



PRODUCTION CHARACTERISTICS OF INDIGENOUS IRAQI SHEEP BREEDS: A COMPREHENSIVE REVIEW

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Abstract. Indigenous Iraqi sheep are a valuable part of the country's livestock genetic resources and provide a significant contribution for meat, milk and wool production, rural livelihoods and food security. The knowledge available is summarized on the major indigenous Iraqi sheep breeds Awassi, Hamdani, Karadi, Arabi and Guraishi focusing on their production traits, phenotypic diversity, adaptive capacity, and their genetic potential for improvement. There is considerable differences between these breeds in their size, growth rate, carcass characteristics, milk yield and quality, and wool quality. The northern breeds, such as Hamdani and Karadi are in general relatively large, and have desirable meat production qualities, while the Awassi breeds are especially valuable for milk production and their adaptability to the semi-arid environment. The Arabi sheep are highly adapted to hot environments of southern Iraq and yet they have good reproductive and milk productivity. There is also significant variation among individuals within breeds (within-breed variation) which has been documented in available studies and can be exploited through selection without loss of valuable indigenous genetic resources. The Iraqi sheep are mostly fat-tailed and have adaptive traits that enable them to withstand the variability of feed availability, climatic stress and extensive production systems. Yet, the productivity is still held back due to poor nutrition, degradation of forage resources, lack of organized breeding programs, disease pressures and the lack of contemporary characterization of some populations, namely Guraishi sheep. Moreover, wool of some breeds remains completely poorly characterized and the potential in the field of traditional and value-added products is not exploited. Future improvement programmes should incorporate standardisation of phenotyping, molecular and genomic tools, reproductive and production data, and conservation. This method would not only improve the productivity of sheep but also maintain the indigenous adaptability and genetic diversity in Iraqi sheep.

Keywords: Indigenous Iraqi sheep; Awassi sheep; Hamdani sheep; Karadi sheep; Arabi sheep; Production characteristics; Genetic resources; Phenotypic diversity

Introduction

One of the oldest domesticated livestock species, sheep have been vital to agricultural systems for more than 10,000 years. They are known for their resilience in cold conditions, their high productivity of marginal grazing areas and their ability to produce meat, milk, wool and skins, which makes them a critical component of livestock production, especially in dry and sub-humid areas. Sheep are found in all continents, and the world sheep population exceeds 1.3 billion, with most sheep in Asia and Africa; they play an important role in food security and the lives of rural communities in Asia and Africa, particularly in developing countries and transform low quality forages into high quality animal protein without requiring much management. The Middle East, particularly the Fertile Crescent (modern-day Iraq), is an important region for sheep domestication, where selection of a range of different fat-tailed breeds was crucial for the pastoral and mixed farming systems. Over the centuries, these breeds have contributed to products, cultural and socio-economic values. Natural and human selection have given indigenous breeds remarkable adaptations to local climates, endemic diseases and nutritional challenges.

Iraq has many sheep genetic resources in its indigenous flocks and sheep are the most abundant livestock in the country. These breeds are known for their ability to adapt to their environment, particularly in regions with environmental limitations, such as drought resistance and resistance to local diseases and ailments. There is a considerable diversity of indigenous breeds such as Awassi, Hamdani, Karadi and Arabi with each breed having distinctly different morphological and functional characteristics and well adapted to specific ecological zones, which is extremely important for sustainability of livestock in future. However, indigenous Iraqi sheep have not been investigated as much as European breeds, and not many researchers and policy makers have a comprehensive knowledge about them. Genetic diversity is essential for traits like disease resistance and reproductive efficiency, and is at risk due to threats such as crossbreeding, urban expansion and climate change. The molecular and genomic tools available for quantifying genetic diversity within indigenous populations can also be used to aid in the improvement of these populations while retaining adaptive traits. The review will synthesis knowledge about indigenous Iraqi sheep breeds with elements of classification, geographical distribution, adaptive capacity, and will discuss with breeding strategies and conservation problems. Finally, it aims to serve as a useful guide for stakeholders in sheep production and conservation of genetic resources.

