze an area for only one day.

A. Continuous Grazing

Continuous grazing is the simplest where animals are confined to one area during the grazing system. Although simple, it increases gastrointestinal nematode (GIN) problems, reduces forage production and has the lowest harvest efficiency (percent of forage grown that is consumed). It has deleterious effects to forage in that species that are most preferred are most heavily defoliated, reducing their persistence. Also, forages closer to a water source, mineral source or barn are defoliated more extensively. Continuous grazing is the least preferred grazing system for goats since it promotes internal parasites which are a great problem in goats. However, continuous grazing is the system of choice for controlling brush and weeds since the goal is to overgraze brush and weeds to reduce their persistence and thereby control them.

B. Rotational Grazing

Rotational grazing is a system where pasture is divided into multiple paddocks and each paddock is grazed for a period of time while the other paddocks are rested. The advantages of this are greater forage production (20%) in that plants are able to recover from defoliation, greater harvest efficiency due to less trampling, more uniform grazing in that animals are "forced" to consume less desirable plants before they are moved to the next pasture, and greater forage species diversity is maintained. Rotational grazing generally increases harvest efficiency from the 50% observed with continuous grazing to 70% with rotation grazing due to reduced trampling losses. Harvest efficiency is improved as days on a given pasture are decreased. The disadvantages are the extra cost of fencing and water points and increased level of management required. Often forage quality is slightly reduced, seldom a significant factor. Also, if the rest period is long enough, infective larvae numbers are reduced. Pomroy et al. (2002) demonstrated that Angora goats grazing native range with 5 days grazing interval and 65 day rest interval greatly reduced fecal egg counts and pasture contamination. Most likely, a 45 day rest period would have been adequate, but in more temperate areas, a longer rest period may be required. With long rest periods, forage quality is reduced, especially with introduced forages and baling or grazing cattle or horses half way through the rest period may be useful. The forages could also be mowed to keep them in a vegetative state. Generally, pastures are grazed to a defined residue height, sufficient for regrowth and high enough (3-4" residue) to minimize animals consuming infective larvae. Moveable electric fencing can be used with goats, four strands equally spaced to .8 M height being adequate to confine goats. Providing water and mineral is another consideration. Shelter is another problem and moving the guard dog feeder can be another problem. During times of excessive forage growth, forage can be baled. However, many goat enterprises are so small that haying equipment could not be efficiently used in small paddocks. A minimum of 8 paddocks is necessary for rotational grazing and 12 would be preferable to allow for management flexibility. It is difficult to control GIN in grazing goats without a rotational grazing system.

C. Creep Grazing

Creep grazing is using a creep gate to allow kids to graze a pasture separate from their dams. Potential advantages include a high quality pasture may provide better gains and fewer parasite problems. Creep grazing kids on Mimosa enabled them to select a higher quality diet and have higher bodyweight gains. Does lost less weight, but similar results could be obtained by reducing stocking rate (Yiakoulaki et al., 2007). Creep forward grazing has been utilized in cattle where a creep gate is utilized to allow calves to graze the higher quality pasture ahead of their dams. Such has potential with goats to aid with parasite control as well as providing improved quality of forage for the kids. This could be beneficial for weaning in that kids are already used to grazing and functioning independently.

D. Co-Species Grazing

Co-species grazing is grazing goats with another species such as cattle, sheep or horses. Goats work very well with cattle in a co-species grazing system in that they will control most types of brush and weeds (sericea lespedeza, multiflora rose, kudzu and many others). Co-species grazing is a win-win practice since the producer not only makes money from his goats converting unwanted brush and weeds to meat to sell at a profit, but has the additional money saved by not having to spray or apply some other method of weed control. Goats can be run in front of cattle, with cattle or behind cattle. It is probably easier management-wise to run goats with cattle, but the electric fence needs to be modified to control the goats. See Hart and Potraz (2015) for further details on fencing options. Goats generally graze in their own group and cattle keep to themselves. There is no significant risk of disease crossing between cattle and goats. Waterers must be modified for goats to drink from and goats will often use cattle mineral feeders. Cattle are often rough on goat mineral feeders which could be placed in a creep area where the cattle are excluded. When grazing with sheep, the goats require copper levels that are toxic to sheep. One solution is to feed a sheep mineral to all animals and give goats 6 grams of Copasure capsules per year. Another solution is to mount the goat mineral feeder on a platform such as a wooden wire spool that goats have to jump on to access the mineral and this will usually exclude sheep from the goat mineral.

VII. MANAGING FOR BRUSHY SPECIES

Brush has many advantages for goats. Because animals are grazing away from the ground, they pick up very few infective parasite larvae, and some browse plants have antiparsitic qualities. The protein content of browse is high, but availability of protein may be affected by tannins in the browse. Energy levels are moderate and will not support a high level of goat production, but usually adequate for does with twins. Calcium is adequate, phosphorus deficient and trace minerals unknown, so it is best to keep a high phosphorus mineral available. It is possible with rotational grazing to utilize brush as a renewable resource as done in South Africa. Delay grazing in the spring until plants are fully leafed out, graze one week and rest a minimum of 8 weeks between grazings and allow the plants to recover fully before frost. In this way brush can be maintained indefinitely.

VIII. PASTURES FOR PARASITE CONTROL

When permanent pastures get heavily contaminated and there is a crisis, goats can be fed in confinement until pasture can be produced which has a low level of contamination and high nutrient quality and/or high level of antiparsitic tannins. Some pastures reduce parasites by avoidance ie. grazing high away from the ground so as not to pick up infective larvae, such as cowpeas and other forages suppress parasites by being toxic to larvae and worms in the animal, usually by tannins such as with the lespedezas. Kentucky State University Extension developed a system to prevent parasites in goats utilizing forage sorghums or hybrid sudangrasses that were planted in clean till (buried infective larvae) and animals grazed on plants grazed at such a height as to not get close to picking up infective larvae. Another crop that is good for this is sun hemp, a legume that produces a generous amount of high quality forage that grows at such a height that goats are not grazing near the ground. Annual lespedeza has tannins that reduce parasitism and can be overseeded into pastures and reseed itself. Sericia lespedeza is a perennial legume that is well documented to control parasites. Animal production may be impaired if animals are grazed on sericea lespedeza for an extended period of time (8 weeks or more).

IX. STOCKING RATE

A mature 100 lb goat will eat about 2500 lbs. of forage in a year. To arrive at a stocking rate, if you know the annual hay production of your forage, multiply it by .60 for harvest efficiency and divide it by the portion of year's nutrients you expect the goat to harvest from pasture (1500 lbs is a good estimate; 60% of nutrients from pasture) to arrive at an initial stocking rate. After the first year, the producer should be able to observe forage sufficiency and make the necessary stocking adjustments. If native range is the pasture, range production estimates are available in the Natural Resource Conservation Service web soil survey(http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) or Google web soil survey. First you define your area of interest (where your farm is and borders). Then select the Soil Data Explorer tab and then select Vegetative Productivity on the left side. Select Range Production normal year from drop down menu and then click view rating button lbs. per year. Scroll down below map to view predicted yield for each soil type. The yield data can be multiplied by .60 for native range or .50 for brush to obtain harvestable forage yield and then divide by 1500 lbs or what you have selected above to arrive at stocking rate. Stocking rate can be adjusted the next year based on current year observations. Also, it is best not to stock more animals than you can carry in a dry year. Another method find what the recommended cattle stocking rate and considering 5-6 goats /hd cattle, multiply by 5-6 to arrive at number of goats.

X. PLANT NUTRIENTS

Plant nutrients are critically important in forage production, especially for improved pasture species and annual plants. Soil pH is especially important for clover establishment and persistence as well as maintaining an earthworm population. A soil test is very important for determining the plant nutrients available to the forage and recommendations for application of plant nutrients. Generally, yield goals are required for soil tests to give fertility recommendations. The soil type in itself may be a limitation on yield as well as rainfall. Local extension expertise should be consulted for plant nutrient recommendations. Nitrogen may be provided by legumes if they are productive. Phosphorus is often limiting and in certain areas potassium is limiting. Generally fertilizer is applied when a pasture is seeded, overseeded, or interseeded such as with a no-till drill. When pastures are overseeded with cool season annuals, plant nutrients are applied, usually after the base forage goes dormant. For permanent pastures after the initial soil test, pastures are sampled every 3 years and fertilized as necessary. Many of the plant nutrients are recycled by grazing ruminants in their excreta, but often half the nitrogen is lost while phosphorus and potassium are more efficiently recycled.

XI. POISONOUS PLANTS

Some producers are concerned about toxic plants in their pasture, but every plant is poisonous at some stage in its lifecycle and animals manage to avoid toxicity. Goats graze many toxic species without encountering toxicity. This is due to goats consuming a diversity of species on any given day. The goats never consume a toxic dose of any one species, their greater size of liver as a % of bodyweight gives them extra capability to detoxify toxins. Also, some plant species may counteract the toxicity of other plant species. If goats have adequate quantity and array of forage species to choose from they will seldom get toxicity. Goats learn from their mothers what plants to eat and what plants to avoid. If goats are moved to an area with very different forage species, they may not have the knowledge to select against toxic plants. Also, in plants that are normally non-toxic that goats are used to eating, if there is occasional toxicity such as due to environmental factors, animals may not be able to identify the plant as being toxic and avoid it. Generally, toxicity is rare in goats.

XII. **SUMMARY**

Managing the forage system so as to provide as much of the nutrients required for animal production from pasture can greatly reduce production expenses, increasing enterprise profitability. The quantity and quality of nutrients should be calculated at monthly or weekly intervals and the quantity of nutrients provided by the existing forage base calculated. The periods that have a forage deficit, can be supplied by overseeding annual forages, establishing new species or stockpiling forage for deficit periods. Harvested forage should be utilized as little as possible since it usually costs several times what grazed forage does. This requires a forage management plan that should be written out with help from available expertise and technical resources.

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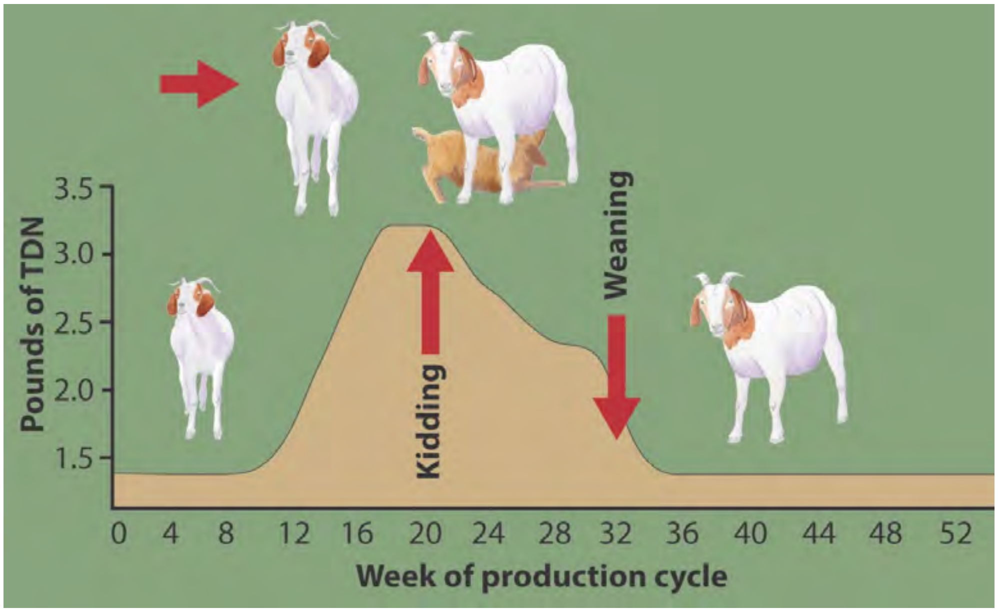

Figure 1: Nutrient requirements in relation to kidding from Langston Meat Goat Production Handbook.

