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Ingredients and Pathways for Sustainable Sheep Breeding Strategies under Low Input Production Systems: The Example of Two Distinct Sheep Breeds

Djemali M*[1] and Hamrouni A[2]

[1]Animal Genetic and Feed Resources Research Lab, INAT, Carthage University, Charles Nicole Mahrajène, Tunis, Tunisia
[2]Animal Genetic and Feed Resources Research Lab, INAT, Carthage University, Tunis, Tunisia

***Corresponding author:** Djemali M, Animal Genetic and Feed Resources Research Lab. INAT, Carthage University, 43 Avenue Charles Nicole 1080 Mahrajène, Tunis, Tunisia, Tel: +216 98 319 029, E-mail: mdjemali@webmails.com

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Abstract

Near East and North Africa have 90 percent of their territory classified as arid or semi-arid rangelands. Increasing importation of animals and animal products are still followed due to an increasing consumers' demand and poor producing abilities of existing native breeds. The objectives of this paper were to: 1) underline major genetic constraints for improving native sheep breeds productivities under low input production systems, 2) identify main ingredients and pathways for sustainable sheep breeding strategies under low input production systems. The Sicilo-Sarde dairy sheep, which represents the only specialized dairy sheep, breed in Tunisia and North Africa went through a dramatic decline in its population size in mid-nineties due to indiscriminate crossing and a very low milk price. The breed was rescued by the formation of a breed association in 2003. Breed owners doubled their milk price in one year by negotiating it through the association and the breed-regained interest. National and international research programs joined efforts to work with the association to cut down inbreeding in the remaining flocks, optimize feeding, nutrition and genetics. Inbreeding was brought down by injecting Italian sarda genes using Intra uterine AI. Phoenicians introduced the Barbarine sheep from the steppes of Central Asia in the Carthaginian period, 3000 years ago. Even though major research work (inventories, genetics and genomics) was conducted for more than 60 years on the Barbarine sheep in North Africa, the breed is showing a decreasing producing ability in growth traits. Barbarine lambs weaning weights have decreased on average by 8 kg since the sixties. Low heritability estimates found for its growth traits under low input systems appeared to be the reason for not investing in breeding programs even though genetic variation exists. Ingredients and pathways to establish sustainable breeding strategies for sheep breeds raised under low input environments were presented.

Keywords: Diversity; Genetics; Barbarine; Sicilo-Sarde; Production System

Introduction

Animal genetic resources are playing many important roles for humankind. Besides providing food, their social, cultural and environmental contributions are recognized worldwide and their diversity represents the raw material to improve productivity and satisfy changing consumers demand while coping with climate uncertainties. Small ruminants, especially native breed types, play an important role to the livelihoods of a considerable part of human populations in the tropics, Africa and Asia from socio-economic aspects. Therefore, integrated attempt in terms of management and genetic improvement to enhance production is of crucial importance. The majority of sheep and goats in developing countries are encountered in low input production systems and the resilience of local communities in rural areas is often linked to the wellbeing of small ruminants. The latter make use of scarce feed resources in predominantly semi-arid and arid environments to convert them into nutritionally valuable products. Low input farming systems, under these circumstances, do not only allow preserving these valuable assets for the poor, but also ensure access of animal products to urban populations [1]. From a total of 681 reported goat breeds by FAO, many breeds were reported to display adaptations to mountains regions (62), to heat (30), to humidity (7), to cold (14), to extreme diets (11), to water scarcity(20) and to dry environments (20) [2]. From a total of 1283 sheep breeds reported by FAO in 2015, breeds that showed tolerance to heat were 83, cold (57), humidity (2), extreme diets (21), water scarcity (21), mountainous regions (151), and 55 are adapted to dry environment [2]. Small ruminants' genetic diversity stands as a real biological reservoir of alternatives for the world to cope with a variety of environments and climatic constraints. Economical and biological efficiency of sheep production systems generally improves by increasing productivity and reproductive performance of ewes. It is worth noting that some of these breeds are still at their "raw stage" and others are under indiscriminate crossing due to a lack of suitable breeding schemes. The objectives of this paper were to: 1) underline major genetic constraints for improving native sheep breeds under low input production systems, 2) demonstrate the importance of farmers organization in saving and promoting threatened breeds, and 3) identify main ingredients and pathways for sustainable sheep breeding strategies under low input production systems.