Methods

This study employed a comprehensive literature review approach to synthesize available scientific evidence on the production characteristics of indigenous Iraqi sheep breeds, with particular emphasis on Awassi, Hamdani, Karadi, Arabi, and Guraishi sheep. Relevant peer-reviewed journal articles, scientific reports, books, and institutional publications addressing breed characteristics, production systems, morphological and phenotypic traits, growth performance, carcass characteristics, milk production and composition, wool characteristics, environmental adaptation, and genetic resources were examined. Studies providing quantitative or descriptive information directly related to indigenous Iraqi sheep were prioritized, while publications concerning other sheep populations were considered only when they provided relevant comparative or contextual information. The selected literature was critically reviewed and organized thematically according to major production traits and breed characteristics. Information from the included studies was then comparatively synthesized to identify differences among breeds, within-breed variation, production potential, environmental adaptability, existing knowledge gaps, and opportunities for genetic improvement and conservation. Particular attention was given to differences in management conditions, nutrition, sex, age, production environment, and measurement procedures when interpreting results across studies. This approach enabled the integration of historical, phenotypic, productive, and genetic evidence into a comprehensive assessment of indigenous Iraqi sheep resources and their potential contribution to sustainable livestock production and future breeding programs.

Results and Discussion

Sheep Production in Iraq:

Historical Background of Sheep Production in Iraq:

The land of Iraq has a special place in the history of domestication of animals because it is situated in the Fertile Crescent, one of the earliest regions of agricultural development. Sheep husbandry began in organized fashion in the area, as evidenced by archaeological evidence, about 10,000-11,000 years ago when the Asiatic mouflon (*Ovis gmelini*) was domesticated [1, 2]. Sheep have been part of Iraqi agriculture since then, producing meat, milk, wool, skins and manure and providing the economic security of pastoral and smallholder farming communities. Sheep production has a long history in Iraq, and the result of this production, as well as natural and artificial selection, are the development of some indigenous breeds that are very adapted to the various ecological conditions in Iraq [3].

Sheep have been traditionally kept in extensive production systems, grazing natural pasture during the summer in the northern mountains and then moving to the central plains and southern semi-arid regions. In these systems, animals were able to survive when water availability was limited, the quality of forage was variable, and the ambient temperature was high. Indigenous breeds have been bred and adapted to Iraqi conditions over centuries to possess useful characteristics such as utilization of feed, resistance to environmental stress, and satisfactory production performance with low levels of inputs [4]. Despite the introduction of semi intensive and intensive systems of production in some parts of Iraq, traditional pastoralism still supports a significant fraction of the sheep industry in Iraq.

Current Status of the Iraqi Sheep Industry:

Sheep are the main livestock production in Iraq and one of the major agricultural resources in the country. The Food and Agriculture Organization (FAO) [5] states that Iraq has several million sheep spread across all the governorates, but the number of sheep fluctuates each year due to climatic conditions, disease outbreaks, feed availability, and socio-economic conditions. The national flock is largely comprised of indigenous breeds of which Awassi is the most common, followed by Hamdani, Karadi, Arabi and several local breeds [3]. Sheep meat and dairy products are major sources of food security as they are provided to local markets, where the sheep industry plays a significant role. Sheep meat is one of the most popular meat protein products among the Iraqi people, due to its good taste, its cultural value, and its suitability in traditional Iraqi cuisine. Sheep are also used for meat production, and the milk used in production of yoghurt, cheese, and other dairy products is an important source of income for rural communities, especially where small-scale production methods are used and are an important household activity [4].

Although sheep are an economic asset, the Iraqi sheep producers are encountering several problems which have impeded their productivity in recent decades. These include deterioration of natural rangelands, escalating feed costs, extended droughts, climate change, infectious diseases, lack of veterinary support in some regions and inadequate implementation of structured genetic improvement schemes. In addition, political unrest and changing land use have impacted traditional grazing and livestock mobility, decreasing the production efficiency in some areas [3].

Major Sheep Production Systems in Iraq:

Sheep production in Iraq can generally be classified into four major management systems, each characterized by distinct feeding practices, flock sizes, and production objectives.

Nomadic Production System:

The nomadic production system remains common in the western desert and some northern mountainous regions. Under this system, shepherds migrate seasonally with their flocks in search of pasture and water resources. Feeding depends almost entirely on natural vegetation, with limited supplementation during periods of forage scarcity. Although production levels are relatively low compared with intensive systems, production costs are also comparatively low because grazing resources constitute the principal feed source [3]. Indigenous Iraqi sheep are particularly well adapted to this production system because they possess excellent walking ability, tolerance to prolonged water deprivation, and the capacity to utilize sparse vegetation efficiently. Fat deposition in the tail serves as an energy reserve during periods of nutritional deficiency, allowing animals to survive seasonal fluctuations in feed availability [3], [4].

