

SOLUTIONS FOR GRAND CHALLENGES IN GOAT AND SHEEP PRODUCTION

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ABSTRACT

Goats and sheep are valuable livestock as they produce food, such as meat, milk, fleece, and other products. In addition, goats and sheep are important both for agriculture and biomedical research. Even though these small ruminants provide essential goods, there are major obstacles preventing the efficient, sustainable, and profitable production of goats and sheep. This review is significant because it summarizes major challenges facing goat and sheep production, their negative impacts, and specific science-based solutions to overcome them. These challenge areas are education and training, research, translational research/biotechnology, goat and sheep health, and effective/efficient/sustainable/profitable agribusiness. The solutions include effective teaching of goat and sheep science to next generation and empowering the public, supporting and pursuing innovative and translational research, preventing and treating diseases, facilitating technology transfer, and developing sound agribusinesses. This resource is expected to be helpful to scientists, students, and goat and sheep producers. In addition, the information on the current state of goat and sheep agriculture will help the public better understand and appreciate challenges and opportunities in small ruminant production.

Keywords: Agriculture, biomedical research, goat, sheep, sustainable production

INTRODUCTION

Nature, Origins, Domestication and Science of Goat and Sheep

Goats in the mountains of Asia Minor and the Middle East were domesticated in Western Asia between 6,000 and 7,000 B.C, primarily from the stocks of indigenous bezoar goats. Sheep origins are not so simple. It is hypothesized that most domesticated sheep are derived from the European mouflon which

came from the Fertile Crescent about 3,000 B.C. Originally domesticated for meat, further breeding of goats and sheep led to the animals being used for fiber and milk (<http://www.ansi.okstate.edu/breeds/disclaimer.html/goats> and <http://www.ansi.okstate.edu/breeds/goats/index.html/sheep>, 2016). Goats and sheep have low maintenance requirements and high productivity eventually leading to the production of goat breeds such as the Nubian, Alpine, Boer, Kiko, and sheep such as Dorset, Merino, and the Dorper (Aziz, 2010). Unlike wool sheep, Dorper and some other breeds allow for lower

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maintenance due to self-shedding. Therefore, there are key differences between goats and sheep. Goats are more self-reliant and curious in nature with narrow upright horns. They have different chromosomal counts, goats have 60 and sheep have 54 chromosomes. Goats prefer to eat with their heads up, known as browsing, sheep require more intensive management and eat with their heads down, grazing.

Asia has the largest population of goats and sheep, but other regions especially the western world see growth as well. Current data identify the US as 8th in world goat population and 9th in sheep (Aziz, 2010). As of 2010, the number of sheep operations in the US was 81,000 with the total sheep and lamb inventory at 5.5 million in 2011. From the same source in 2010, there were 152,000 goat operations and of that, 31,000 were Angora or dairy goat operations, and 128,000 were for meat goat or other operations. The increase in goat numbers in the US can be attributed to the rapid growth of ethnic groups. The Southeast US has the largest growth in goat numbers in part because of the tobacco buyout program presented by the Congress. Tobacco farmers were offered incentives if they would move into other areas of production agriculture, thus leading to the growth of the goat industry in the Southeast (<http://usda.mannlib.cornell.edu/usda/current/ShpGtInd/ShpGtInd-08-09-2011>, 2011).

According to data on live animal population from FAOSTAT in 2014, Southeast Asia had 31.1 million goats (3.07 percent of goat populations spread all over the world) and 17.54 million sheep (1.47 percent of sheep populations spread all over the world). The goats are located throughout 11 countries with the highest population of 18 million heads (59.95%) in Indonesia followed by Myanmar with 5.6 million heads (18.06%), and the Philippines with 3.7 million heads (11.87%). With 16 million heads (91.71%), Indonesia had the largest population of sheep in Southeast Asia that is followed by Myanmar (11.6 million heads, 6.62%). From the same source in 2004, Southeast Asia had 53 goat breeds (5 percent of the world's population) and 33 sheep breeds (1 percent of the world's population) (<http://www.fao.org/faostat/en/#data/QA>, 2017). There are many goat breeds, for example,