Importance of livestock in NENA region

In a region like Near East and North Africa (NENA) in which 90 percent of the territory is classified as arid or semi-arid rangelands, increasing animal numbers and importation of animals and animal products are still followed to satisfy a massive demand for animal products [1]. Livestock share of Gross Value Agricultural Production in NENA region varied in 2013 in many countries of the region between 24% and 53%. FAO statistics in 2014 showed that the region meat production, meat consumption and meat importation represented 2%, 4% and 15% (14% beef, 21% poultry and 34% sheep and goats) of the world, respectively [1]. This highlights the need for a new policy orientation towards reducing flock/herd growth and increasing animal productivity through breeding schemes efficiency. Empowering the region in animal breeding skills to establish suitable breeding strategies is a potential pathway for the region and similar regions to cope with increased production costs by improving animal's productivity. Since 2008, when agricultural commodities and food prices skyrocketed, cost of agricultural production increased, farmers revenues decreased and social crises dominated many parts of the world [1]. The impact of currency devaluations in countries in the NENA region, particularly Tunisia, Algeria, and Morocco, continue to maintain high feed prices in local markets [1]. Consequently, options for the management of existing animal resources, including small ruminants, in a sustainable way become essential to empower increasing populations to secure their food needs. Suitable animal breeding pathways will not only improve the productivity on a cumulative way, but also will reduce the pressure on already fragile lands. The FAO second report on the State of the World's Animal Genetic Resources for Food and Agriculture [2] highlighted that the majority of countries reported the presence of breeding programs. It should be clear that, beside cattle, mainly dairy, the activities referred to in the FAO report are only fragments of coherent breeding strategies [2]. The low production ability of native sheep breeds was the origin of many crossing programs with imported exotic breeds leading to a real threat to their integrity and a major reason for their extinction. This is happening in times when it is possible to establish suitable breeding programs as well as coherent crossbreeding activities to enhance native breed's ability to better produce even under harsh conditions.

The Barbarine Breed between science and reality

In Tunisia, like many other developing countries, small farmers in rural areas are the ones who own most of small ruminant genetic resources (80%). The Barbarine fat-tailed sheep is the most numerous and important breed in the country with a distribution in all agro ecological zones from temperate to desert passing by the semi-arid and arid production environments. The Phoenicians introduced the Barbarine from the steppes of Central Asia in the Carthaginian period, 3000 years ago [3]. During lifetime, the Barbarine can store between 5 to 8 kg of fat in its tail as a body reserve to be mobilized under harsh conditions. There are approximately 4 million breeding females in Tunisia, 60 % of them are the fat tail Barabrine. It is worth noting that a large scientific work has been accomplished on the Barbarine breed for more than 60 years and thus at all levels (physiology, nutrition, and genetics) [4-6]. A national program including animal identification and performance recording was established since the sixties for the Barbarine breed.

Even though numerous scientific efforts were made to characterize the Barbarine breed (production, reproduction, genetics) and to describe its adaptation traits as the tolerance for high temperatures, extreme diets and water shortage, lamb weights at weaning (90 d.) have decreased, on average, by 8 kg since the sixties [7]. Various reasons could be given to explain this linear decrease. However, when the breeding strategy of the Barbarine was examined, many weaknesses were identified including the lack of a description of clear breeding objectives for the breed, no definition of the relevant traits involved and their economic weights are still not known. A few rams are selected every year, not enough to satisfy a comfortable level of the breed population size. A coherent breeding scheme is still missing for the Barbarine breed [7]. Livestock owners, developers and policy makers should be fully aware that sustainable management breeding strategies rely on technical and organizational components. The technical component includes identification of animals, selection objectives, traits to measure, genetic evaluation end dissemination of the genetic superiority. The organizational component includes farmers organizations or breed associations and selection plans (one tier or two tiers) [8-10]. In absence of all the cited ingredients and components, sustainable management of animal genetic resources will be hard to achieve and scientific findings will have limited impact on the Barabrine genetic improvement or similar breeds. In recent years, the fat of the tail of the Barbarine is becoming a constraint because consumers shifted from fat to lean meat and butchers are having difficulties selling it because it represents 15% of the carcass. This situation has led to an increased trend of thin tail animals in the market at the expenses of barbarine lambs. This trend was encouraged by butchers pretending that thin tail breeds have better carcass yield and meat quality than the Barbarine. Surveys were conducted in known lamb production regions in the country and main results showed that thin tail breeds are butchers favorite because butchers encounter difficulties in selling the fat of the tail of the Barbarine [11]. Butchers apparent judgment is in total contradictions of scientific findings proving that the barabrine and thin tail breeds are not different in carcass yield and carcass quality [12]. In response to butchers attitude, farmers started a massive crossbreeding of Barbarine with thin tail breeds leading to a genetic erosion of the Barbarine genotype. Research and policy makers are still incapable for devising better management strategies for these available genetic resources and stop the loss of a well-adapted breed like the Barbarine. The lack of coherent breeding strategies for the Barbarine sheep is a crucial problem to overcome. Breeed owners should be empowered through organization and a Barabrine lamb chain value to reverse this negative trend dictated by butchers. The need for effective national institutions to implement appropriate breeding strategies for the sustainable management of animal genetic resources is essential for any country or region. Long-term sustainability should be sought to ensure the balance between people, livestock, the rural landscape and food security, including nutrition.