Semi-Nomadic Production System:

In many regions of Iraq, the management system for farming is semi-nomadic. Aerial feeding of flocks occurs in favourable seasons with barley grain, wheat straw, hay or crop residues being fed in winter and drought conditions. This is a hybrid of the two management styles, and generally leads to better reproductive success and growth rates than nomadic management due to a partial mitigation of the negative effects of nutritional deficiencies through feed supplementation [4]. In the northern part of Iraq, the seasonal growth of pasture is aided by rainfall and most commercial Awassi and Hamdani flocks are grown under semi-nomadic conditions.

Semi-Intensive Production System:

During the past decades, semi-intensive production has grown significantly as producers have sought increased productivity. As part of this management system, sheep graze for short durations, and receive formulated, concentrated feed and conserved forages within enclosed production areas. Feed quality and quantity positively affect growth rate, reproductive efficiency and milk production, especially in late pregnancy and lactation stages in breeding ewes [3]. Semi-intensive systems also allow for better health management, genetic selection, control breeding and production records, so they are well suited for genetic improvement programs.

Intensive Production System:

Intensive sheep production however is relatively small in Iraq but is gaining significance around urban centres where high quality meat and dairy products are becoming more in demand. Animals are kept during the majority of production period and fed balanced concentrate diets to ensure optimal production. These are carefully monitored, and in practice the feed conversion ratio is better, and growth rates are higher than those of conventional systems [3]. It is however, not widely used among smallholder farmers due to the need for financial investment, managerial expertise and a reliable supply of feed, which are not available in large numbers to most farmers in the target areas.

Economic Importance of Indigenous Iraqi Sheep:

The economic significance of sheep production extends far beyond meat production. Indigenous Iraqi sheep generate income through multiple products, including milk, wool, skins, breeding stock, and manure. This multipurpose production system enhances household resilience by diversifying revenue sources and reducing dependence on a single agricultural commodity [3]. Sheep are particularly valuable for smallholder farmers because they require relatively modest initial investment and reproduce efficiently under extensive management. In many rural communities, sheep function as a financial reserve that can be sold during periods of economic hardship, thereby contributing directly to household food security and poverty reduction [3].

Awassi sheep, the dominant dairy breed in Iraq, produce milk that is widely used for manufacturing traditional cheeses and fermented dairy products. Their relatively high milk yield among fat-tailed breeds has also attracted international interest, leading to genetic improvement programs in several countries outside Iraq [4]. Hamdani and Karadi sheep are primarily valued for meat production because of their larger mature body size and favorable carcass characteristics, whereas Arabi sheep exhibit excellent adaptation to the hot climatic conditions of southern Iraq, ensuring sustainable production under harsh environments [3]. The continued conservation of indigenous Iraqi sheep breeds therefore represents not only an agricultural priority but also an important component of national food security, rural development, and the preservation of valuable animal genetic resources. Their unique combination of productive performance and environmental adaptation provides an essential foundation for future breeding strategies aimed at improving livestock productivity while maintaining resilience under increasingly variable climatic conditions [3], [4].

Morphological and Phenotypic Characteristics of Indigenous Iraqi Sheep:

Morphological characterization is one of the basic steps for the identification, classification, conservation and genetic improvement of animal genetic resources [6]. Prior to the use of molecular markers, external appearance, body conformation, coat attributes, horn type and body measurements were used as the main distinguishing features of sheep breeds. Despite the usefulness of the genomic tools to obtain more accurate data on the genetic relationship, phenotyping remains an essential tool for several reasons: first, it is low cost and is feasible under field conditions, and second, it is directly linked to productive performance and adaptation [6].

The morphological diversity in indigenous Iraqi sheep is a result of their adaptation to the varied

ecological zones from the mountainous regions of northern Iraq to hot alluvial plains and semi-desert regions of central and southern Iraq that they have occupied over thousands of years. Recognizable breed-specific phenotypes have developed, but common features of fat-tailed sheep characteristic of West Asia have been retained, through environmental, management and long-term natural selection [3]. One of the most extensive phenotypic descriptions of Iraqi sheep was performed at the national level recently by Rajab et al. [7]. The animals examined were 572 sheep of the five breeds (Awassi, Hamdani, Karadi, Arabi, and Guraishi) and the animals were morphometrically examined following standard procedures under the same conditions, and the results were presented in terms of several morphometric and qualitative traits. The study confirmed statistically significant phenotypic variation among the indigenous populations and a high diversity within the Iraqi sheep genetic resources [7].

