

REVIEW: SOLUTIONS FOR GRAND CHALLENGES IN GOAT AND SHEEP PRODUCTION INDUSTRY

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ABSTRACT

Goats and sheep are valuable as they are a source of meat, milk, fleece, and other products. These livestock are also important both for agriculture and biomedical research. However, the efficient, sustainable, and profitable production of these small ruminants faces major obstacles. Hence, this review analyzes these major challenges specifically, their negative impacts on the industry, and suggests some science-based solutions to overcome them. Those challenged areas are education and training, research, translational research/biotechnology, goat and sheep health, and maintenance of an economically sustainable agribusiness. The suggested solutions include the effective teaching of goat and sheep science to the next generation and public empowerment, support for innovative and translational research, disease prevention and treatment, support for technology transfer, and development of sound agribusiness practices. This review is helpful particularly for scientists, students, and the goat and sheep producers. In general, these information on the current state of goat and sheep agriculture will also help the public to better understand and appreciate the challenges met and opportunities provided in small ruminant production enterprises.

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

INTRODUCTION

Nature, Origin, Domestication and the Science of Goat and Sheep

The domestication of goats in the mountains of Asia Minor and the Middle East occurred between 6,000 and 7,000 B.C, primarily from the stocks of indigenous bezoar goats (Naderi *et al.* 2008). Domesticated sheep are believed to have

originated from the European mouflon which came from the Fertile Crescent about 3,000 B.C (Naderi *et al.* 2008). Originally, the sheep were domesticated for meat but later were bred for fiber and milk production (OSU 2016). The low maintenance requirements and high productivity of goats and sheep raising eventually led to the production of goat breeds such as the Nubian, Alpine, Boer, Kiko, and sheep such as Dorset, Merino, and the Dorper (Aziz 2010). Dorper and some other breeds also incur lower maintenance cost due to self-shedding. Key

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differences exist between goats and sheep. They have different chromosomal counts; goats have 60 and sheep have 54 chromosomes. Goats prefer to eat with their heads up (browsing) while the sheep require more intensive management and eat with their heads down (grazing). Goats have narrow upright horns and are more self-reliant and curious in nature.

Asia has the largest population of goats and sheep, but other regions in the West also produce large number of goats and sheep. Currently, the US ranks 8th in world goat population and 9th in sheep (Aziz 2010). In 2010, the number of sheep operations in the US was 81,000 and in 2011, the total sheep and lamb inventory was at 5.5 million. In 2010, 31,000 of the 152,000 goat operations were Angora or dairy goat operations, and 128,000 were for meat goat or other operations. The increase in goat numbers in the US was 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. The 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 (USDA 2011).

Based on live animal population data, Southeast Asia had 31.1 million goats (3.07 percent of the world goat populations) and 17.54 million sheep (1.47 percent of sheep population worldwide (FAO 2014). The goats are located throughout 11 countries with the highest population of 18 million heads (59.95%) found in Indonesia, 5.6 million heads (18.06%), in Myanmar and 3.7 million heads (11.87%) in the Philippines. With 16 million heads (91.71%), Indonesia had the largest population of sheep in Southeast Asia, followed by Myanmar with 11.6 million heads (6.62%). 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) (FAO 2017). Among these goat breeds, are the Alpine, Anglo-Nubian, Angora, Australian feral, Barbara, Beetal, Bengal, Boer, Cashmere, German Improved Fawn, Indo-Chinese, Jamnapari, Katjang, La Mancha, Saanen, and Toggenburg. Among the Southeast Asian sheep breeds, 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 (FAO 2007). The sheep are produced mainly for meat, fertilizer, carpet making, shavings, and fighting. The Garut sheep with dominant white hair color found in Indonesia are commonly used for meat and the black ones are kept for fighting.