the Alpine, Anglo-Nubian, Angora, Australian feral, Barbara, Beetal, Bengal, Boer, Cashmere, German Improved Fawn, Indo-Chinese, Jamnapari, Katjang, La Mancha, Saanen, and Toggenburg. Moreover, Southeast Asia has many sheep breeds, among them are the Awwasi, Barbados Black Belly, Blackhead Persian, Border Leicester, Corriedale, Dorper, Katahdin, Merino, Morada Nova, Poll Dorset, Priangan, Rambouillet, Romney, Santa Ines, St.Croix, Suffolk, and Sussex (<ftp://ftp.fao.org/docrep/fao/011/a1250f/annexes/Subregional%20reports/Asia/SouthEastAsia.pdf>, 2007). Sheep are produced mainly for meat, fertilizer, carpet making, saving, fighting and any other purpose. Garut sheep in Indonesia with dominant white hair color are usually used for meat and the black ones are kept for fighting. Goats are produced for meat and milk.

Gembrong goats from Indonesia are also used for fishing by scattering its meat into the sea (The Ministry of Agriculture of the Republic of Indonesia, 2003). Some goat breeds are produced for milk production. Non-cattle milk accounts for approximately 15% of the total milk consumption by humans worldwide and Asia contributes approximately 59% of the world goat milk production (Universiti Putra Malaysia and FAO, 2012). Sheep and goat milk are primarily used in the artisan sector. Goat milk is preferred by increasing numbers of consumers due to its healthier characteristics and being more acceptable for individuals who desire dairy products but are lactose intolerant. In Asia, 13 dairy breeds of goats are identifiable and two breeds from Southeast Asia, of the 13, Etawah goats are from Indonesia and Bach Thou goats are from Vietnam (Devendra, 2010).

In the meat industry, there has been a shift to raising self-shedding hair sheep and declining inventory numbers due to the utilization of synthetic fibers (<http://usda.mannlib.cornell.edu/usda/current/ShpGtInd/ShpGtInd-08-09-2011>, 2011). Hair sheep require little to no shearing while still producing a good quality carcass. Goat meat consumption has risen due to the recent increase in ethnic immigration as well as other factors. To date, goat is the fourth most consumed meat following sheep, pork, poultry,

and beef. It has a unique flavor and is a leaner red meat (<http://extension.psu.edu/business/ag-alternatives/livestock/sheep-and-goats/meat-goat-production>, 2012). Sheep meat, lamb, and mutton have a more intense aroma and the species flavor is more pronounced (Schönfeldt et al., 1993).

Sheep and goats help prevent wildfires by eating the grass and brush that are the fuel. They also control invasive weeds such as kudzu and Johnson grass and even plants that can be poisonous or unpalatable to other livestock. Goats are useful for disadvantageous producers who have limited acreage and want to produce fiber, dairy, meat or a combination of products in a dual production set up. Goats are more convenient and require lower costs to manage and are less labor intensive compared to most other livestock (<http://usda.mannlib.cornell.edu/usda/current/ShpGtInd/ShpGtInd-08-09-2011>, 2011). Both goats and sheep have breeds that are maintained for purely their aesthetic appeal and for exhibition purposes. They offer benefits for child enrichment. Being smaller-scale livestock makes them great for family-oriented livestock experiences. Many Departments of agriculture, animal and veterinary sciences at the universities offer small ruminant courses to students. Central or local government agencies, extension agents through the universities, private organizations, and farmer groups can provide training and education to producers.

Major Challenges in Goat and Sheep Production, Their Negative Impacts and Science-based Solutions

Education and Training

The goat industry continues to grow in developing countries and to gain acceptance in modern times in countries with higher to moderate incomes, because sheep and goats are so adaptable to their environment, and they have multiple purposes including fiber, milk, and meat (Morand-Fehr et al., 2004). Despite this growth, there are needs in the education and training fronts that include: 1) promoting interest in animal science in the new generation, 2) goat and sheep science in curricula of

undergraduate and graduate and veterinary medicine, 3) training extension agents in goat and sheep production, 4) training producers in best practices in goat and sheep production, and 5) educating the public about goat and sheep production. This can be largely attributed to the lack of well-trained extension agents. However, even where there are programs in place, “the main causes of non-participation in educational programs are: the lack of content’s response to their needs, the lack of time, their low level of confidence towards the extension agents, and their belief that their participation in an educational process will make them feel uncomfortable” (Lioutas et al., 2010).