Body Size and Live Weight:

Body size is one of the most informative characteristics as it affects growth performance, maintenance needs, carcass yield, reproductive ability, and market value. The differences in body size of Iraqi sheep breeds are linked to the genetic backgrounds and environmental adaptations. Rajab et al. [7] showed that there was a clear geographical trend in the body size of the national study. Generally, sheep from the north were found to be larger in body size and higher in live weight than sheep from the south of Iraq. The overall body weight of the Hamdani sheep was highest while that of Guraishi sheep came close to being highest, followed by Karadi and Awassi sheep in the intermediate position. The Arabi sheep always had the smallest mature body size of the breeds studied [7].

This north-south gradient may be attributed to a combination of factors such as climate, pasture availability, altitude, selection practices from the past, and local production goals. Rainfall in the north is greater than that in the south in Iraq, and the natural vegetation in the north is more productive, resulting in better nutritional conditions for the skeletal development and body build.

But bigger size does not necessarily mean higher productivity. Moderate grower weight animals also may result in reduced maintenance energy demands and exhibit higher biological efficiency within extensive grazing systems. Therefore, body size optimum depends on the production environment not just based on maximum body weight at adulthood [3].

Linear Body Measurements:

Linear body measurements are objective descriptions of body conformation which are widely used in identification and selection of breeds, for estimating live weight and for selection of breeding animals. Common measurements taken are: the height at the withers, body length, heart girth, and chest length, width and depth, hip width and length, rump length, cannon bone circumference, head length, ear length and tail length. Of these the heart girth has consistently been shown to be one of the best indices of live body weight in sheep. Karim and Karym [8] found that there were good relationships between body dimensions and live weight of Karadi sheep which make the use of morphometric measurements a good option for estimating live body weight in absence of scales. These are especially useful in smallholder production systems in Iraq [8].

The same results were reported by Rajab et al. [7] in case of Iraqi breeds, in which significant differences were found between the breeds for most morphometric traits. However, chest circumference had smaller variation as compared to some other measurements, and it would be unadvisable to use a single linear measurement in isolation for breed discrimination. There are several benefits to the use of morphometric data in breeding programmes. Body measurement is a inexpensive method to obtain, simple equipment to use and could help identify animals with desirable growth potential prior to slaughter. These measurements, along with pedigree and performance data, help to more accurately assess genetic merit.

Coat Color and Pigmentation:

One of the most obvious qualitative traits in identification of breeds is coat color. The coat colour of the horses is determined by relatively few genes as compared to quantitative production traits but offers valuable information about breed identity and population structure. Most Iraqi local sheep have a whitish fleece with darker markings on the face, ears or on the lower part of the limbs. This is a typical trait of the Awassi, Hamdani and Karadi sheep [3]. The economic value of coat color is of relatively small importance. However, it may have an impact on heat absorption, camouflage, preference, and acceptance among the regional population. Furthermore, there are commonly field indications of the pigmentation patterns during breed registration and conservation programmes.

Head Profile, Ears, and Horns:

The head is one of the most characteristic regions to be phenotypically characterized. The indigenous Iraqi sheep breeds normally have convex facial profile (Roman nose) which is usually observed in Awassi and Hamdani breeds. Many West Asian breeds have this trait, and it has been long known as a characteristic of many such breeds [3, 4]. Ear shape varies between breeds, too. The Awassi sheep normally have long drooping ears while the Karadi and Hamdani sheep have medium to long ears. Under field conditions, ear size and ear orientation are relatively stable, qualitative traits, which also can help to breed identification. Horn development is strongly influenced by sex. Rams have well-developed coiled horns and females are polled or have only slightly developed horns. The presence of horns is no longer economically important in the contemporary production system, but is useful for breed description, it may be an historical selection among pastoral communities.

Fat Tail Morphology:

The indigenous Iraqi sheep has one of the best developed fat tails that is seen in any sheep breed. Sheep are the most productive species in the Middle East, North Africa and Central Asia, and are one of the most successful adaptations to dry environments [3]–[4]. Fat tail is a specialized adipose tissue depot that can store excess dietary energy in times of nutritional abundance. They can be utilized in times of drought or lack of seasonal feed for maintenance, reproduction and survival. There is therefore a greater resilience to fat-tail development under extensive grazing where feed availability is highly variable throughout the year.