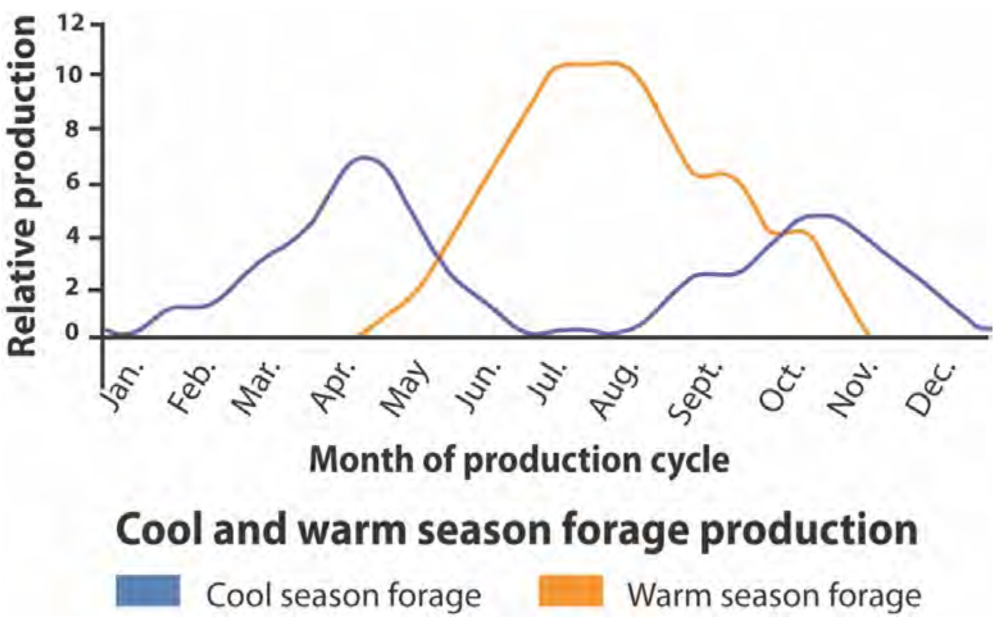

Figure 2: Seasonal production patterns of cool season and warm season grasses.

Table 1. Browse species consumed by goats

Common name	Scientific name	Common name	Scientific name
Blackberry	*Rubus oklahomus*	Multiflora rose	*Rosa multiflora*
Smooth Sumac	*Rhus glabra*	Dogwood	*Cornus drumumdii*
Winged sumac	*Rhus capallinum*	Privet	*Ligustrum spp.*
Poison ivy	*Toxicondendron radicans*	Mulberry	*Morus spp.*
Oak spp.	*Quercus spp.*	Sweet gum	*Liquidambar styraciflua*
Hawshorne	*Crataegus viridis*	Poplar	*Populus spp.*
Greenbriar	*Smilax bona-nox*	Eastern red cedar	*Juniperus virginiana*
Elm	*Ulmus Americana*	Russian olive	*Elaegnus augustifolia*
Winged elm	*Ulmus alata*	Honey suckle	*Lonicera japonica*
Honey locust	*Gleditisia tricanthos*		
Black locust	*Robinia pseudoacacia*		

Year-Round Forage Production for Sustainable Goat Farming

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Abstract

Goat farming in the U.S. is based on pastures and other grazing lands. Forages available for grazing throughout or most of the year are essential for supplying required nutrition for goats and minimizing production costs. However, most goat farmers do not have pastures that are productive for an extended period. This situation results in poor performance of animals and high costs of production due to the purchase of hay, grain, and/or commercial feeds. Forage availability can be improved by enhancing the productivity, quality, and production duration of pastures with the cultivation of warm- and cool-season grasses, legumes, and forbs in suitable combinations, including annuals and perennials. The cultivation of mixed forages will increase diet variety, improve forage quality and productivity, expand production duration, and efficiently utilize nutrients and water available in the system. The inclusion of browse species in grazing systems will also improve diet variety, minimize internal parasite problems, and better utilize the soil resources. Grazing opportunity can also be extended with the development of a woodland grazing system by adding grazing facilities, such as fences, watering systems, shelters, and feeders (for minerals and supplementary feeds) in existing woodlands. Farmers can also consider establishing a silvopasture system after the first and second thinning of forests or plantations by growing suitable forages and/or their combinations in spaces available between trees or tree rows. Such operations will diversify farmers' income opportunities (short-term from animals and forages, and long-term from tree products), and increase environmental quality and social acceptance of land resources.

Keywords: Browse, Grass, Legume, Silvopastures, Woodlands

I. INTRODUCTION

Goat production in the U.S. is based on pastures and other grazing lands. The availability of sufficient amount of quality vegetation (planted forages and browse, and spontaneous shrubs, vines, and trees) preferred by goats throughout or most of the year is the key to the success of grazing/browsing-based goat farming. Grazing is goats' consumption of vegetation that generally remain close to the ground surface and browsing is consumption of woody species, such as shrubs and tree branches, and vines that generally grow taller than the herbaceous vegetation. Grazing/browsing opportunity for goats can be increased substantially by improving the existing pastures or developing new pastures, cultivating desirable browse species, and developing silvopastures after the first and/or second thinning of woodlands or plantations. Silvopasture development is also possible in nut orchards and other tree production systems when all components of the system are managed well. Moreover, incorporation of existing woodlands into the grazing systems can be greatly helpful to supplement feed requirements for goats, increase variety in diet, minimize the infestation of gastrointestinal parasites, and enhance the growth of target trees in the system. Furthermore, spontaneous shrubs, vines, trees, and other vegetation present in underutilized lands can be included for grazing goats with the provision of necessary grazing facilities, such as fencing, shelters, water, minerals, and predator control measures. In this paper, all these different possibilities on improving grazing/browsing opportunities for goats and minimizing production costs are briefly discussed.

II. PASTURE IMPROVEMENT

Pasture is land area planted with forages for grazing. Pastures should contain facilities required for grazing animals, such as perimeter fencing to contain animals in the property and keep wild and other undesirable animals out, and cross fencing to divide the entire pasture into multiple sections (8 would be enough for most cases) for rotational grazing. Other facilities required for grazing goats are shelters to protect them from rain and other inclement weather conditions, mineral feeders, water troughs with clean drinking water made available 24/7, concentrate and hay feeders (if supplementation is needed), and guardian animals (such as guard dogs) to protect goats from predators. Farmers should consider developing pastures before installing all these grazing facilities. There are several steps to pasture development or improvement. Each of these steps is presented below:

A. Site Selection and Soil Test

An area that is well-drained and has productive soil should be selected for developing pastures for goats. Goats do not like swampy or wet areas, and such areas would also harbor parasites and pathogens (disease-causing microbes). Disease and parasite problems, such as footrot, coccidiosis, barber-pole worms, and liverflukes commonly occur if pastures are swampy and wet. After suitable sites have been identified, soil samples should be collected from the sites at least three months prior to the planting date and tested at a state or local soil-testing laboratory. Soil pH should be corrected based on laboratory results and recommendations. The pH is the measure of how acidic or alkaline the soil is. The pH ranges from 0 to 14, with 7 being neutral, below 7 acidic, and above 7 alkaline.

Different types of forages require specific pH ranges to perform well. This is because the nutrients present in soil are more available to plant roots only at certain pH ranges as shown in Figure 1. In this Figure, the band widths of different nutrients indicate their availability for plants, with broader band indicating higher availability and thinner bands indicating lower availability. When the pH is too low or too high, fertilizing pastures does not increase any forage production unless the pH is fixed. Therefore, it is very important to maintain the desirable soil pH to make the pasture productive. Farmers must take care of the soil pH first before planting or fertilizing.

To prepare a representative soil sample for a soil test, collect 15-20 subsamples (take samples from 0-4-inch in depth from perennial pastures and 0-6-inch in depth from annual pastures with a soil auger or shovel and knife) from a uniform area of 20 acres or less that has similar soil type, topography, and vegetation (avoid collecting samples from high animal traffic areas and manure piles). Put all these samples in a bucket, mix well, and remove stone, debris, or any other non-soil materials, then take a pint of well-mixed soil sample to send to the laboratory. If pasture size is more than 20 acres and/or the pasture is not uniform in terms of soil type, vegetation coverage, and topography, separate samples should be collected to represent each of those areas of the fields.

While collecting and preparing soil samples, one needs to be mindful of that from the pint of soil sample sent to the lab, only a portion will be used to determine the pH and nutrient content of the soil. This means, if the soil sample is not representative of the entire field, for which the sample is prepared, the results would not be accurate in terms of calculating the needed lime and fertilizers for that field. So, it would be worth the time and effort walking the whole pasture area, taking random samples from the target field, mixing the samples well and removing the non-soil materials from the sample, and labeling the sample box with owner's name and address, field name, and forages to be grown or being grown (lime and fertilizer recommendations differ for different forages).

B. Weed Control

Any plants present in the pastureland that are not desirable to goats must be controlled before planting selected forages. Although goats eat numerous plants that are considered weeds in cattle pastures, there are many plants goats do not consume much. Examples of such plants are mullein, copperweed, camphorweed, coffeeweed, small-flower morning glory, false nettle, horsenettle, cactus, broome snakeweed, yucca, and thistle. Depending on the type and severity of weeds, one can use various methods of weed control: mowing/bush-hogging, repeated tilling (if the land is not sloppy and there is not a much risk of erosion), applying herbicide, or combination of two or more of these. If there is sparse distribution of weeds in pastures, one can either spot spray with the selected herbicide or uproot it if it is in an organic production system. Whichever method is used, weeds must be controlled before they flower and produce viable seeds. One weed plant is capable of producing thousands of seeds. If we wait too long, most weed seeds would drop to the ground, germinate, and take over pastures quickly. Farmers should be mindful that there may be thousands of seeds in the pastures accumulated from previous years, and these seeds can germinate when they get favorable conditions. More information about controlling weeds can be found from the county Extension agents or the weed specialists located near your area. A publication available at this link can also be very useful to be familiar with and control common pasture weeds found in the Southeast: https://www.tuskegee.edu/Content/Uploads/Tuskegee/files/CAENS/TUCEP/Livestock%20program/WeedProceedings.pdf

C. Soil pHAMendment

Follow recommendations from the soil-testing laboratory to apply lime to correct acidic soil (if the soil pH is below 5.8), or any of these products: sphagnum peat, elemental sulfur, aluminum sulfate, iron sulfate, acidifying nitrogen, and organic mulches to correct alkaline soil (if the pH is above 7.0). Application of any of these products must be done 3-6 months before the forage-plantation date, as soil pH changes slowly after the application of amendments.

D. Fertilizer Application

Recommendation for applying major nutrients (phosphorus, potassium, and nitrogen) required for desirable forage growth would be included in the soil-test report sent to you by the soil-testing laboratory. Phosphorus and potassium fertilizers can be applied a week prior to planting or at the time of planting, as these fertilizers are more stable than nitrogen fertilizer. Since nitrogen escapes from the soil very quickly, it should be applied when the forage plants can utilize it the most, or when the forages actually need it – that is when forages are actively growing. Apply the first dose of nitrogen fertilizer once all forages are germinated well and the pasture field looks green. Subsequent doses can be applied after one or two rotational grazings if need be. If nitrogen fertilizers are added before forages are germinated well, weeds would grow fast and choke the growth of planted forages.