Goats mainly produce both meat and milk. Goat meat can be consumed by humans or in some cases it can be used as feed for fish in aquaculture. 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 (FAO 2012). Sheep and goat milk are primarily used in the artisan sector. Due to its healthier characteristics, goat milk is preferred by increasing numbers of consumers and is becoming more acceptable for lactose intolerant individuals. Two of the 13 identified dairy breeds of goats are from Southeast Asia, the Etawah goats from Indonesia and Bach Thou goats from Vietnam (Devendra 2010).

Due to the utilization of synthetic fibers, the meat industry shifted to raising self-shedding hair sheep that resulted in declining inventory numbers (USDA 2011). Hair sheep produce a good quality carcass, yet they require only little to no shearing at all. However, goat meat consumption has risen due to the recent increase in ethnic immigration, among other factors. Recently, goat is among the five most consumed meat following sheep, pork, poultry, and beef. It has a unique flavor and a leaner red meat (PSU 2012) while sheep meat, lamb, and mutton have a more intense aroma and the species flavor is more pronounced (Schönfeodt *et al.* 1993).

Sheep and goats help prevent wildfires by eating the grass and brush that serve as 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 disadvantaged 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 to raise and require lower costs to manage and are less labor intensive compared to most other livestock (USDA 2011). Both goats and sheep have breeds that are purely

maintained for their aesthetic appeal and for exhibition purposes. They offer benefits for child enrichment. Being a smaller-sized livestock makes them great for family-oriented livestock experiences. University departments of agriculture, animal and veterinary sciences also offer short term small ruminant courses to students. Moreover, the central or local government agencies, the extension agents through the universities, private organizations, and farmer groups can provide training and education to producers.

Negative Impacts of Goat and Sheep Production and Science-based Solutions

Education and Training

Sheep and goats are so adaptable to their environment and have multiple uses including fiber, milk, and meat that the industry continues to grow in developing countries and to gain acceptance in modern times in countries with higher to moderate incomes (Morand-Fehr *et al.* 2004). Despite this growth, however, the industry faces challenges in the education and training fronts that include: 1) promoting interest in animal science among the new generation, 2) inclusion of the goat and sheep science in the curricula for undergraduate, graduate and veterinary medicine students, 3) availability of trainings for extension agents in goat and sheep production, 4) availability of trainings on best practices in goat and sheep production for the producers, and 5) existence of education campaign activities 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 the needs of the producers, their 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 disconnection has led to a decrease in general knowledge and understanding of how food is produced or where food comes from

(Johnson & Hamernik 2015). Thus, as the media become more influential and fewer people have the first-hand experience, the raising of livestock has become 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, considering the extremely high degree of variability in vaccination and deworming protocols among producers (Merkel & Gipson 2011).

Hence, the need for science-based solutions to combat the negative attitudes toward goat and sheep production. 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 and the next generation of producers. As such, Langston University attempted to improve the technical knowledge of producers through an online course. Four years later, a survey was sent to 160 producers who utilized and were certified *via* the provided online course. These producers showed an improvement in overall herd management (Merkel & Gipson 2011). Another effective method for furthering the interest and ability of younger generations in the field of animal science, is their participation on a Collegiate Judging Team. Not only is an agricultural and science-based lifestyle promoted, but the results also illustrated a preference given to potential candidates who have participated in judging teams because of the advantage they have in areas of communication, critical thinking, and information management (Byrd *et al.* 2011). In order to promote interest in animal science, several schools have formulated programs which include: 1) more classes and school field trips to farms, 2) offering of Future Farmers of America

(FFA) and 4H classes/trainings to all students especially of low-income backgrounds, and 3) providing opportunities for new breed of agricultural teachers who will replace those who will soon retire. Once the younger generation in the secondary education develop interest, they will more likely pursue similar interests in the undergraduate and graduate level. Grants and study programs should be available for these students. Recruiters at universities should also make sure that these potential students are aware that sheep and goat production majors and/or courses are offered at said universities. Overall, the production of an accurate and widely disseminated information on the sheep and goat industry should continue to help improve people's awareness on the industry.