All major Iraqi breeds have fat tails, but there are some variations in tail size, shape and distribution of fat. The differences might affect carcass composition and consumer preference, especially since the tail fat is a significant culinary component in many Middle Eastern countries. It is important for modern breeding programs to consider the dual importance of fat-tail morphology. Under low input conditions with frequent nutritional stress, moderate amounts of fat can be beneficial, but under intensive systems it can negatively affect the percentage of lean in the carcass.

Sexual Dimorphism:

All the Iraqi indigenous sheep breeds are sexual dimorphic. Generally, the adult ram is larger than the ewe in body size, skeletal size, and muscle growth. They also have a better development of horns and wider head shape. These differences are mainly due to the endocrine control of growth with anabolic effects of testosterone on muscle and skeletal development. Studies conducted on Karadi sheep have also shown larger body size in male than in female [9], [8] while Ayied et al. [9] reported that the mature growth potential of the male Arabi sheep is more than that of the female. During breed evaluation, recognition of sexual dimorphism is vital as comparisons between breeds must be made between the different sexes. The lack of consideration of sex differences may mask true breed differences.

Phenotypic Variation Within Breeds:

There is variation both between breeds and within each indigenous breed. Variations in body size, pigmentation, wool traits, and growth rate can be due to nutrition, age, management, health, environmental factors, and genetic differences. Within-breed variation is the basis for genetic improvement since selection must be based on the ability to maximize the number of good individuals within a certain number of good genes. An overemphasis on a limited number of phenotypic traits could have a negative impact on the effective population size and inbreeding. Therefore, phenotypic characterization should be used with pedigree data and molecular genetic analysis, if possible. The most reliable way of identifying breeding animals with a value from a genetic point of view is to combine the two pieces of information (morphological and genomic).

Growth Performance and Meat Production Characteristics:

Growth and meat production are important traits in sheep production in Iraq, as lambs and mutton are among the most important commercial products of most indigenous flocks. Milk and wool payments are important additional contributions for producers of these products in Awassi and some northern populations, but for most producers, lamb survival, growth rate, market weight, carcass type, and feed efficiency are important economic factors. There are significant differences in mature body size, growth rate, agricultural characteristics, and nutritional response among Iraqi breeds, which are related to genetic, geographic, and production system.

Birth weight is a key factor affecting lamb survival, lamb growth to weaning, and lamb production

after weaning. It is affected by genotype, sex, litter size, ewe body condition, nutrition of the ewe in pregnancy and season of lambing. Male lambs are typically larger than female lambs in indigenous Iraqi sheep and single-born lambs are heavier than twins. These relationships are similar to those reported in Awassi and other fat-tailed sheep breeds in the Middle East. Under extensive production, early growth is especially significant as the lambs that grow poorly during the suckling phase can suffer significant reduction in survivability and slower rate of market weight gain. Thus, maternal milk production indirectly affects meat productivity. This explains why Awassi sheep, although well established as a dairy type of breed, can produce satisfactory numbers of lambs when managed appropriately.

The relative importance of the birth weight should, however, be taken with a pinch of salt. Very high birth weight has been found to be associated with increased risk of dystocia and very low birth weight has been found to be associated with increased risk of neonatal death and impaired thermoregulation. Ideally, then, breeding for birth weight should be for an optimum rather than a maximum weight.

Post-weaning growth is a measure of lambs' ability to convert feed nutrients into body tissue and thus is directly related to slaughter age and production cost. There are many factors that affect average daily gain, such as genotype, energy intake, dietary protein, health, sex, and management. Yateem et al. [10] have tested Awassi lambs with diets of various ME levels. A total of 21 lambs (about 4 months of age, an average weight of 23 kg) were fed low-, medium-, or high-energy diets for 72 days. The highest energy treatment lambs had a mean daily gain of around 189.7 g/day in addition to superior feed efficiency and desirable carcass traits. The results show a great ability of Awassi lambs to respond to enhanced nutritional provision.

The ratio of protein to carbohydrate in the diet can also have a significant impact on growth performance. Yateem et al. [11] performed another experiment with Awassi lambs with three protein diets. The highest protein lambs had average daily gain of around 210.8 g/day with the best feed efficiency and carcass traits when compared to the lower protein treatments. These studies demonstrate a key point in the interpretation of the performance of breeds in traditional grazed systems low growth rates do not necessarily reflect indigenous sheep's genetic potential. With a proper match of energy and protein, much more can be harvested, but the nutritional factors can have a significant effect on suppressing growth.