Application of nitrogen fertilizers may not be necessary if leguminous forages are planted alone, or mixed with grasses to one-third or more of the grass-legume mixture. This is because specific *Rhizobium* bacteria associated with leguminous forage roots fix atmospheric nitrogen (N) and make it available for plants, provided desirable soil conditions for N fixation exist. Such conditions include enough carbon and mineral nutrients (calcium, molybdenum, iron, sulphur, potassium, phosphorus, and copper); optimum pH (around neutral – 6.5-7.5), temperature (68-77^{o}F for temperate legumes), and soil moisture (25-75% of field capacity); and a high concentration of carbon dioxide but low oxygen level present in the soil.

E. Organic Matter for Building Pasture Soils

Other than applying commercial fertilizers, farmers must consider adding organic matter to their pastureland to improve productivity and long-term soil health. Organic matter is any animal or plant product, such as compost, crop residues, feed and forage byproducts or wastes, leaf litter, lawn clippings, wood chips, and many other similar products. Soil organic matter helps bind soil particles together into aggregates; maintains porous structure; holds air, nutrients, and water in the soil; and increases biodiversity and microbial activities. All these conditions promote the productive capacity of soil. Adding organic matter into the soil is a long-term process, and farmers should continue this effort throughout the farming life and beyond. One can realize the difference once such practice is continued for many years.

F. Land Preparation

A well-prepared seed bed may be necessary to establish perennial pastures with small seeds, such as bahiagrass, bermudagrass, sericea lespedeza, white clover, and chicory (Tables I & II). Such beds can be prepared with disking and cultipacking. Farmers lacking needed equipment for preparing seed beds may choose to do light harrowing without disking soil. Another option would be the use of a no-till drill that drills seeds into the soil without opening much of the ground and covers the drilled seeds right after drilling. No-till drill can be rented from local vendors (if they are in your local area) or may be available from the Natural Resources Conservation Service (NRCS) soil-district office near your location. One needs to be familiar with the proper use of this drill, such as on adjusting the rate of seeding and planting depth for the type of forage seeds being planted before renting and using it.

G. Forage Selection

Selection of forages suitable to the pasture soil and climatic condition as well as desirable to goats is one of the most important decisions farmers need to make well in advance of the planting date. It will be wise to include the combination of warm- and cool-season annual and perennial grasses, legumes, and forbs in goat pastures for extended production and providing variety in goats' diet. Annual forages grow during their growth season and die at the end of the season. So, these forages need to be planted every year if they are desired to grow. Annual ryegrass, crimson clover, crabgrass, hairy vetch, and browntop millet are the examples of annual forages (Tables I & II). Some of these forages, such as annual ryegrass, crimson clover, and crabgrass will reseed well if grazing is managed to let these forages produce viable seeds. In such cases, annual plantation would not be necessary. Perennial forages grow during their growing season, undergo dormancy when the growing season ends, and resume growth during their growing season for several years once established well and managed properly. Bahiagrass, bermudagrass, chicory, sericea lespedeza, and white clover are the examples of perennial forages (Tables I & II).

Forages that grow during the cool portion of the year (late fall-spring) are known as cool-season forages. Examples are white clover, arrowleaf clover, rye, ryegrass, and chicory (Tables I & II). Warm-season forages grow during the warmer portion of the year (late spring-early/mid fall). Examples are bahiagrass, bermudagrass, crabgrass, and sericea lespedeza (Tables I & II). Forages can be grasses, legumes, or forbs. Grasses have a fibrous root system, parallel leaf venation, and produce a single seed leaf (monocotyledons). Examples are rye, ryegrass, and bahiagrass. Legumes have a taproot system, reticulate leaf venation, and bear two seed leaves (dicotyledons). Forbs are broadleaf herbaceous plants that are neither legumes nor grasses, e.g. chicory.

Individuals planning to start goat farming without any pre-established pastures have to develop a forage production plan prior to planting any forages. Such plans may include number of paddocks to be developed, types of forages to be grown in each paddock, planting schedule, and grazing and harvesting (excess forage as hay) schedule. Farmers with existing pastures can overseed them with suitable companion forages to diversify the available vegetation and extend the grazing duration. Information presented in Tables I and II can be a guide for farmers, especially those located in the southeastern U.S., to select forages suitable for their pasturelands. Farmers from other regions may need to work with local county agents or livestock or forage specialists. One can devote a couple of paddocks (2-3) to establish cool-season perennial grasses/legumes, and the same number of other paddocks to establish perennial warm-season grasses/legumes at the beginning of pasture development. Once these perennial forages are established well, suitable annual grasses/legumes/forbs can be overseeded to provide forage production for an extended period.

Farmers need to consider including a paddock or two for growing tannin-containing forages, such as sericea lespedeza (AU Grazer type that is more suitable for grazing than other varieties) to minimize goats' gastrointestinal parasite problems. AU Grazer is a patented variety, and Sims Brothers, Inc. (Phone: 334-738-2619, Email: service@simsbrothers.com) located in Union Springs, Alabama is the sole producer and distributor for this seed. In the forage production and grazing plan, farmers should also account for potential woodland grazing, browse production plots, and any other areas with natural vegetation or crop residues that can be incorporated into the grazing system for goats.

H. Seed Procurement, Preparation, and Plantation

The recommended amount of seed should be planted during the suitable planting season appropriate for the selected forages (Tables I & II). Usually, cool-season forages are planted from September to November and warm-season forages from March (after the killing frost is over) to May. Some forages can be planted beyond these timeframes as presented in Tables I and II. If seed drills are used, seeds should be planted to the recommended depth (Tables I & II) to have good germination. Seeds planted too deep cannot germinate, and this can be the number one cause of stand failure. If seeds are broadcast in the prepared seed beds or harrowed field, consider using 20% more seeds than that recommended for drilling.

Legume (clovers, vetches, peas, beans, sericea lespedeza, alfalfa) seeds should be inoculated before planting to a new field to have N-fixing bacteria work for your crop. Check with the seed suppliers whether the legume seeds you have bought are pre-inoculated. If not, order the suitable inoculums while purchasing legume seeds, and inoculate (mix with seeds) immediately before planting. Follow the instructions on the inoculum packet for proper storage and inoculation. Detailed instruction on inoculation is found in "Forage Production and Grazing Browsing Management" YouTube video: https://www.youtube.com/watch?v=wq9wTE7-HkA. Seeds need a good soil contact and moisture for germination and growth. Lack of good seed-soil contact is the second major reason for stand failure. To take advantage of moisture, it will be wise to schedule planting around rain forecast or soon after rain (after the excess rain has drained through the system) to avoid damage to soil and standing forages.

I. After Planting

Allow enough time for the planted forages to establish well by keeping grazing animals off the planted fields. In case of limited soil moisture, irrigation of the newly established pastures will help better forage establishment and growth. Perennial forages require more time to establish compared to annual forages. When forages have developed a strong root system and shown good canopy density and height covering the pasture field well (Figure 2), then controlled grazing can begin to let animals harvest 50% of the leaf volume. Once 50% of the vegetation is eaten, move animals to the new paddock to maintain the pasture productivity and persistence. Weeds can be a problem in the new planting; they can be controlled with grazing or chemicals depending on the type and severity.

J. Subsequent Soil Test,AMendments, and Overseeding

Repeat soil tests annually for cultivated or annual pastures and hay fields, and once in 2-3 years for permanent pastures. Apply lime and fertilizers as recommended. Overseed the pasture the following season if required (if the land cover with desirable forages is between 40-75%).

K. Additional Resources

1. Sustainable year-round forage production and grazing/browsing management for goats in the Southern Region https://www.tuskegee.edu/Content/Uploads/Tuskegee/files/CAENS/TUCEP/Livestock%20program/Year-RoundPasture_Handbook(1).pdf.

2. Year-round pasture production and management https://www.tuskegee.edu/Content/Uploads/Tuskegee/files/CAENS/TUCEP/Livestock%20program/YearRoundPasture_ProductionManagement.pdf.

3. Cool-season forages for sustainable goat production: Research highlights https://www.tuskegee.edu/Content/Uploads/Tuskegee/files/CAENS/TUCEP/Livestock%20program/Winter_Forage.pdf.

4. Year-round pasture and grazing calendar https://www.tuskegee.edu/Content/Uploads/Tuskegee/files/CAENS/TUCEP/Livestock%20program/Year-round%20Pasture%20Calendar.pdf.

III. INCLUSION OF BROWSE SPECIES

Goats are good browsers. They consume significant quantities of shrubs, vines, and tree leaves and twigs when such vegetations are available in their grazing systems. Several studies have shown that goats spend a substantial amount of time browsing (32-90% depending on the season, wetness, plant community present in the grazing system, and time of the day) (Bhattrai et al., 2017; Papachristou, 1997; Sharma et al., 1998; Wallis de Vries and Schippers, 1994; Yayneshet et al., 2008). In several countries around the world, where goat raising has been a tradition for hundreds of years, browse species are widely used to feed goats either through the cut and carry system or through grazing. However, such practices are not common in the U.S. Most pastures developed for goats are like those for cattle or sheep, although goats have quite different vegetation preferences than other ruminants. When goats graze close to the ground surface, they often suffer from gastrointestinal parasite problems, especially during warm, humid, and wet pasture conditions. To minimize health problems and improve performance of goats, inclusion of a good amount of browse (50-60%) in the grazing system is necessary. Farmers may want to devote separate paddocks to cultivate browse species, such as bush indigo, wild plum, mulberry, mimosa, groundsel, blackgum, winged elm, beautyberry, and many other shrubs that are locally adapted and consumed well by goats. Such species will take a year or two to establish well and produce biomass for goats' browsing.

Most of the browse species will produce biomass during the warm portion of the year (May-September/October). Goats can be rotationally stocked in the browse plots to let them harvest fifty percent of the canopy and moved out to allow the regrowth of the vegetation and bring animals into the plots again when plants attain a full canopy. Browse plants may require six to eight weeks or more of rest to resume full canopy. Alternatively, limited stocking can be practiced by allowing goats into the browse plots for a couple of hours each day or every couple of days depending on the available vegetation. Moreover, if open pasture and browse plots are adjacent or located nearby, goats may be allowed to have access to both types of plots and let them choose where to eat from. Whichever method is used, it should be some kind of controlled grazing, where animals can be moved in and out of the browse plots as appropriate. A continuous grazing system should never be used in managing the system containing browse. Additionally, farmers must be watchful of animals' behavior while they are in the system containing browse plants, as animals may damage these plants by debarking and/or breaking branches and main stems. If such behavior occurs, animals' access to browse plants must be stopped immediately.

Coppicing (cutting browse plants to the ground level) or pollarding (cutting browse plants to a certain height) of browse to around two to three feet from the ground level may be necessary if they grow beyond the reach of goats. Such cuttings should be done once the browse species go to the dormant state, and this can be repeated every year or every couple of years depending on their growth and desired canopy cover. Goats must be taken out of the browse plots at least six weeks before killing frost to replenish plant carbohydrate for winter survival and spring regrowth, and goats should not be brought back until the full canopy develops to avoid debarking and other potential damage (breaking stems and branches, trampling, chewing the tip of the main stem and branches). Poudel et al. (2017) reported significant damage caused by goats and sheep on dormant browse plants. If farmers have woodlands or shrublands, it will be better to utilize such resources for stocking goats and minimize or avoid the need to develop browse plots.