Research

Everyone from the producers, consumers to researchers understand the major challenges that the goat and sheep production industry faces - the lack of fundamental knowledge about the goat and sheep science including genetics, breeding, nutrition, immunology, growth and development, meat cuts and nutritional benefits. Such lack of knowledge stems from inadequate basic researches in the specified areas such as animal production performance, product health benefits, breeding records, and proper selection of goats and sheep. Hence, new knowledge is essential to enhance understanding in these critical areas. For example, because of a poor record keeping system, it is difficult to distinguish origins of certain breeds and to 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 of 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 knowledge produced from research. This is a major issue for the producers because they have to wait for 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 disconnection between what the researchers publish and what producers gain from these publications.

These challenges faced by the goat and sheep production industry are significant because these are hindrances to an effective, efficient, and profitable agribusiness. Many negative impacts stem from these issues, one of which is that the breed guidelines have been established without much knowledge of the breeds' genetics and potential genetic similarities between breeds. Several breeds are slowly 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 regarding the dairy goat and sheep production, these countries' economies are much affected. One main challenge 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 negatively affects the goats and sheep producers who consequently do not have enough experience or capital to stay in business.

Thus, the need to discover and invent solutions through well-designed researches that will result in efficient, sustainable, and profitable goat and sheep production. A larger budget would then lead to the conduct of more comprehensive studies on performance, breed evaluations, and product development (Shields 2012). It is also important to increase the producers' knowledge on the industry by publishing more peer-reviewed articles in scientific journals (Haenlein 2001). These

solutions sound 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

Other challenges involve the lack of translational research or biotechnology that stem from a lack of transformative research (i.e. significant research, selection schemes from well-established breeding organizations, technology transfer), an inadequate collaboration on applied research between academia and industry, and the lack of standardized record keeping which is important for economic viability (Kosgey & Okeyo 2007). 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 & Browning 2012).

These challenges have significant negative impacts on the animal production, health, genetic improvement and breeding for economically important goat and sheep traits. Maintaining health in goat and sheep is more of a challenge than other livestock because of the lack of medicines that are FDA approved to be used on goats and sheep in the US (Pellerin & 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 absence of genetic and breeding activities for certain traits that are disease resistant. Diseases can transfer from one animal to another resulting in a decrease in overall profits. Not only are these negative impacts important, but also an understanding of possible solutions to such issues confronting the goat and sheep production industry.

One possible solution to help improve breeds is the creation of a breeding center (Barrera-Saldaña *et al.* 2010). This center can facilitate the increase of breeding activities for

certain traits like disease resistance and other genetic improvements. There is the need to identify reproductive genes that cause genetic mutations that are responsible for phenotypes associated with reproduction (Lupton 2008). Transgenic goats can be generated that produce recombinant proteins for biopharmaceutical purposes. Finally, gender issues in livestock production should also be considered when designing training programs and targeting trainees (Yisehak 2008).

Goat and Sheep Health

Animal health is another 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 how to maintain it. In the US, the lack of education and research on small ruminants' health compared to that of other livestock results in the lack of information for producers on how to better improve their herd health. Health-related challenges also include lack of understanding on the one-health, zoonotic diseases, parasites and resistance to parasites, selection for disease-resistant animals, predators, and the potential threat of bioterrorism. These adversely affect 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), that originally was geographically localized to the African continent is spreading to new regions and poses a potential threat to the 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 early three years of growth (NAHMS 2001).

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 & Roger 2013). Brucellosis, anthrax, and foot and mouth disease (FMD) are some of the most prevalent in the area. Brucellosis infects cattle, sheep, goats, and pigs and is notifiable at office international des epizooties (OIE). In the southeast Asian region including Myanmar, Singapore, Malaysia, Indonesia, Lao People Democratic Republic (PDR), the Philippines and Cambodia, the disease is considered endemic even though few countries sporadically report its occurrence (Bamaiyi *et al.* 2014). Of the officially reported cases of brucellosis in seroprevalence in 2010, 10.8% were goats in Thailand (Bordier & 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 reported seven cases that occurred in Lao PDR in 2008. The reservoirs of anthrax are herbivores, carnivores, and omnivores (Bordier & Roger 2013). Another zoonotic disease, FMD is endemic in mainland countries of Cambodia, Lao PDR, Myanmar, Malaysia, Thailand, and Vietnam. In 2015, FMD outbreaks occurred in Lao PDR, Vietnam, and Myanmar. The FMD vulnerable cattle, buffalo, goat, sheep, and pig produced infected cattle and buffalo in Lao PDR, cattle and pig in Vietnam, and cattle in Myanmar (Qiu *et al.* 2017).