Comparative evaluations are better evidence of genetic differences than are isolated within-breed studies. Al-Sherwany and Alkass [12] directly compared Awassi and Karadi male lambs fed two levels of feed and slaughtered at two weights. There were 616 lambs in total, 16 weaned lambs from each breed and the animals were slaughtered at 36 kg and 44 kg and the overall mean daily gain was about 258 g/day. Ad libitum feeding of lambs was significantly greater than feeding lambs 3% of their body weight, with concentrate. Interestingly, some growth traits were not as breed dependent as expected considering only the mature body shape. This is significant because there are clear differences in both morphology and geographic origin between Karadi and Awassi sheep and their growth rates may be very similar when fed standard feed. It highlights the importance of separating body size (phenotype) from real efficiency of growth.

The Hamdani sheep are generally considered to have good meat production potential, due to their large mature size. Comparative data of direct standardized type for Hamdani, Guraishi, Karadi, Awassi and Arabi lambs, however, are still relatively limited. This is a significant deficiency in the sheep research in Iraq. A national breed comparison under the same feeding, age and slaughter conditions would give solid proof to determine the breed specific meat production capabilities.

Feed conversion efficiency is becoming more significant with intensive and semi-intensive sheep production as feed is the most variable cost. An animal with rapid growth that has an excessively high feed requirement may be less desirable economically than an animal with slightly lower growth rate that will have slightly better feed efficiency. On the other hand, a study of the energy levels by Yateem et al., [10] revealed that high energy feeding did not only enhance the performance of Awassi lambs, but also it reduced the feed intake per unit gain. In the highest energy group, lambs had a feed-efficiency value of ~4.7, showing the close association between nutrient density and biological efficiency.

The same was observed in the lambs fed the highest protein level in the protein level study. These findings show that nutrient balance is important more than just the quantity of feed. When comparing

breeds in the future it is important to consider more than just weight gain, but also the residual feed intake, feed conversion ratio, metabolizable energy utilization and protein efficiency. As feed costs increase and environmental constraints make production of animals more efficient, such characteristics will be needed more.

Dressing percentage is one of the most significant commercial meat production measurements, and it is the ratio of carcass weight to slaughter weight. Yateem et al. [10] found that approximately 48.4% of the dressing percentage in lambs fed high energy diet in Awassi breeds. There were positive relationships between growth and carcass characteristics and energy concentration, and slaughter performance is highly dependent on nutritional status.

Dressing percentage was also enhanced with higher protein diets. The highest-protein group achieved an average dressing percentage of about 51.7%, in addition to increased rib-eye area, according to Yateem et al. [11]. The overall dressing percentage based on slaughter weight of Al-Sherwany compared to direct comparison with Awassi was approximately 46.5% and calculated relative to empty body weight was approximately 54.4% for Al-Sherwany. The overall dressing percentage based on slaughter weight of Al-Sherwany compared to direct comparison with Awassi was about 46.5% and calculated relative to empty body weight was about 54.4% for Al-Sherwany. Awassi lambs had higher dressing percentage based on slaughter weight than Karadi lambs. The results have shown that there is significant variation in dressing percentage depending on the method of calculation, dietary treatment, breed, slaughter size, gastrointestinal fill and fat deposition. Thus, in carcass studies it should be clearly defined whether dressing percentage is based on the live slaughter weight or empty body weight.

Muscularity of the carcass and the yield of lean meat can be estimated by the longissimus muscle, which is a common measurement by rib-eye area (REA). Al-Sherwany and Alkass [12] reported an overall rib-eye area of about 15.0 cm² between the two groups of Awassi and Karadi lambs. The slaughter maturity of lambs had significant effect on rib-eye area, with heavier lambs (44 kg) having a larger area than lighter lambs (36 kg).

The highest dietary protein concentration resulted in approximately 12.05 cm² of rib-eye area in Awassi lambs as reported by Yateem et al. [11]. The findings of this study indicate that nutrition can significantly influence muscle development. To improve the animals, selection for increased muscularity should take into consideration feed efficiency and reproductive ability. A high emphasis on achieving lean growth may have a negative impact on ewe maintenance requirements if it is genetically linked to increased mature size.

In Iraqi sheep fat deposition plays a vital role especially all the major indigenous breeds are fat-tailed sheep. A large fat percentage in the tail is possible unlike the thin-tailed European breeds. Adaptively, fat-tail deposition is an advantage in that stored energy can be released in times of nutritional limitation. However, from the modern carcass point of view, over fatness may lead to a decrease in the saleable proportion of lean meat.