“In the US, the average consumer is now at least three generations removed from the farm. This disconnect has led to a decrease in general knowledge and understanding of how food is produced or where food comes from” (Johnson and Hamernik, 2015). Thus, as the media become more influential and fewer people have the first-hand experience in raising livestock, it becomes increasingly more difficult for extension agents to have the knowledge necessary to help clients. As a result, consumers and potential producers are affected, as it is harder for them to find accurate, truthful information to aid them in their decision-making and herd health management. This failure to promote interest in animal science will ultimately impact the younger generations by causing them to not only miss out on critical life skills but also by causing them to not see agriculture as a desirable career sector. Furthermore, producers are affected by the lack of training in regard to the best goat and sheep production management practices, as seen in the fact that there is an extremely high degree of variability in vaccination and deworming protocols among producers (Merkel and Gipson, 2011).

Potential science-based solutions to combat the negative attitudes toward goat and sheep production need to be researched. The central idea is to bring more attention to the spreading popularity of goats and sheep by increasing funds for research and educational programs as well as finding efficient and effective ways of bringing the necessary training needs to this generation of producers and the next. One effort to improve the education of producers

was attempted by Langston University, where an online course was created. Four years later, a survey was sent to 160 producers who were certified via the provided online course – producers who utilized the online course showed an improvement in overall herd management (Merkel and Gipson, 2011). Another proven method, this one for furthering the interest and ability of younger generations in the field of animal science, is participation on a Collegiate Judging Team. Not only is an agricultural and science-based lifestyle promoted, "results illustrate...preference may be given to potential candidates who have participated on judging teams because of the advantage they may have in areas of communication, critical thinking, and information management" (Byrd *et al.*, 2011). In order to promote interest in animal science, schools have several solutions. Some of these programs include: 1) more school field trips to farms and classes in schools, 2) ensuring FFA and 4H are offered to all students especially of low-income backgrounds, and 3) making sure there are up and coming agricultural teachers available to replace the many that are currently looking to retire. Once younger people in secondary education develop interest, it is more likely for them to pursue similar interests in undergraduate and graduate education. Grants and study programs should be available for these students, and recruiters at universities should make sure that potential students are aware that sheep and goat production majors and/or courses are offered at said universities. Overall, making accurate production information more widely available should help continue the trend of improving education methods within the sheep and goat industry.

Research

The major challenges the goat and sheep production industry faces are observed by everyone from producers and consumers to researchers. There is a lack of fundamental knowledge about the goat and sheep science including genetics, breeding, nutrition, immunology, growth and development, meat cuts and nutritional benefits. The roots of such a lack of knowledge stem from inadequate basic research in the specified areas. Production

animal performance, product health benefits, breeding records, and proper selection of goats and sheep are a few such challenges in this field. New knowledge is essential to enhance our understanding in these critical areas. For example, because of a poor record keeping in the past, it is difficult to distinguish origins of certain breeds and maintain breed lines (García-Peniche *et al.*, 2012). Comprehensive studies of the primary differences between breeds of sheep or goats are limited, because of small sample sizes, or use experimental designs that are not appropriate for statistical inference (Blackburn *et al.*, 2011). There is a lack of phenotypically distinct herds to identify specific markers in breeds. Challenges for both producers and researchers arise with the lack of funding and loss of knowledge produced from research. This is a major issue for the producers because they have to wait a long time to reap the benefits from the research projects that depend on funding and bright minds (Shields, 2012). This is in part caused by the highly expensive research technologies needed to perform adequate experiments and not enough highly qualified researchers trained to use this technology. In addition, there is a lack of research facilities equipped with the latest state of the art technologies used for goat and sheep research. Limited research funding prevents experiments that would catalyze the production of solid information on these growing industries. Furthermore, there is a distinct disconnect between what the researchers publish and what producers gain from these publications.