IV. WOODLAND GRAZING

The inclusion of woodlands into the grazing system for goats offers multiple benefits. First, it would increase the grazing and browsing (eating from shrubs, vines, and tree branches that are above the ground level) (Figure 3) opportunity for animals starting in late spring. This is when the understory vegetation and trees develop a full canopy and should be ready for grazing/browsing. Browse species continue producing biomass until mid-fall before leaf falling and dormancy occur. The time from late spring to mid-fall is critical for goats in warm and humid areas, where challenges from internal parasite infestation, especially the barber pole worm, is very high. Goats having access to browse will avoid the chances of picking up parasite larvae that would occur if they had to graze close to the ground surface. Gastrointestinal parasite larvae usually remain within 2-3 inches from the ground level and may move up on the forage blade above that height when the forages are moist, such as during early morning with dews and during and after rain (Karki, 2018; Miller, 2004).

Second, since several shrubs and trees have a good amount of condensed tannin, a bioactive compound that is harmful to gastrointestinal parasites, woodland grazing can be helpful to minimize the parasite problems in goats other than from browsing as described in the above paragraph. A study conducted at Tuskegee University identified several browse species with good amounts of condensed tannin (CT), along with their nutrient profile and goats' preference for these species (Karki, 2017). Some of these species are wild plum (CT – 5.7%), winged elm (CT – 7.7%), and sweetgum (CT – 3.5%). All these species were eaten well by Kilo wethers used in the study. Other species that contain a good amount of condensed tannin are longleaf and loblolly pines (both needles and bark; CT – 5-9%), bush indigo (CT – 5%), and white lead tree (CT – 4%) (Karki et al., Unpublished).

Third, animals will have a mild and comfortable environment during the warm-season grazing period because of the tree shade present in the system. Animals would perform better when they are comfortable versus when they face challenging weather or extreme temperatures. Fourth, defoliation of the understory vegetation by goats would reduce the woodland understory that would otherwise impede animal and human movement into the system for management activities (by farmers) and utilization of the available vegetation (by animals). Moreover, such defoliation minimizes the competition of understory vegetation for nutrients, space, and moisture with target trees, thereby facilitating better growth and performance of target trees in the system. Furthermore, grazing/browsing would decrease the fuel load in the system and diminish the risk of woodland fire hazards. Use of goats to minimize the understory vegetation and forest fire is very important in high-risk areas, such as nearby neighborhoods or wildlife reserves.

To take advantage of all the potential benefits described above, farmers should plan on developing grazing facilities in the woodlands they own. The essential facilities for initiating woodland grazing include perimeter and cross fencing along with gates placed in strategic locations for moving animals from plot to plot (for rotational grazing), watering system, mineral feeders, and shelters. Other facilities, such as concentrate (grains, agricultural byproducts, or commercial feeds) and hay feeders (in case animals need to be supplemented during the woodland-grazing period) and guardian animal(s) may be required. Many farmers may be eligible for cost share from NRCS through the Environmental Quality Incentives Program (EQIP). Producers need to contact the local NRCS office to get detailed information.

V. SILVOPASTURE DEVELOPMENT

Additional grazing opportunities can be created by developing silvopasture systems. Silvopasture is one of the most popular agroforestry systems that involve the production of trees and agricultural crops on the same piece of land. A silvopasture system includes trees, forages, and grazing animals managed on the same land unit for economic, environmental, and social benefits. Greater economic benefits are possible from the silvopasture system compared to its individual components (forest or other tree production systems, pasture-based livestock production, or hay), as it offers short-term incomes from livestock and/or forages and long-term incomes from trees.

Because silvopasture systems are known for higher levels of carbon sequestration and better utilization of nutrients and water within the system, they are considered more environmentally sound compared to its components practiced alone (Sharrow and Ismail, 2004; Shrestha and Alavalapati, 2004). Tree shades present in the system provide milder climatic conditions for grazing animals, resulting in a longer grazing duration compared to pastures without trees (Karki and Goodman, 2010). Greater social benefits are obtained from the silvopasture system because of its appealing scenery (hedonic value) and sound environment compared to its individual components.

Silvopasture development is possible after the first or second thinning in timber plantations. Tree thinning is a usual management practice for managing timber plantations and producing good quality saw logs. After thinning, forages can be established in the available ground space between trees or tree rows. Similar steps as described earlier under "Pasture Development" can be followed to establish forages in the silvopasture system. However, while selecting forage species to be grown in this system, shade tolerant species are to be selected. Silvopasture can also be developed for a nut production system when trees are mature and beyond the risk of animal damage. When trees are young or susceptible to animal damage, forages can still be produced between tree rows and harvested for hay or silage, and used for animal feeding when there are limited forage available for grazing, such as during winter, rather than buying hay or other feeds from outside sources. Alternatively, trees can be protected with electric fencing, tubing, or similar other means and animals used for grazing the available forages in the system. Whichever method is used for protecting trees or harvesting forages, it should be economical to farmers.

If farmers are planning to develop new plantation with timber or other tree species (fruits, nuts, Christmas trees), they can consider establishing forages between tree rows from the very beginning and harvest those forages for hay or silage, which can either be used to feed animals at home or sold for extra incomes if farmers have more than they need.

Precautions: Although the incorporation of tree production systems, such as woodlands, silvopastures, and nut orchards can increase the grazing opportunity for goats, increase diet variety, help minimize gastrointestinal parasite infestation, diversify the income opportunities, minimize the understory brush and consequently fire hazards, and much more, farmers must be aware of the potential damage goats may inflict on the desirable trees present in the system. To avoid such damage, goats should be used in the tree production systems only after trees are grown with their terminal buds beyond the reach of goats and trunks are strong enough to resist goats' rubbing on them and bending them. Goats love to rub their head and body on objects handy to them including trees. They can also easily pull down or bend young trees that have young and weak trunks.

Goats may also debark some species of trees when they have continuous access to them or forages are in limited supply. Therefore, they should be watched closely while stocked in the tree production system and moved out immediately if any tree-damaging behavior is observed. Rotational stocking must be practiced when using goats in the tree production system. Studies conducted with Kiko wethers in the silvopasture system containing 10-12-year-old longleaf and loblolly pine trees in Tuskegee, Alabama found wethers debarking trees, especially longleaf pines during the cool-season grazing period (Karki et al., 2018). However, the debarking was minimal to nil during the warm-season grazing period and even during the cool-season grazing period when plot gates were kept open allowing them in and out of the pine-silvopasture plots at their will (Poudel et al., Unpublished). Another study conducted in woodlands with Kiko wethers during late spring, summer, and fall did not show any significant damage to the desirable trees present in the system. These studies show that various factors (season, available vegetation, and management) influence the tree-debarking behavior of goats.

Farmers can use different strategies, such as non-confinement (keeping the plot-gate open for allowing animals in and out of plots at their will) of animals in the small tree-production plots and the inclusion of other woody species in the grazing system with trees. Other strategies would be to avoid grazing when trees are dormant or more attractive to animals and to select type and breed of goats that are less damaging to trees to minimize possible tree damage while using goats in the tree production system.

VI. BENEFITS OF A YEAR-ROUND GRAZING SYSTEM

Year-round production of forages and browse, and consequently goat production based on a year-round grazing system can be possible by implementing several approaches, as described above (I-V) and presented in Figure 4. Multiple benefits are possible from year-round grazing systems. Incorporation and management of various plant species will increase the bio-diversity below and above ground. Biodiversity promotes sustainability of the whole system. With the year-round vegetation production in the system, ground surface will be kept covered most of the time, which will reduce the risk of soil erosion. With the presence of active root systems in productive grazing lands, the microbial community will remain active and promote soil health. Moreover, the porous structure of soil is maintained that facilitates root penetration into the soil, water infiltration through the system (less run off), and soil aeration. All these conditions are desirable for soil health and productivity.

Forages and other vegetation available for grazing throughout or during most of the year will minimize requirements for supplementary feeding, thereby making the system economically viable. Karki and Karki (2017) reported that with the development of cool-season pastures, two goat farmers in Alabama were able to save $1,431-

$1,537 in the production costs of 35-40 heads of goats during the cool-season grazing period. Moreover, when legume forages or browse are incorporated into the grazing system, forage quality increases that promotes animal performance and reduce health problems, as goats with good nutrition have a stronger immune system than when they are fed poorly. Such improvements will minimize goat-health costs.

Because legumes fix atmospheric nitrogen and make it available for plants, the inclusion of legumes into a grazing system minimizes or eliminates the use of commercial nitrogen fertilizer, thereby reducing forage production costs and protecting environmental quality (by reducing the chances of environmental pollution that would have occurred from the manufacturing and application of N fertilizers). The use of legumes in pastures also increases forage biomass yield and soil quality (Karki et al., 2009). These authors stated that incorporation of crimson clover into the bahiagrass pastures increased forage biomass by 40 percent, forage quality (crude protein, CP) by 27 percent, and water-stable soil aggregates significantly, as compared to the bahiagrass pastures maintained with the application of commercial nitrogen fertilizers. Water-stable aggregates are very important for soil health, as they maintain the porous structure in soil that promotes soil aeration, root growth, water infiltration, carbon storage, and microbial activity.

VII. PROVISION OF SUPPLEMENTARY FEED

Depending on weather conditions and location, vegetation available for grazing may be limiting, when plants become dormant or dead such as during winter months or non-productive periods, such as during a draught. For the forage-deficit period, farmers should make a provision for supplementary feeds, such as hay, grains, agricultural byproducts, or commercial feeds, or a combination of two or more of these. Farmers can also stockpile forages grown in the fall, and strip graze the stockpiled forages during forage-deficit periods. Tall fescue, bahiagrass, and bermudagrass can be stockpiled for eight weeks with close grazing or mowing at the beginning and applying sufficient nitrogen fertilizers if necessary for desirable forage biomass accumulation. Stockpiled forage can be grazed after frost when little or no green forage is available.

VIII. KEY POINTS

1. The provision of year-round availability of vegetation desirable to goats can be made by cultivating the suitable combinations of warm- and cool-season (both annuals and perennials) grasses, legumes, and forbs, along with incorporating browse plants into the grazing system.

2. Browse can add variety in diet, minimize gastrointestinal parasite problems, and improve goat health and performance. Browse can be added to grazing systems either through the development of woodland grazing plots or by planting browse in selected paddocks.

3. Development of silvopastures, when possible, in tree production systems, such as timber plantations and nut orchards, increases and extends grazing opportunities for goats.

4. Proper grazing management is necessary for maintaining persistent, productive grazing lands and protecting trees and browse plants present in goats' grazing systems.

5. Development and management of year-round production of desirable vegetation for goats can minimize production costs, improve the productivity and health of the whole-farm system, and promote environmental health.

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Tables and Figures

Table I. Selected grasses with suitable soil type, production region, planting time, seed rate, planting depth, and suitable companions.