The thickness of the fat in the subcutaneous position was significantly higher in Awassi lambs than in Karadi lambs as reported by Al-Sherwany and Alkass [12]. The average fat thickness for their experimental groups was about 2.86 mm, with heavier slaughter weight resulted in more fat thickness. This finding emphasizes the need to establish optimum slaughter weights, specific to the breed. Slaughter delay can result in greater yield of carcass weight and rib-eye area but may also lead to undesirable fat deposition. The optimum slaughter point is thus dependent on the cost of feed, consumers' preferences, the price structure of the carcass and the demand for tail fat.

Another important factor is sex. Due to androgenic effects on skeletal and muscular growth, male lambs tend to grow faster, develop more muscle and deposit fat differently than females. In recent studies on Awassi lambs, the growth performance, carcass characteristics, meat quality, digestibility, nitrogen balance and blood metabolites of Awassi ewes and rams were specifically compared [13]. Twenty-seven lambs were fed under standardized feeding conditions, and the study was found to be useful in elucidating that sex must be taken into consideration when interpreting the results of productive and carcass characteristics in Awassi lambs [13]. This is a critical factor to consider for breed comparisons. If the sexes are not adequately accounted for in the statistical model, sex differences in studies can lead to false breed rankings.

Carcass composition is greatly affected by slaughter weight. As lambs grow, their carcass weight and

muscle area grow, but the percentage and distribution of fat change. In the comparative Awassi – Karadi experiment higher dressing percentage, rib-eye area and fat thickness were obtained from the lambs slaughtered at 44 kg as compared to those slaughtered at 36 kg. This answer manifests a biological-economic contradiction. Gaining weight at slaughter may be beneficial to overall yield of the carcass but may reduce production efficiency due to the need for excessive feed to be deposited as fat rather than lean tissue. So, it is necessary to evaluate optimum market weight for each breed and each production system.

Important factors in meat quality are tenderness, juiciness, flavor, color, water holding capacity, intramuscular fat, pH and nutritional composition. Iraqi consumers have always shown a preference for lambs of indigenous breeds, but a comparison of the objective meat quality of the indigenous breeds by the consumers is still limited. The studies conducted in Awassi in recent years go beyond the traditional growth and carcass studies and have focused on meat quality characteristics, as well as blood and nutritional variables. This research line is relevant because the competitiveness of the future markets will not only rely on the amount of available carcass, but also on the quality of the products. The following may be compared: ultimate pH, meat colour, Warner–Bratzler shear, cooking loss, water-holding capacity, intramuscular fat, fatty-acid composition, protein content, and sensory acceptability. This information could also be used to develop geographical markers or products of excellence for Iraqi lamb.

Extensive systems have had a strong influence on the formation of indigenous Iraqi sheep, rather than intensive feedlot systems. As a result of their biological attributes, they can survive, walk, utilize poor forage, persist in reproduction and recover from seasonal weight loss. These breeds can show significant improvements in growth performance and carcass in semi-intensive systems. The results of dietary energy and protein studies in Awassi lambs clearly demonstrate this responsiveness. In future breeding programmes, however, only the extreme superior result from concentrate feeding should not be selected for breeding. Those animals that excel in high-input environments and struggle in a low input environment such as a rangeland may not be suitable for most Iraqi producers.

More suitable goals would be production efficiency that is strong: to be able to sustain both acceptable growth and acceptable reproductive output in both good and poor environments and at different levels of nutrition.

Milk Production and Milk Composition of Indigenous Iraqi Sheep:

Milk production is a valuable economic contribution to indigenous Iraqi sheep, especially the Awassi breed, and milk is used directly or in traditional dairy products in mixed crop–livestock systems. In addition to market value, milk production by the mother has a significant impact on lamb growth, lamb survival and lamb weaning weight. There is a significant difference between the daily milk yield, total lactation yield, lactation length and milk composition of the different breeds of Iraqi sheep, and is influenced by ewe age and parity, litter size, nutrition, flock management, and genetic background. Within the indigenous breeds of Iraq, Awassi sheep have been considered the most significant dairy breed, while the other breeds such as Hamdani, Karadi and Arabi are multipurpose breeds with milk production being used for both lamb growth and household dairy production. Recent Iraqi studies also showed that these latter breeds may have significantly more dairy potential than is sometimes believed.