Finally, possible solutions for these challenges are available. For example, innovative research is needed on the prevention, diagnosis and treatment of many diseases. The risk of zoonotic spread of the above pathogens, whether animal-to-animal or animal-to-human, can be controlled using proper personal protective equipment and good hygiene. Other approaches in reducing zoonotic disease incidences are; to apply the One-Health

concept, to prioritize resource allocation, and to develop an efficient surveillance system (Bordier & Roger 2013). No approved drugs are available for use on goats and sheep coccidiosis, however, two drugs, Amprolium and Ponazuril, 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, a condition that became an important major industry-wide threat. Education on the proper anthelmintic drug use and selection of naturally resistant animals will help in reducing the emergence of resistant goats and sheep parasites.

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 worm 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 & Gray 2004). Studies on nematophagous fungi show promising results as a biological control method against parasites of ruminants (Chandrawathani *et al.* 2002).

Other factors affecting small ruminant health are the predators such as domestic dogs and coyotes. Proper fencing and snare traps are effective when used as preventive mechanisms for predators. Bioterrorism, the use of zoonotic pathogens as weapons to devastate the food supply in another country, is a major concern (Blancou & Pearson 2003), and the solutions require national and international government interventions that include prevention, preparations, rapid detection, education, combating, proper biosecurity measures, promotion of national and international peace, the involvement of intelligence specialists to detect potential bioterrorism and increasing the

risk assessment awareness. These precautionary measures may decrease the chances of or the effects of an attack (Blancou & Pearson 2003).

Sustainable Agribusiness

Surveys among the goat farmers produced ten challenges, namely; 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 yet the market is small due to seasonal needs, and competition with the other livestock productions is fierce. The low numbers of small ruminant producers and little record keeping/databases, resulted in a limited genetic progress in the goats and sheep industry (Tedeschi *et al.* 2011). Major factors such as the increasing human population and limited lands available for livestock, created an importantly decreasing opportunity for goat and sheep producers. These challenges have negative consequences on the agriculture industry, the environment, the economy and the quality of life. The cost of production negatively impacts those producers who are rotating pastures more so than those producers not rotating pastures. The fact that goats are bought and sold several times before slaughter and processing reflect a poor marketing system. Overwhelmingly, most producers agree that poor government support contributed to more production challenges.

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

CONCLUSION

Goats and sheep are valuable livestock as they feed the world, produce valuable byproducts, and serve as specimens both for agriculture and biomedical researches. Thus, in order to increase the goat and sheep production systems, there is a need to minimize, if not to eliminate the effects of the limiting factors against the efficient, sustainable, and profitable production of goats and sheep in the United States and the world, and to educate the public on the advantages of goat milk and meat, fleece, and other products.

As a currently expanding livestock industry, there is comparatively limited information available about goat meat 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 just among the many solutions. Veterinarians and extension agents could communicate better with producers by providing educational programs on the best practices in breeding, health, and nutritional management. Along with research, extension, and animal scientists, the government support for the industry could help solve difficulties by improving laws, marketing, trade, and perhaps by providing more local processing plants (Gillespiex *et al.* 2013).

This paper has highlighted science-based solutions to address the major challenges presented. These include educating and training the next generation and the general public, conducting innovative/transformational/translational research, improving the animal health, and developing sustainable agribusinesses. Thus, this review envisions to help the animal producers and the public to better understand the goat and sheep science and thereby develop resilience towards the current and future challenges in the industry.

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