Forage species	Soil type	Region	Planting time	Seed rate (lb/acre)	Planting depth (in.)	Suitable companion
Warm-season perennial grasses						
Bahiagrass	Sandy	Coastal plain	Spring	10-15	1/4-1/2	Clovers (arrowleaf, berseem, crimson, rose, subterranean) hairy vetch, small grains, annual ryegrass
Bermudagrass	Wide range, but sandy is the best	Warm climate with mild winter	Spring	5-10	0-1/4	
Dallisgrass	Loam and clay	Southern coastal plain	Spring	10-15	1/4-1/2	Clovers (red, white, berseem)
Johnsongrass	Clay	Most of the Southeast	Spring	20-30	1/2-1.0	Clovers (red, berseem)
Warm-season annual grasses						
Crabgrass	Wide range	Most of the Southeast	Spring	4-6	1/4-1/2	
Cool-season perennial grasses						
Tall fescue (MaxQ)	Clay and loam	Humid temperate areas (mid to upper Southeast)	Aug.-Oct.; Early spring in the northern part	20-25	1/4-1/2	Alfalfa, birdsfoot trefoil, clovers (red, white)
Orchard grass			Aug.-Sept.	15-20	1/4-1/2	
Cool-season annual grasses						
Annual ryegrass	Wide range	Most of the Southeast	Sept.-early Oct.	20-30	1/4-1/2	Annual legumes
Small grains (Oats, rye, triticale, wheat)	Wide range	All states	Late summer or fall	90-120	1-1.5	Annual legumes

Source: Karki (2015), Ball et al. (2007).

Table II. Selected legumes and forbs with suitable soil type, production region, planting time, seed rate, planting depth, and suitable companion forages.

Forage species	Soil type	Region	Planting time	Seed rate (lb/acre)	Planting depth (in.)	Suitable companion
Warm-season perennial legume						
Sericea lespedeza*	Clay and loam	Humid region (most of the Southeast)	Spring	20-30	1/4-1/2	Small grains, ryegrass
Cool-season perennial legumes						
White clover	Clay and loam	Humid temperate areas (most of the Southeast)	Early spring or late summer	2-3	1/4-1/2	
Alfalfa	Well-drained clay and loam	All states	Early spring or late summer	15-20	1/4-1/2	
Red clover[1]	Well-drained clay and loam	Humid region (all Southeast States)	Spring or late summer	8-12	1/4-1/2	
Cool-season annual legumes						
Arrowleaf clover	Well drained	Humid areas with mild winter	Sept.-early Nov.	10-15	1/4-1/2	
Crimson clover	Well drained	Humid areas with mild winter	Late summer to early fall	20-30	1/4-1/2	
Hairy vetch	Wide range; sandy is the best	Most of the Southeast	Sept.-Oct.	20-25	1-2	
Forbs						
Chicory	Wide range, but moderately to well-drained soil is the best	All states	Sept.-Oct., or Apr.-May (upper Southeast)	3-4	1/4-1/2	Bermudagras, tall fescue
Brassicas (Kale, rape, turnip)	Moderately to well-drained soils	All states	Spring or Summer	Rape, Kale: 3.5-4.5 Turnip: 1.5-2.5	1/4-1/2	

[1]Biennial or annual in the South

*May be considered as noxious weeds. Check with your state Natural Resources Conservation Service (NRCS) office about its status.

Source: Karki (2015), Ball et al. (2007).

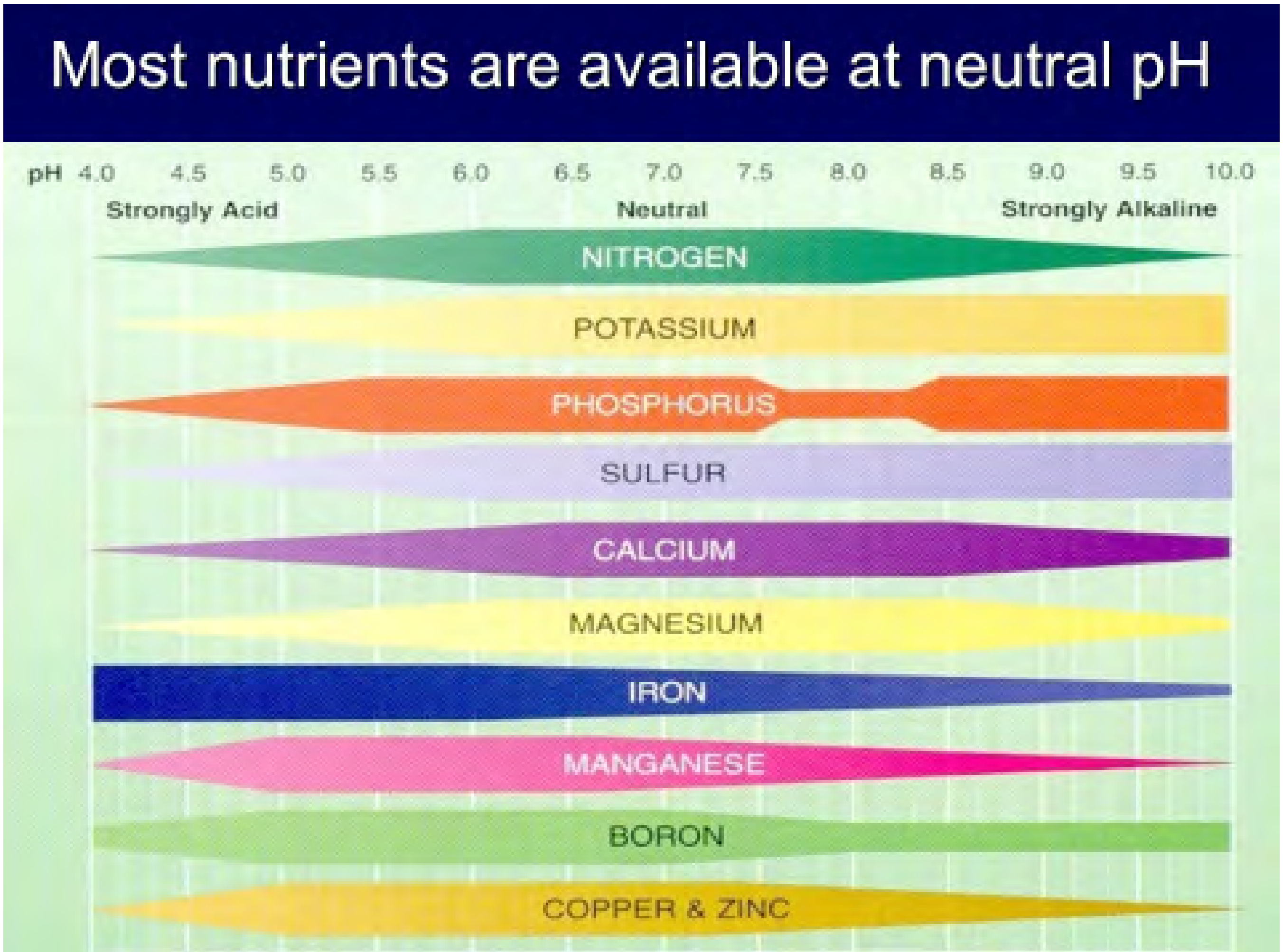

Figure 1. Availability of different nutrients to plants at different soil pH.

Source: Adapted from http://articles.extension.org/pages/13064/soil-ph-modification

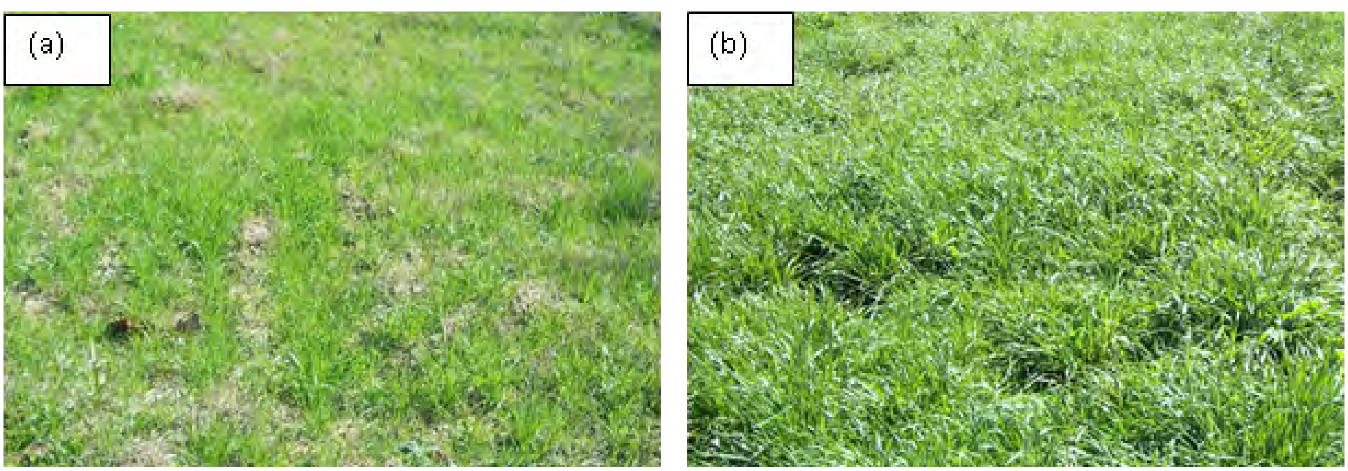

Figure 2. Marshall ryegrass pasture too early to begin grazing (a) and right time to begin grazing (b).

Source: Karki (2013)

Figure 3. Kiko wethers browsing in woodlands, Tuskegee, Alabama.

Photo credit: Uma Karki

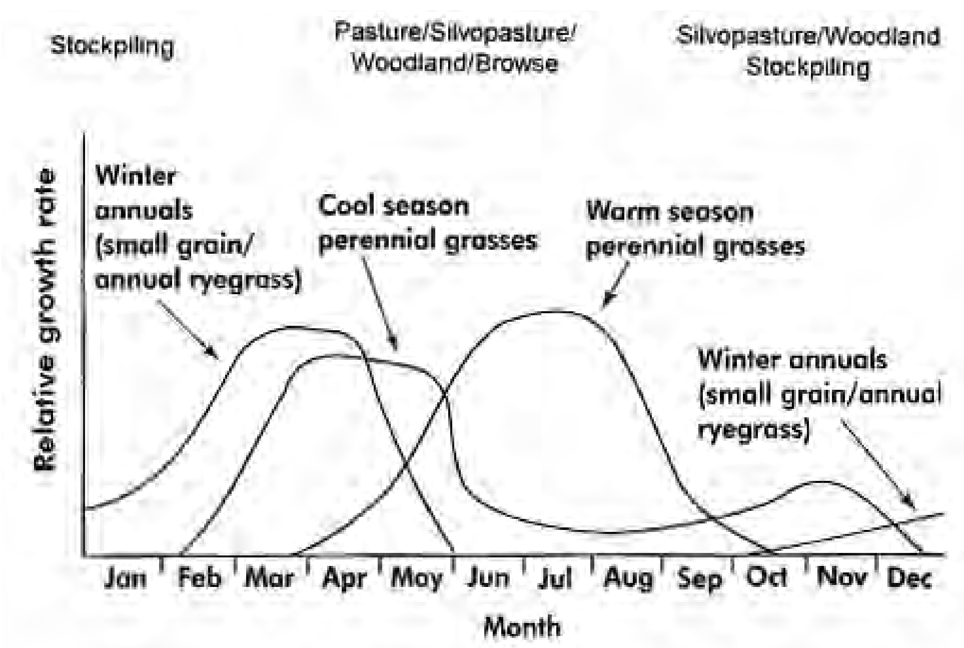

Figure 4. Relative growth rate of different forages throughout a year and potential lean periods, during which the forage need of animals can be supplemented with the provision of stockpiling, silvopastures, woodlands, and browse.

Source: Adapted from Ball et al. (2007) and modified by the author.