Challenges faced by the goat and sheep production industry are significant because they are hindering effective, efficient, and profitable agribusiness. Additionally, there are many negative impacts that stem from these issues. One of the impacts on the goat and sheep agriculture is that breed guidelines have been established without much knowledge of the breeds' genetics and potential genetic similarities between breeds. Several breeds are getting closer and closer to disappearing because it is difficult to know what traits need to be bred back into the line to produce the desired breed (García-Peniche *et al.*, 2012). Dairy goat and sheep farming are significant to the national economy of more than a dozen countries, including France, Italy, Spain, and Greece (Haenlein,

2001). When issues arise with dairy goat and sheep production, each of these countries' economies suffers. One of the largest areas that are negatively affected by these challenges is the lack of research funding. Over the past few decades, the growth of the USDA research budget has lagged behind all of the other national science agencies. With 294 million dollars being spent by the USDA on sustainable practices, only ten percent of their budget is being spent on research, extension, and education (DeLonge *et al.*, 2016). This lack of funding affects the production industry, especially goats and sheep producers, and it can be detrimental to those who do not have enough experience or capital to stay in business.

In order to tackle the challenges, the current need is to discover and invent solutions through well-designed research that will result in efficient, sustainable, and profitable goat and sheep production. A larger budget would then open the door to performing more comprehensive studies on performance, breed evaluations, and product development (Shields, 2012). It is also important to increase producers' knowledge of efficient goat and sheep production by publishing more peer-reviewed articles in scientific journals (Haenlein, 2001). These solutions are simple in nature, but profound in practice; in an ever-changing world that is so widely connected, countries need to implement these solutions to improve the overall standing of global goat and sheep agriculture. Only then will the prospect of a sustainable, efficient, and profitable industry be achieved.

Translational Research/Biotechnology

Many challenges involving lack of translational research or biotechnology stem from lack of transformative research, i.e., significant research, selection schemes and well-established breeding organizations, and from technology transfer that affects the goat and sheep industry today. In addition, there is an inadequate collaboration on applied research between academia and industry. For example, although fertility, growth and development, longevity, meat production, resistance to disease and heat are all important for sustainability and profitability of small ruminant production, there

are not enough phenotypic data and there is no reliable set of biomolecular markers for genomic selection (Pellerin and Browning, 2012). Another challenge is the lack of standardization in record keeping which is important for economic viability (Kosgey and Okeyo, 2007).

These challenges have significant negative impacts on animal production, health, genetic improvement and breeding for economically important traits in the goat and sheep industry. Maintaining health in goat and sheep is more of a challenge than other livestock because there is a lack of medicines that are FDA approved to be used on goats and sheep in the US (Pellerin and Browning, 2012). When the animal is sick it can affect both the producer and the animal because the animal is not producing, which could lessen profits. Another negative impact would be the genetics and breeding issues such as breeding for certain traits that help prevent different diseases from occurring. This is an issue because diseases can transfer from animal to animal which could cause a decrease in overall profits. In addition, the negative impact on the industry is important, but so is understanding and creating the solution to solve such issue in the goat and sheep production industry.

A solution for genetics and breeding of certain issues in the goat and sheep industry would be to promote a breeding center to help improve breeds (Barrera-Saldaña *et al.*, 2010). This can positively affect the industry by increase breeding for certain traits like disease resistance and genetic improvement of the population. In order to overall improve the health of goats and sheep in the industry when referring to reproductive issues. It is important to attempt to identify reproductive genes that can cause gene mutations that are responsible for phenotypes associated with reproduction (Lupton, 2008). There is funding on a small scale for biomedical goats. Goat embryos that were incorporated into golden orb-weaver spider's DNA produce high protein content milk that produces silk. This silk is reported to be seven to ten times stronger than steel that can have many applications including developing more protective gear for the army. This is an example of generating "transgenic" organisms (<http://postnatural.org/filter/Aug->

2014). The gender roles of livestock production should be taken into consideration when designing training programs and targeting trainees (Yisehak, 2008).

Goat and Sheep Health

Animal health is an important challenge in the goat and sheep industry. To attain a sustainable agribusiness plan in small ruminant production, a producer must be knowledgeable of herd health and know how to maintain it. In the US, there is a lack of education and research on small ruminant health compared to other livestock industries. Therefore, producers experience difficulties when searching for information on how to better improve their herd health. Health-related challenges in the goat and sheep industry include lack of understanding the one-health, zoonotic diseases, parasites and resistance to parasites, selection for disease-resistant animals, predators, and the potential threat of bioterrorism. Adverse effects of these impact both the animal and human health.