Importance of farmers in saving a threatened sheep breeds

Cases of success in breeding in the world are numerous but when one of these cases is "Tunisian", it becomes interesting. During the French colonial period, the milk of the Sicilo-Sarde breed, the unique dairy sheep breed in Tunisia and North Africa, was processed by the cheese factory "SOTULAIFROM» to a cheese type "Roquefort" which was exported to France. The breed supplied, at that time, to the cheese unit 7000 l/d that represented only 40% of the total milk produced by the breed. Low sheep milk price and privatization of state and cooperative farms, shifting to dairy cattle in mid-nineties, caused a dramatic decline of the Sicilo-Sarde from 200,000 ewes in 1995 to 25,000 ewes in the year 2000 [11].

All attempts by the government to stop this genetic hemorrhage through European cooperation projects have failed. Faced with this impasse, local breed owners, led by a pioneer, had the idea to create the association of the Sciclo-Sarde breed to save and promote it. By a wise and strategic approach, the breed association has devised a roadmap to give the Sicilo Sarde Sheep its fair value. The first step was the negotiation with the Cheese processing factory "SOTULAIFROM" of a decent price for ewe's milk. In one year, the breed association managed to sell the milk of its members at 1.400 DT / l instead of 0.700 DT / l. Farmers negotiating power allowed them to double the price of their milk in one year. The idea of being in association was already an innovation in the capacity building of breeders to better defend their interests. The second step followed was building strong links with national research in the field of nutrition, genetics, product enhancement and health. Seminars, information days and technological packages have been transferred to the field for the benefit of Sicilo-Sarde breed owners. The step that deserves attention is the one that has "put down" the theory that says we cannot transfer high technology to small farmers. It was the operation of Intra Uterine Artificial Insemination, which was carried out three years in a row (2005-2006-2007), and its success was made by the Sicilo-Sarde breed association which orchestrated a whole heavy and careful planning of AI intrauterine. Intra Uterine AI expertise was lacking in Tunisia at that time. It took an Indonesian Vet the first year, then a second Vet from Argentina the second year, a French and a Tunisian Vets in the third year. Thanks to the association, backed up by the National Institute of Agriculture of Tunisia (INAT), the International Centre for Agricultural Research in the Dry Areas (ICARDA) and the Tunisian Livestock Office (OEP, MOA) that milk-improving genes were introduced from Italy via frozen semen and put in Sicilo-Sarde ewes via high technology.

By having a concrete organized body representing farmers, technolgy transfer improved the performance of ewes from 70l / lactation in 2003 to 140 l / lactation in 2008 [11]. The Association invested to establish their own milk collecting center and a genetic improvement program to select young rams. As a concrete result, the dairy capacity of Sicilo Sarde ewes has improved and the income of farmers, including small farmers, has improved. Farmers organization were able to reverse the situation of their breed from being threatened of extinction to an essential link in a complete production chain. This case has encouraged "Black Thibar" sheep breed owners, from the same region, to form their own association and promote their breed. The Sicilo Sarde case is a true success story for the efficiency of breeding and farmers organization under Low Input Production Systems (LIPS).