Nutritional Requirements of Different Classes of Meat Goats

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ABSTRACT

Feeds constitute the largest expense of meat goat production accounting for about 50% to 60% of the total variable costs. Consequently, any savings in feed costs without sacrificing animal productivity would benefit goat producers. Feeds provide nutrients to animals. The five nutrients needed by animals include water, carbohydrates, proteins, minerals and vitamins. Forages can form the basis of feeds for goats in the southeastern US because of warm and humid weather conditions where year-round forage production is possible. Grain feeding is less profitable in meat goats compared to other species. Since goats are classified as browsers, the forage program should consist of both browse and pasture. However, managing browse species as feed resources can be a challenge, and there is limited information available relative to managing browse species for goats. Goats can meet most of their nutritional needs from forages if forage availability is not limited. The only supplementation needed would be salts and minerals. However, during periods of inadequate forage availability (i.e., drought, and winter months) they do need to be provided with supplemental feeds. Most supplemental feeding programs are based on feeding hay, and grains or concentrates. The average Alabama hay contains 50% to 55% total digestible nutrients (TDN) and 10% to 11% crude protein (CP). When nutrient requirements of different classes of goats are matched with hay quality, hay will probably be adequate to meet needs for maintenance but becomes inadequate for late-pregnancy, lactation as well as for growing goats, especially with regard to energy content.

Keywords: Goats, Nutrition, Requirements, Forages

I. INTRODUCTION

Nutrition impacts on all aspects of animal productivity and health. Producers should provide nutrients to match the needs of animals. Animal nutrient requirements can be met from forages, crop residues, conserved and purchased feedstuffs (Court et al., 2010) but goat production should rely heavily on a good forage program. As indicated above, goats are classified as browsers, and consume browse species, forbs, and leaves. The forage program should consist of both browse and pasture. A good mix is about two acres of browse for every one acre of open grassland although there is no research evidence to support this practice. The biggest problem for maintaining this combination is that the browse will not grow back once the goats have browsed it for more than two growing seasons (Rankins, 2002). There is a need to study the optimum combination of browse and forages for meat goats. Nevertheless, the goal of feeds and nutrition are to provide the five nutrients required by animals namely, water, carbohydrate, proteins, minerals and vitamins.

Goats are natural browsers and given the opportunity, they select over 60% of their daily diets from browse (Table 1) and woody and broadleaf plants (Luginbuhl and Green, 2005; Peischel, 2014)). They are able to select the most nutritious part of the plants given the choice and can meet their nutritional needs. Beside nutritional benefits, other advantages of browsing include fewer internal parasite problems due to higher grazing heights and consumption of condensed tannin-containing browse species (Min et al., 2003; Min et al., 2004).

Table 1. Diet Preference Differences between Different Ruminant Species (percentage of diet).

Plant	Horse	Cattle	Sheep	Goat
Grass	90	70	60	20
Weeds	4	20	30	20
Browse	6	10	10	60

II. WATER

Water is the most important nutrient required by goats. Water comprises between 50 and 81 percent of body mass (Robbins, 1993; NRC, 2001), and plays important roles in virtually all physiological and biochemical processes (NRC, 2007). Goats can loose all their fat, up to 40% to 50% of their protein, but a water loss of only 10% can prove fatal (Rankins and Pugh, 2012). Animals receive water mainly from drinking water but water in feeds and metabolic water also contribute water. Water requirements are affected by the age of the animal, physiological stage, water quality, level of protein in the diet, salt intake, and dry matter intake. For example, pregnancy and lactation increase water requirements by 126% from months 1 to 5 of gestation (Rankins and Pugh, 2012). Water quality can affect water intake. Water quality depends on quantity of dissolved substances it contains. Calcium, sodium, chloride, and bicarbonates are common contaminants (Holland and Kezar, 1995). Higher levels of these salts can cause illness, and even death. Ideally, the pH of water should be between 7 and 8 and goats should have continuous access to fresh and clean water.

III. ENERGY

Carbohydrates provide most of the energy that goats require. It is a well-established fact that energy is the first limiting nutrient under most practical feeding conditions. Many factors affect the energy requirements of goats such as age, gender, season, genotype, body composition, parasitism, physiological stage, and activity (NRC, 2007). Corn is considered the gold standard as a source of energy and other energy sources are compared to corn. Corn contains 90% TDN but is low in protein (8% to 10%). Corn can be fed as a whole corn. However, corn as well as other grains should be gradually introduced to goats to avoid acidosis. In addition to corn, various commodity feeds are available as energy supplements for goats. Soyhulls are readily available in the southeast and are very palatable to goats (Gurung, 2015). The energy value of soyhulls is equivalent to corn when fed as an energy supplement at less than 25% of forage-based diets for cattle (Anderson et al., 1988). An additional benefit of soyhulls is that they contain more protein than corn (11 to 12% protein). They can be fed in the loose or pelleted form (Rankins, 2002). They interfere with fiber digestion less than corn does. Whole cottonseed contains abundant amounts of energy and is a very good source of protein (Solaiman, 2010). Cottonseed contains about 90% TDN and 24% crude protein. The limiting factor for its use in goat diets is the fat content, which is approximately 24%. In general, mature goats can be fed 0.23 to 0.34 kg (0.5 lbs to 0.75 lbs) per day while young growing goats should be limited to less than 0.23 of a kg (0.5 lbs) per day (Rankins, 2002). The seeds can be fed on pasture on a daily or every other day basis. However, there are handling problems associated with whole cottonseed. It is very fuzzy and has a low bulk density thereby limiting its handling options. Store cottonseed in a covered shed or feed bay and not in feed bins. The fuzzy seeds do not auger or gravity-flow very well but seeds can be easily handled with front-end loaders or by hand. Corn gluten feed is another popular byproduct with a medium palatability, which is produced while making cornstarch and corn syrup from corn. It contains various amounts of corn bran, corn germ, and corn steep liquor in a dried and pelleted form. The product is consistent from a particular processing plant but may be quite variable from one plant to another. The crude protein content will be in excess of 18% but may be as high as 23 to 24%. The TDN content ranges from 80 to 87% and the variation is primarily a result of the drying process. If it is heated too hot, it results in a lower feed value, palatability problems and usually a darker color (Gurung, 2015). It can be fed up to 1% of body weight for meat goats. Many commercial supplements are available as energy sources but their description is beyond the scope of this article.

IV. PROTEIN

Generally, a minimum of 7% dietary crude protein is needed for normal rumen bacterial growth and function for goats. If dietary protein drops below 7%, forage intake and digestibility are depressed. Protein deficiency is associated with decreased fiber digestion, reduced growth, decreased immune function, anemia, reduced feed utilization, edema, and death (Rankins and Pugh, 2012). The metabolizable protein reaching the small intestine consists of bacteria, protozoa, or dietary protein that escaped ruminal digestion. The quality (amino acid proportions) of the microbial protein is excellent. Milk replacers, should have protein from milk byproducts to provide an amino acid composition suitable for maximum growth. Soybean meal and cottonseed meal are excellent sources of natural protein for goats. Both contain between 40 and 45% crude protein. Soybean meal is slightly more palatable than cottonseed meal and cottonseed meal is better utilized (higher rumen undegradable protein levels) but goats readily consume both. In the southeastern US, cottonseed meal is generally cheaper than soybean meal (Gurung, 2015).

V. MINERALS

There are seven commonly assessed macrominerals for goats. They include calcium, phosphorus, sodium, chlorine, magnesium, potassium, and sulfur. The eight microminerals are copper, molybdenum, cobalt, iron, iodine, zinc, manganese, and selenium. The designations *macro* and *micro* do not reflect the minerals' relative importance but rather characterize the amount of each that is required as a proportion of the diet (Rankins and Pugh, 2012). Macromineral needs usually are expressed as percentage of the diet, whereas micromineral needs generally are expressed as ppm or mg/kg. The minimum and maximum mineral requirements for goat are given in Table 2. Forages are a major source of minerals for the goat except iodine (Hart, 2015). The major source of iodine in grazing ruminants is from soil splashed on the plant by rain (Healy et al., 1972 However, plant requirements for minerals, such as cobalt and selenium, may be much lower than the level required for animals so animals need to be supplemented with these minerals. Soils can be deficient in some minerals which may be reflected in the plants grown on such areas. However, some plants have an ability to concentrate the minerals available in the soil (Hart, 2015). Mineral contents of plants are affected by many factors such as soil pH, environmental temperature, and season of the year. As goats eat a variety of plants, they are less likely to have mineral deficiencies than other species of animals that eat predominantly one plant species. Copper is a unique trace mineral for goats because the requirements and tolerance for copper by goats are higher than for sheep. Solaiman et al. (2001) showed that copper (100 mg/day) supplemented into a basal diet containing 13.8 mg Cu/kg DM increased average daily gain, gain efficiency and enhanced immune response in goats compared to basal diet alone. However, copper absorption in ruminants is low (<1.0 -10%) compared to values reported for nonruminants (Underwood and Suttle, 1999). However, young ruminants have higher copper absorption (70-85%) before their rumen is fully developed but decreases to <10% after weaning.

The most important consideration in choosing a mineral supplement is the level of calcium and phosphorus. Some mineral mixes are designated 12 - 8, which means they contain 12% calcium and 8% phosphorus. The levels of these two minerals should be the same that is being fed to cattle in your area (contact your county agent or livestock extension specialist). Phosphorus is expensive, so a 12 - 12 mineral will cost more than one that is 12 - 8. However, most forages are low in phosphorus, making it the most common mineral deficiency. The mineral supplement should also contain trace minerals that are deficient in the area. Most mineral supplements are formulated to provide less than half the trace mineral requirements due to toxicity concerns and mineral interactions. A mineral supplement should be provided in the loose form to maximize consumption. The salt level in the mineral drives intake; therefore, no other sources of salt should be available. A mineral feeder should be used to protect from rain and keep the supplement clean. Replenish minerals frequently to keep them fresh (Rankins, 2002). The minimum and maximum mineral requirements for goats are given below in Table 2.

Table 2. General macro-and micromineral requirements for goats

Mineral	Minimum	Maximum
Macrominerals, % of diet		
Calcium (Ca)	0.30	0.80
Phosphorus (P)	0.25	0.40
Sodium (Na)	0.20	---
Potassium (K)	0.80	2.0
Chloride (Cl)	0.20	---
Sulfur (S)	0.20	0.32
Magnesium (Mg	0.18	0.40
Microminerals, ppm in diet		
Iron (Fe)	50	1,000
Copper (Cu)	10	80
Cobalt (Co)	0.10	10
Zinc (Zn)	40	500
Manganese (Mn)	40	1,000
Selenium (Se)	0.10	0.32
Molybdenum (Mo)	0.10	3
Iodine (I)	0.50	50

Source: Hart, 2015

VITAMINS

Vitamins are organic compounds required by goats in minute amounts but are critical in many of body's metabolic processes. They act as co-factors in many biochemical reactions. There are two types of vitamins: fa-soluble and water-soluble. among fat-soluble vitamins, properly functioning rumen can synthesize vitamin K. Water soluble vitamins can be synthesized by properly functioning rumen so do not require to be supplemented to goats. Because the rumen normally synthesizes B vitamins and vitamin K in healthy goats, the only vitamins needed in the diets of nonstressed animals are the fat-soluble vitamins: A, D, and E (Table 3). If an animal has altered rumen function, is parasitized, is on a low-fiber diet, or is being given long-term antibiotic therapy, supplemental B vitamins, especially thiamine may be of value.