Animal and human health are linked through socio-economic, nutritional, and zoonotic pathways. The zoonotic pathway is the most vital because zoonotic diseases are transmissible from animals to humans. These include anthrax, rabies, and leptospirosis (Thumbi *et al.*, 2015). A more recently reemerging zoonotic disease, Rift Valley Fever Virus (RVFV), originally geographically localized to the African continent is spreading to new regions and could be a potential threat to North American sheep and goats. An arthropod-borne disease, RVFV causes abortions and deaths in small ruminants (Rolin *et al.*, 2013). Parasitic diseases such as coccidiosis are the most economically important disease in the small ruminant industry. Caused by protozoa of the genus *Eimeria*, coccidiosis results in diarrhea (often bloody), anemia, weight loss, and death. It is highly contagious and transmitted via the fecal-oral route through ingestion of contaminated water or feces, or licking wool or hair of infected animals (Gibbons *et al.*, 2016). Other intestinal parasites and anthelmintic resistance are also among the major issues. Seventy-four percent of US sheep were found to have been infected with stomach or intestinal parasites within their previous three

years

(https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/nahms/nahms_sheep_studies).

Zoonotic diseases are common in Southeast Asia due to several factors such as geographical positioning with a warm and humid climate, socio-economic situation and socio-cultural practices (Bordier and Roger, 2013). Brucellosis, anthrax, and foot mouth disease (FMD) are some of the most prevalent in the area. Brucellosis infects cattle, sheep, goats, and pigs and is notifiable in OIE. In the southeast Asian region which includes Myanmar, Singapore, Malaysia, Indonesia, Lao People Democratic Republic (PDR), Philippines and Cambodia, the disease is considered endemic even though few countries sporadically report its occurrence (Bamaiyi, *et al.* 2014). In 2010, of the officially reported cases of brucellosis in seroprevalence, 10.8% were goats in Thailand (Bordier and Roger, 2013). *Brucella melitensis* is the main etiologic agent of ovine and caprine brucellosis whose prevalence was 13%. Seropositive animals have higher rates of abortion, stillbirth, infertility, calf mortality, and lameness (Bamaiyi, *et al.* 2014). An anthrax outbreak in Southeast Asia occurred in Lao PDR in 2008 where there were seven cases. The reservoirs of anthrax are herbivores, carnivores, and omnivores (Bordier and Roger, 2013). The FMD is endemic in mainland countries (Cambodia, Lao PDR, Myanmar, Malaysia, Thailand, and Vietnam. In 2015, FMD outbreaks occurred in Lao PDR, Vietnam, and Myanmar. Another zoonotic disease is FMD. Cattle, buffalo, goat, sheep, and pig are vulnerable to FMD which infected cattle and buffalo in Lao PDR, cattle and pig in Vietnam, and cattle in Myanmar (Qiu *et al.* 2017).

There are solutions for these challenges. For example, innovative research is needed to study prevention, diagnosis and treatment measures of many diseases. The risk of zoonotic spread of the above pathogens whether it is animal-to-animal or animal-to-human can be limited and controlled using proper personal protective equipment and good hygiene. Another approach to reducing zoonotic incidence is to apply the One-Health concept, prioritize resource

allocation, and develop an efficient surveillance system (Bordier and Roger, 2013). There are no approved drugs for use on goats and sheep to treat coccidiosis; however, there are two drugs, Amprolium and Ponazuril, that when used off-label have been effective (Gibbons *et al.*, 2016). Anthelmintics have been widely used to prevent and treat parasitism resulting in anthelmintic resistance to parasites to evolve and become an important major industry-wide threat. Education on the proper anthelmintic use and selection of naturally resistant animals will reduce the emergence of resistant parasites in goats and sheep production.