Major genetic constraints for genetic improvement under LIPS

Heritability estimates are based on the ratio of the genetic component, usually the additive component, to the total phenotypic variance [8,13]. When heritability estimates are not low, setting up selection programs are encouraged. Under low input production systems, small heritability estimates were usually reported due to a large phenotypic variance. The scope of heritability estimates, under low input production systems, showed relatively low values not encouraging breeders to follow selection pathways under given circumstances. This was a main reason for not recommending selection under such circumstances and, consequently, no effort is invested in genetic improvement of breeds under low input environmental production conditions. This situation was a major hidden constraint for the lack of suitable breeding strategies to promote autochthonous breeds. In animal breeding, direct and maternal heritability estimates and evaluation models were recommended for a variety of breeds within a variety of environments in the world. Using two different models, where the first included a direct additive effect and the second included a direct additive, maternal additive, maternal environmental and the genetic covariance between direct and maternal genetic effects for lamb weights and lamb weight gains, showed that in both models, the residual variances remained high and almost the same [14]. This showed that the additive genetic variance, given by the first model (the additive one), was divided in the second model into different variance components (direct additive, maternal additive, maternal environmental variance and the genetic covariance between direct and maternal genetic effects). The additive direct model reflected the available genetic variability but it does not recognize the maternal component described by the second model. The maternal model gave smaller heritability estimates because the splitting of the existing genetic variance in different sub components while the error variance remains large and almost the same as in the direct model. This is why Bedhiaf and Djemali (2006) [15] proposed to use new genetic ratios instead of the classical heritability formulas. The new genetic parameters seemed to be more appealing to fit low input production systems. The new ratios described the contribution of the additive and the maternal effects to the total available genetic variability and not to the total phenotypic variability. Excluding the error variance from the total phenotypic variance does not make sense "statistically", but, may be, future generations should come up with a better alternative to express the real weight of the additive genetic variance component when the error variance is high. One aspect should be underlined is heritability estimation in the "narrow sense" is based on the assumption of the absence of other genetic components and covariance's between the additive and dominance and epistasis effects. In reality, all these effects should be considered when evaluating genetic components. Heritability in the "large sense" seems to fit better under low input harsh environments. No doubt that genomics advances are bringing many direct responses and short cuts in predicting animals breeding values directly by reading through their genetic makeup. Being aware that animal genetic variability does exist and can be valued under low input production systems is essential to start building on human resources training and empowering specialized institutions.

There is no doubt that the world is now in its genomic era. While developed countries have reached this era through a cumulative process of all genetics (Mendelian, population, quantitative, computing, statistics and genomics), many developing countries are jumping and investing in genomics without a solid foundation on population and quantitative genetics, computing, statistics and breeding plans. The lack of a "critical mass" of skilled human resources in animal breeding, needed to form a reliable foundation on which genomics can be added, is a major constraint.

Potential ingredients and pathways for sustainable sheep breeding in low input production systems

Since the rediscovery of Mendel's Laws in early 1900's until today's genomics era, advances in genetics have been milestones in human's history and in livestock development. Their impact has been cumulative and beneficial in providing food and improving animals' productivity. This is true for developed countries that invested in science and genetics in environments where farmers joined efforts in breed associations and competed to promote their breeds and become animal genetic exporters. On the other hand, the majority of developing countries are still food and animal genetics importers. This is happening at the expenses of a large reservoir of native breeds known for their adaptation traits but with poor producing abilities compared to imported breeds. The majority of developing countries has more than 70 percent of the land, used for food and agriculture production, and approximately 80 percent of the world's livestock with 70 percent of all breeds [10]. In September 1999, a workshop was held in Bella, Italy on developing breeding strategies for lower input animal production environments. The emphasis was on how to make genetic changes in medium and low input production systems. The need to maintain and improve local genetic resources has been recognized as a priority, at the world level [10]. Given their diversity, adaptation and their various roles played under low input systems, native breeds, like small ruminants, are capable to be efficiently productive if essential ingredients and coherent breeding schemes are implemented and followed. Breeding strategies should involve high-level decision makers, farmers, and technical skilled human resources. Specific livestock development goals should be defined [9]. The available genetic variation for native breeds is the raw material that can be used to make them more efficient in using available feed and water resources even if they are scarce. Breeding goals, animal identification, traits recording, genetic evaluation, and breeding structures to use the best animals and generate genetic progress are key ingredients and pathways to generate genetic progress and improve the productivity of native sheep breeds in a cumulative and sustainable way. Biodiversity studies depicting a deep picture of the genetic variability of the available sheep breeds provide favourable opportunities for both genetic conservation programs as well as enhancing production efficiency by means of controlled and well-designed crossbreeding systems exploiting breed diversities, heterosis and breed complementarity [16]. The maintenance of genetic diversity in livestock species requires the adequate implementation of conservation priorities and sustainable management programs, which should be based on comprehensive information regarding the structure of the populations, including sources of genetic variability among and with breeds. It is still worth in investing in human resources training and education to be able to match classical genetics with genomics in order for developing countries to be able to save their animal genetic resources and establish reliable bases governing the development of sustainable animal breeding strategies.

Conclusion

This paper focussed on the importance of native sheep breeds as a reservoir of genetic variability to produce food under low input production systems. The poor producing ability of native sheep breeds is linked to the absence of coherent breeding strategies and farmers organizations. There are, however, potential ingredients and pathways to establish reliable bases governing the development of future sustainable sheep breeding strategies in low input production systems. Examples from NENA region were used and discussed mainly the Barbarine fat tail breed and the Sicilo Sarde dairy sheep.

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