Table 3. General vitamin requirements of goats

Vitamin	Rates of feeding
A	11, 000 IU/ kg of feed
D	4,400 IU/ kg of feed
E	176 IU/ kg of feed
K	Properly functioning rumen can synthesize adequate levels

Source: NRC, 2007

FEEDING HAY TO GOATS

Hay is the most common feedstuff fed to goats. If hay is being fed to the goat herd, it is important to determine the quality of the hay being fed and then determine whether energy, protein, both or neither is required to supplement the hay. For mature goats that are not in late-pregnancy or nursing kids, hay will probably be adequate to meet nutritional needs unless it is very poor quality. However, if the goats are in late-pregnancy or in lactation, supplemental energy will likely be required and for lactation, both energy and protein will likely be needed. Many grains, byproducts including many commercial feed supplements are available to complement hay to meet the nutrient gaps. However, it is very difficult to determine the energy content of these feeds because labeling laws do not require that TDN content be part of the label. Most feed manufacturers will give an estimate of TDN if contacted. Crude protein content, fat and fiber must be listed in the feed tags. When selecting feeds for goats, it is generally better to utilize feeds that contain natural protein versus non-protein nitrogen or urea because goats are very susceptible to urea toxicity. It is important to discuss the particular feed in question with the company representative and get some estimate of energy (TDN) that the feed contains. An extremely effective way to supplement goats in the southeast is to allow them to limit graze pastures containing cool-season, annual forages that are extremely high in energy and protein content. Ideally, ryegrass, rye, wheat, oats or some combination of these forages should be planted on a prepared seedbed in September and then used after January as a high-quality supplement to hay. When used as a supplement, about two hours of grazing time per day works quite well which has been proven effective with beef cattle. The advantage of this type of system as opposed to putting out dry feed as a supplement is that the dominant goats do not control the submissive goats like they would when eating from a feed trough. However, disadvantage is that the growth of the forage is weather dependent.

VI. FEEDING GUIDELINES FOR DIFFERENT CLASSES OF GOATS

FEEDING YOUNG KIDS

Newborn kids must receive colostrum as early as possible. It's rich source of proteins, milk solids, globulins, fats and vitamin A. Kids have no immunity antibodies when they are born and receive passive immunity from their mothers through colostrum consumption. A newborn need to receive 10% to 20% of its body weight in colostrum, preferably within 3 to 12 hours after birth. If it is not available from the dam, frozen colostrum supplies can be thawed and used. Colostrum absorption decreases rapidly from birth through 36 hours of age (Solaiman, 2010). Cross-species colostrum often is better than no colostrum. Rearing orphaned kids on milk replacer is quite expensive and labor-intensive. If possible, orphans should be grafted onto another doe and only rearing them on milk replacer only if this cannot be accomplished (Rankins and Pugh, 2012). Milk replacers should be fed according to manufacturers' directions. The most economical way to raise orphans is to get them onto a starter feed as soon as possible. Commercial starters are better than home mixes as has been shown in NY studies. Pellets have higher intake. Also, few people can get the feed ingredients to make their own. Calf starter will work better. Offering 114 grams (0.25 lbs)/day of a mixture of corn, oats, alfalfa pellets, molasses, and soybean meal that provides 14% to 16% crude protein works well (Rankins and Pugh, 2012). Top-dressing the feed with a dry milk replacer also may stimulate early intake of the dry feed. Other ingredients known to be extremely palatable to young ruminants are soybean hulls and various sources of bran, including wheat bran.

It is very important to get young goats off to a good nutritional start is to begin with creep feeding. Creep feeding is defined as allowing the young kid's access to a high quality feed that the nannies cannot access. This is usually accomplished by placing the feed behind a gate with openings that the kids can fit through and the nannies cannot. A creep feed should contain at least 16% crude protein and should be extremely palatable. Commercial calf creep will work well and is widely available. Young goats will typically start consuming appreciable quantities of a creep feed at about 6 weeks of age. Creep feeds need not be complex, but they must be palatable because they are competing with milk. Pelleting or coarse grinding feeds usually increases intake. Fine grinding usually results in decreased intake as animals (particularly lambs) age. Pellets should be small enough for consumption. In goats, pellet size larger than 5 to 7 mm may decrease intake. Until the animals reach 3 to 4 weeks of age, however, palatability is the key to successful creep feeding. Low-fiber creep feeds containing 16% to 20% protein usually work best. Enhanced performance may be attained if salt (0.5% of the creep feed), ammonium chloride (0.2 kg/440 kg of feed, or 10 lb/ton), and vitamin E are added to creep feeds (Rankins, 2002). Generally, when feed costs are low and kid prices are high, creep feeding usually is profitable. It is less profitable when feed costs are high and sale prices are low. In the final analysis, the feasibility of creep feeding is determined simply as a matter of feed costs versus animal sale prices.

FEEDING YEARLINGS

Most females need to gain between 0.11 and 0.23 kg (0.25 and 0.5 lb) per day from weaning until breeding depending on their weaning weights. Yearlings considered as replacements should be kept on the best available pasture. In most instances, however, this management approach will require some supplemental energy or concentrate feeding. Concentrate feeding should be fed up to 1% of body weight depending on breed, species, size, and so on) of a 12% to 14% crude protein should be offered in settings of poor-quality forage. Overfeeding young females, can result in excessive fat deposition in the mammary glands and decreased lifetime milk production. If females are to be bred as yearlings, a moderate growth rate is most desirable. The female should obtain 65% of her projected mature weight by the time of breeding. In reality, a range of weights probably exists within which small-framed goats may have acceptable conception rates at 55% to 60% of their projected mature weights, whereas some large-framed animals may need to be closer to 70% of their mature weights. So long as a good, well-planned forage system is available, females can achieve desired weight gains with little or no grain supplementation. Good-quality grass pasture will need to be supplemented with additional energy and protein sources. Animals maintained on grass-legume mixtures will require less supplementation. Nevertheless, animals should be weighed and body condition scored regularly whenever possible regardless of the breeding system. If the BCSs of the group begin to drop below 2.5, the producer should offer a source of supplemental energy; conversely, if the scores rise above 3.5, less energy supplementation is needed. A good-quality mineral mixture used for adult males as described below is appropriate for use in yearlings.

FEEDING REPLACEMENT BREEDING MALES

Feeding developing males should be forage-based. They should be developed using as much forage as possible, with just enough supplemental feeding (0.5 to 1.0% of body weight) to produce desirable gains and there is no need to worry about urinary calculi. Growing males should be offered a good-quality mineral mixture but care must be taken to include steps to prevent urinary calculi and other production-related diseases. A good quality hay and 1 to 1.5 kg of grain mix containing 14 – 16% CP is adequate. The other recommended nutrient levels are listed in Table 5.

FEEDING DRY DOES

Most medium quality forages can provide adequate levels of nutrients to dry does. The goal is to gain a small amount of body weight so they are ready for breeding. The average quality bermudagrass hay with 50% to 54% TDN and 8% to 10% CP level can be sufficient. However, the mineral mixture should be supplemented. The least expensive mineral mix is a mixture of 50% Dicalcium Phosphate and 50% Trace-mineralized salts provided free choice with adequate supply of clean, fresh water. The does should be maintained at a BCS at or just under 3 during the breeding season.

FEEDING PREGANT DOES

The does in the early gestation period can be maintained on an average quality hay with mineral supplementation similar to dry does. The goal is to economically feed does while maintaining proper body condition. A BCS of 2.5 to 3 is adequate during early gestation. The most important consideration is to gain a partial fetal and placental growth during this period. However, the doe nutrition is very critical during the last six weeks of pregnancy because approximately 70% of fetal growth occurs during this period. If does are not properly fed, the consequences can be low kid birth weights, lower energy reserves on the new born kids, and increased death losses at time of kidding. On the other hand, if does are overfed, this can result in obesity and contribute to dystocia and pregnancy toxemia (Rankins and Pugh, 2012). The pregnant does should be supplemented to between 150 to 454 grams (1/3 to 1 lbs) of grains per day. This will help prevent pregnancy toxemia which is the accumulation of ketones in the blood due to accelerated fat catabolism, although pregnancy toxemia in goats is less common compared to sheep. Do not feed alfalfa hay as a sole source of forage to pregnant does in the last trimester of their pregnancy because alfalfa hay is imbalanced with respect to its calcium to phosphorus ratio, and generally contain higher levels of potassium.

FEEDING THE LACTATING DOE

The milk production peaks within 2 to 3 weeks after kidding and then declines 8 to 10 weeks after parturition. This is the most critical period for does because they need high amounts of nutrients to produce milk. The nutrient needs depend on litter size also. Lactating does can consume up to 4% to 5% of their body weight in dry matter. Energy is the most important nutrient. Does should be fed to meet their nutrient needs. High quality forages such as spring pasture or moderate quality alfalfa hay can provide adequate levels of nutrients but if bermudagrass is the forage source, a 16% dairy ration, 1.18 kg (2.6 lbs) of hay and 910 grams (2.0 lbs) of ration should be fed to meet the nutrient needs for a 50 kg (110 lbs) Boer doe (Hart, 2015). The nutrient recommendation levels are listed in Table 5.

FEEDING HERD SIRES

Breeding bucks should be maintained on a medium quality forage diet because they can obtain most of the nutrients from it. However, if bucks are still growing they need to be provided with additional supplements. Replacement bucks should be gaining faster than doelings. Whole shelled corn at the rate of 206 grams (0.5 lbs) to 454 grams (1 lb) would be adequate. The BCS for breeding buck should be maintained at three or higher before, they enter the breeding season. Feeding higher amounts of grains can lead to urinary calculi. If it is necessary to feed higher levels of grain, producers should use a commercial concentrate with urine acidifiers to prevent urinary calculi.

Breeding bucks can loose up to 10% to 20% of their body weight during the breeding season and so they be fed supplements 4 to 6 weeks before the breeding season (Solaiman, 2010). Although the feeding rates vary according to BCS, a daily ration of 2.7 kg (6 lbs) to 3.64 kg (8 lbs) of forage and 454 grams (1 lb) to 91008 grams (2 lbs) of 12% to 14% protein supplement is adequate. The dicalcium phosphate and trace mineralized salt mixture (50:50 ratio) should be provided free choice. Trace mineral salt supplementation should be based on local soil types. The nutrient recommendations are given in Table 5.

Table 4. Example Kid Starter Grain Mix

Ingredient	Example 1	Example 2
Cracked corn	50%	50%
Soybean hulls	30%	----
Oats	----	30%
Soybean meal	15%	15%
Molasses	5%	5%

Table 5. Daily nutrient requirements for meat producing goats[1,2]

Nutrient	Young Goats[3]		Does (50 kg or 110 lbs)				Bucks (36.4 – 54.5 kg or 80 – 120 lbs)
	Weanling 13.6 kg or 30 (lbs)	Yearling (27.3 kg 60 lbs)	Early Pregnant	Late Pregnant	Average Milk	High Milk	
DM, kg or lbs	908 g (2.0 lbs)	3.0	1.46 or 4.5	2.05 kg or 4.5	2.05 kg or 4.5	2.27 kg or 5.0	2.27 kg or 5.0
TDN, %	68	65	55	60	60	65	60
Protein, %	14	12	10	11	11	14	11
Calcium, %	0.6	0.4	0.4	0.4	0.4	0.6	0.4
Phosphorus, %	0.3	0.2	0.2	0.2	0.2	0.3	0.2

[1]NRC, 2007; [2]Pinkerton, 1989; [3]Expected weight gain >200 g (0.44 lbs)/day.