The research attempts to decrease resistance have included the genetic selection of resistant animals, nutrition manipulation, ethnoveterinary therapy, biological control, and vaccinations. Supplementing goat feeds with legumes reduced the egg count of grazing lambs that were not given anthelmintic. Papaya seed suspension and papaya sap have exhibited anthelmintic activity *in vitro* against *Haemonchus contortus*. Other plant extracts from nicotine, *Areca catechu*, *Curcuma aeruginosa*, *Zingiber purpureum*, *Monordica charantia* and *Morinda citrifolia* showed varying degrees of anthelmintic activity against *H. contortus*. Crude extracts of *Mimosa pudica* and *Tinospora rumphii* were highly effective against *Haemonchus* larvae *in vitro* and reduced worm egg counts. *Arthrobotrys oligosporus* are used for the biological control of sheep nematode parasites (San and Gray, 2004). Nematophagous fungi seem to have promise as a biological control against parasites of ruminants.

Another factor affecting small ruminant health are predators such as domestic dogs and coyotes. Proper fencing and snare traps are effective when used as prevention mechanisms for predators. Bioterrorism, the weapons of zoonotic pathogens to overwhelm the food supply in another country, is a major concern (Blancou and Pearson, 2003), and the solutions require government participation at national and international levels and include prevention, preparations, rapid detection, education, combating. Proper biosecurity measures, promotion of national and international peace, and the involvement of intelligence specialists to detect potential bioterrorism and increase the risk assessment awareness. These precautionary

measures may decrease the chances of or the effects of an attack (Blancou and Pearson, 2003).

Effective/Efficient/Sustainable/Profitable agribusiness

Questions posed through surveys of goat farmers found eleven challenges: high cost of production, lack of a clear marketing system for goats, lack of a goat meat processor in the vicinity, lack of steady demand, pasture management problems, disease, internal parasites, predators, competition of foreign goat meat product, and low government support for the industry. Resources for goat and sheep production are expensive, the market is small due to seasonal needs, and competition with the other livestock productions is fierce. Due to poor numbers and little record keeping/databases, there is limited genetic progress within goats and sheep (Tedeschi *et al.*, 2011). Major factors such as increasing human population and limited lands available for livestock, create an important opportunity for goat and sheep production systems. All of these challenges have negative impacts on agriculture, the environment, the economy and quality of life. The cost of production negatively impacts producers rotating pastures more so than those producers not rotating pastures (due to labor costs), costs of more land and more fencing as well as the increased cost of more water systems. The fact that goats are bought and sold several times before slaughter and processing reflect a poor marketing system. Overwhelmingly, producers agree that poor government support poses additional challenges to production.

Institutional or economic challenges require integrated research, extension, animal scientists, and industry solutions (Gillespie *et al.*, 2013). Measures can be taken to improve the cost of goat and sheep operations such as finding more “green” solutions to control parasites such as selective dewormer usage with the FAMACHA system and rotational grazing (Silva *et al.*, 2014). Rotational grazing may have economic benefits on the final products because this would reduce parasite infestation, drug residues in the final products, and lower the need for anthelmintic treatments. Rotating pastures would also improve sustainability by protecting pastures

from overgrazing. As a currently expanding livestock industry, there is comparatively limited information available about meat goat production in the US, specifically factors that can impact efficiency and productivity (Qushim *et al.*, 2016). Making comparisons with other livestock industries such as cow-calf operations or analyzing production structures established in other countries/regions of the world could provide possible models for domestic research. Better and standardized record keeping, the more efficient scale of operation, adoption of average cost-reduction technology, and better pasture management and marketing strategies, better and safer housing are all among the solutions. Veterinarians and extension agents could play a key role in communicating with producers by providing educational programs on the best practices in breeding, health, and nutritional management. Along with research, extension, and animal scientists, government support for the industry could help solve difficulties by improving laws, marketing, trade, and perhaps providing more local processing (Gillespiex *et al.*, 2013).

CONCLUSION

Goats and sheep are valuable livestock as they produce food for feeding the world, producing valuable byproducts, and for both for agriculture and biomedical research. In order to increase the goat and sheep production systems, there is a need to eliminate the limiting factors preventing the efficient, sustainable, and profitable production of goats and sheep in the United States, and to empower the public with knowledge on the advantages of goat milk and meat, fleece, and other products. Major challenges have been addressed throughout this review. Science-based solutions that have been highlighted include education and training the next generation and the public, innovative/transformational/translational research, improving animal health, and developing effective/efficient/sustainable/profitable agribusinesses. This review is important because it helps the animal producers and the public better understand the goat and sheep science

and to develop resilience in current and future challenges.

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