VII. CONCLUSIONS

Meat goat production should be forage-based in the southeastern US where year-round forage production is possible. Forage-based goat production is not only profitable but it is environmentally sustainable and meat is of higher quality. Moreover, goats prefer less grains compared to other ruminant species. The additional supplementation including minerals and vitamins should only complement forages.

ACKNOWLEDGMENTS

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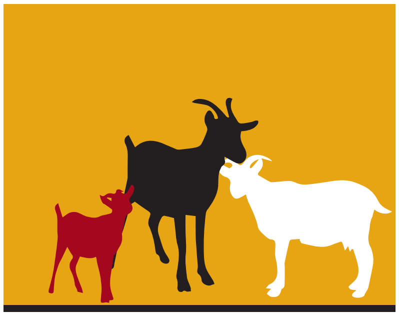

SECTION SIX

GOAT MARKETING AND VALUE-ADDED PRODUCTS

Marketing Toward the Future

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ABSTRACT

United States goat producers face many challenges with regards to marketing. Goat farmers (n=1015) who responded to the Needs Assessment Survey for the upcoming NAHMS 2019 Goat Study ranked marketing of meat, milk, and fiber as the third most important management priority. Although the demand for goat products is definitely increasing, the market is fractured. There is a general lack of infrastructure and many producers do not sell their animals or products for fair or profitable prices. Production costs are often too high, and there is a need to improve production efficiency through use of better genetics, nutrition, and management. Imports pose a particular challenge to US goat producers, as domestic production often cannot compete with the availability and lower cost of imports, be it frozen goat meat from Australia or goat cheese from Europe. Government regulations also hinder market development, because non-commercial slaughter is an important aspect of goat marketing, and burdensome regulations keep many dairy goat producers from developing a commercial enterprise. Surveys show that meat goat producers utilize a variety of marketing methods, with more than 60% of meat goats sold at public livestock auctions. In contrast, almost 80% of dairy goat owners do not market their products commercially. In order for the US goat industry to expand and meet the growing demand for product, producers need to combine efficient production practices with profitable marketing strategies.

Keywords: goat, marketing, sales, meat, dairy

MARKETING

Demand for goat products is increasing, but the fractured market lacks the infrastructure and market structure found for other livestock species. There are a variety of markets available for goat producers.

Surveys show more than 60% of meat goats are sold at public livestock auctions (sale barns), but there are many such auctions that do not focus on small ruminants, so prices may not be competitive, and animals may be re-sold through several different auctions until they move closer to consumers. Many auctions do not offer USDA grading of Selection 1 (good muscling/condition), 2 (moderate muscling /condition) and 3 (least muscling/lowest condition) and many do not conduct sales by the pound as is offered for more traditional livestock. To move forward into the future, changes are needed to further develop a viable market structure.

Sale barn pens; photo by Susan Schoenian.

Because the majority of goat meat and milk product consumers are non-traditional (immigrant and/or ethnic populations), direct marketing to consumers is one option some goat producers choose for selling live animals. Advertising for this market (and others) can be on social media sites or general sales sites online. For meat animals, producers need to check local and state laws to see if harvesting on the seller's farm by the customer is allowed. If this type of on-farm processing is not allowed, it is permissible to haul an animal for a customer to an abattoir for processing. In both cases, it is essential to sell the live animal to the customer. Producers cannot sell or transport meat unless they follow a myriad of regulations.

Abattoirs processing goats, especially under State or Federal inspection, are not common and there are not the variety of meat products ('cuts') as there are for livestock meat products. More facilities processing goats, especially those with State or Federal inspection to allow for direct marketing meat and those buying animals for their own retail sales, would benefit future goat markets. Determining market demand for specific goat meat products (cuts of meat for example) and then educating abattoirs and butchers on processing and retail sales would also benefit the industry.

Direct sales to abattoirs with a retail store can be a profitable market, but again, those may be difficult to find. In many areas, there are livestock buyers who will go to farms and pick up animals, but generally only for a larger number of consistently sized animals. In order to meet the requirement for larger numbers for a livestock buyer, a sale barn or other markets, producers can work together in a cooperative manner to supply this demand.

Goat meat for sale; photo by Susan Schoenian.

Government regulations also hinder market development for dairy products, with burdensome regulations for marketing food products, such as fluid milk and cheese, keeping many dairy goat producers from going commercial. However, increasing numbers of goat milk producers are developing milk products less governed by regulations like soaps and lotions. Milk for pet consumption is another option with less regulatory oversight if allowed in the State. Those marketing such products often do so through direct marketing.

CHALLENGES AND OPPORTUNITIES

Many goat producers do not sell their animals or products for fair or profitable prices. In order to determine prices needed to sustain a business, it is vital that records are kept on inputs (costs to the producer, including labor costs, depreciation, opportunity costs, etc.) so proper outputs (selling prices) are obtained. Many times, production costs are too high or a lack of adequate inputs such as purchasing quality genetics, providing proper nutrition and using best management practices results in lack of efficiency and lower outputs obtained. Alternative (i.e. drylot vs pasture-based) or hybrid production systems might be more efficient and thus more profitable in some situations.

Currently, and likely into the future, imports do/will pose a particular challenge to US goat producers. Domestic production cannot compete with the availability and lower costs of imports, be it frozen goat meat from Australia/New Zealand or goat cheese from Europe. Unless a drastic decrease in import availability occurs such as a depletion of the wild goat population currently harvested in Australia for low-cost exports, drastic changes will be needed to increase US goat production efficiency to reduce costs for profitable marketing into the future. A realistic business and marketing plan is essential for any enterprise, but is especially important prior to entering the goat industry.

For breeding stock production, not understanding proper selection, breed registration (if purebreds) and realistic marketing can hinder farm sustainability for meat and dairy goats. Producers should understand not all offspring will be sold for breeding. Also, prices fluctuate with the quality/performance of the animal for sale, demand, and competition for sales in the area. Developing a unique product or focusing on high performing animals (with records) can improve marketing and profitability.

There are a few production performance tests (i.e. buck tests) that provide genetic information for selection and marketing of genetically superior meat animals, and these have gained in popularity over the past few years. Collecting data and providing it for programs to obtain estimated breeding values (EBVs) or estimated progeny differences (EPDs) for important marketable traits like growth, maternal ability, or even parasite resistance is another valuable tool for selection and marketing as well, but few goat producers currently participate in these programs. An example of a program providing EBVs/EPDs for goats includes the National Sheep Improvement Program, also known as NSIP. For dairy goat producers, participating in the American Dairy Goat Association Dairy Herd Improvement (DHI) Registry/DHI Association for milk records would also provide valuable genetic information for marketing animals.

Dairy goat showmen; photo by Susan Schoenian.

Selling animals for the show ring may require showing (and winning) which can be expensive, and most animals will not be show quality, so alternative markets are needed. Good performance records and highly valued pedigrees are also used for marketing for show and registered breeding stock producers. Understanding the present market and trying to predict what will be desired in the future will help farm owners select, keep and breed animals meeting market demand.

Overall considerations for marketing now and in the future include not only understanding the markets available, but developing the goat and goat product market structure, increasing the number of abattoirs for processing, and developing more efficient production and marketing systems to increase profitability.

A couple of buck kids; photo by Susan Schoenian.

REFERENCES OR ADDITIONAL RESOURCES

Marketing videos (relevant for goats too) areavailable at: www.sheepandgoat.com/webinars

Goat Marketing http://articles.extension.org/pages/19614/goat-marketing.

Marketing Meat Goats, the Basic System; Marion Simon, State Specialist for Small Farm and Part-time Farmers, Kentucky State University Cooperative Extension Program, 400 East Main St., Frankfort, KY 40601, http://articles.extension.org/pages/62566/ marketing-meat-goats-the-basic-system.

Marketing of Meat Goats. S. Jones, M. McCarter and S. Cheney. University of Arkansas ANR fact sheet FSA3094 www.uaex.edu/publications/pdf/fsa-3094.pdf.

Tips for Marketing Sheep and Goat Products attra.ncat.org/attra-pub/download.php?id=410.

An Overview of Sheep and Goat Marketing. www.slideshare.net/schoenian/an-overview-of-sheep-and-goat-marketing.

Goat Milk Products: Quality, Composition, Processing, Marketing (from eXtension website) http://articles.extension.org/pages/32775/goat-milk-products:-quality-composition-processing-marketing.

NAHMS Goat Producer Needs Assessment: https://www.aphis.usda.gov/animal_health/nahms/goats/downloads/goat19/needs-assess.pdf.

For more information, contact your local County Extension Office, State Land-Grant University, small business offices, and/or local, state or national breed associations.

SECTION SEVEN

SPECIAL RECOGNITIONS

Beginning Farmers and Ranchers Workshop

As a means of addresses the continued decline of young people choosing farming as a career and to support a "new generation" of beginning farmers and ranchers, this year's National Goat Conference included a workshop highlighting opportunities available to persons interested in the Beginning Farmers and Ranchers Program. Rodney Brooks, Regional Specialist in Georgia for the USDA Farm Service Agency along with Robert Zabawa, Miles Robinson and Gwen Harris included attendees of various resources available to them through USDA as a part of this program, including partnerships for new/beginning farmers and ranchers so that young people may be informed and understand farming and ranching.

Innovative Farmers Award

At this year's National Goat Conference the organizers recognized three farmer families with the Innovative Farmer Award. These individuals have applied innovative measures to reach out to and share what they have learned with other producers, their community, and/or their local food systems. Further, each has done so through different types of activities, including educational, leadership, and more! Irrespective of their methods, these producers have had a positive impact on the goat industry locally, regionally, nationally and beyond. It is with the highest esteem that these individuals are honored. Awardees included the following:

- Katherine Harrison of the Harrison Farm in Groveport, Ohio
- Warren and Mary Ducre of the Ducre Farm in Hayneville, Alabama
- E. Gerald Gooden of the Triple G Cattle and Goat Ranch in Opelika, Alabama

Demonstrations and Hands-On Experiential Learning

The National Goat Consortium is committed to providing quality training opportunities to attendees at the National Goat Consortium. The 2018 National Goat Conference will prove to be no different with a number of demonstrations and hands-on experiential learning opportunities to include the following:

- Carcass Fabrication presented by ***Derris Burnett from Mississippi State University.***
- Unmanned Aerial Systems presented by representatives from ***Delta Solutions.***
- Guardian Dogs presented by ***Sam Abney with the American Goat Federation.***
- FAMACHA presented by ***Nar Gurung from Tuskegee University.***
- Health Management Practices…Ask a Vet! presented by ***Harold Higgins with Tuskegee University.***
- Hay Baling and Hay Quality presented by ***SunSouth Representatives.***

Producers' Roundtable

Research has shown that having a forum for open and productive conversations of difficult topics provides an opportunity for program participants to learn by listening and interacting amongst each other. It has been shown that useful ideas are often generated and reappear in different settings, promoting further dissemination of ideas. The National Goat Conference Producers' Roundtable provides an opportunity for attendees, including farmers, agricultural professionals, and other stakeholders, to focus on important topics with appropriate conversational rules that are sure to result in success.

Ask an Expert

The Ask an Expert forum is to provide answers to critical issues that face the goat industry. Specifically, a panel of experts in the goat industry will join attendees to discuss the future of the goat industry in the face of the numerous challenges that call for sustainable agriculture while facing increasing weather challenges as well as the increasing competition for food.

Notes

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