The Awassi is one of the most important dairy sheep breeds of West Asia. Its economic value is based on its production of useful milk, the fact that it is relatively high in milk solids, it is well adapted to the environment, and it can produce under semi-arid conditions. Therefore, many milk production trials have been conducted in several countries with these attributes, and Awassi genetics have been valued as a valuable source in the dairy sheep improvement schemes.

Awassi sheep have, however, a strong dairy potential that is highly dependent upon the management. The milk production of traditional flocks can be significantly lower than that of selected dairy populations, due to the lamb suckling, low feed supplementation with concentrates, lower availability of forage during certain periods of the year and shorter recording periods. Therefore, comparisons between studies should be made by differentiating the total biological milk production from the actual milk yield from manual or mechanized milking.

Environmental and maternal factors also affect milk production in Awassi ewes from Iraq. At University of Mosul, a study with Awassi and Hamdani ewes revealed that the breed has significant

effect on daily milk production, and year, ewe age, lamb sex and parity of the lamb were also found to be significantly affecting performance. These findings suggest that the observed milk yield may be a result of a combination of genetic and non-genetic factors as opposed to breeder effects.

Comparative studies between individuals of different breeds are especially informative about breed differences. In the study performed on Awassi and Hamdani sheep at the University of Mosul [14] milk yield and milk composition were studied together with lamb growth. Overall mean milk yield per day for experimental animals was 563.4 g/day, and mean milk fat, protein, lactose and SNF were 6.93%, 5.47%, 4.46% and 10.78% respectively. The breed significantly affected the daily milk yield and the percentage of fat, showing measurable differences in daily milk yield and dairy traits among the Awassi and Hamdani populations.

A larger study was carried out by Al-Dabbagh [14] using records from 1116 Awassi ewes and 432 Hamdani ewes for three years. The study confirmed that several environmental factors and the breed had a significant effect on daily milk output of the cows, and the maternal milk characteristics were also important for the lambs' growth. The relatively high number of records in this investigation is particularly valuable as many breed-comparison investigations in indigenous sheep are of comparatively small experimental populations. The bigger the data set, the more reliable the breed evaluation is and the more firm is the basis for the genetic evaluation.

Hamdani sheep are commonly cited as meat type due to their high body weight but some research in Iraq shows that they have valuable dairy attributes. A comprehensive review conducted recently by Alkass et al. [15] summarized different Iraqi studies that have been carried out on the production of Hamdani ewe milk. The lactation period reported in the literature varied from about 132 to 180 days or more, and lactation yield varied from about 77.3 to 128.8 kg of total lactation per ewe depending on the study. The test-day yields in various flocks ranged from around 0.364 kg/day to 0.792 kg/day.

There's a significant number of differences between studies that's biologically significant. It suggests that the milk yield of Hamdani is affected immensely by flock management, nutrition, recording system, parity, and environment. For instance, the average daily milk production per flock was around 0.521, 0.591, 0.656 and 0.526 kg [15] and this was due mainly to differences in management and feeding.

This work has also shown that Hamdani milk is found to have high levels of fat, protein, lactose and total solids. The high solids content is beneficial for cheese and yoghurt production as milk fat content and casein level have a strong influence on the yield of cheese and yoghurt. Available evidence thus indicates that Hamdani is not a meat sheep only but can also be used as a meat animal. Instead, they are a true multipurpose population with important potential for milk production.

Recent work has begun around molecular evaluation of dairy traits, rather than phenotypic evaluation. Al-Barzinji and Arab [16] studied polymorphisms of candidate genes related to milk production in Hamdani ewes. They found that there were differences in the total and daily milk yield depending on the genotype. Compared to several alternative genotype combinations, the combination of AAABAB at the investigated loci was associated with a total milk yield of around 116.24 kg/ewe/lactation, and a daily milk yield of about 645.75 g/ewe/day. In this study, the importance of the study to the future of Iraqi sheep improvement is that it showed that measurable genetic variation existed within the Hamdani population for milk-production traits. For larger numbers of markers, the information provided by the candidate genes might be useful in addition to the traditional phenotypic selection process; however, before any individual marker can be used in national breeding programs, it needs to be validated in more extensive populations. In summary, the potential to achieve greater predictive accuracy using the thousands of SNP markers associated with genomic selection is likely to be higher than selection based on candidate genes. However, this molecular research are the first steps in the direction of genetically driven improvements of the local Iraqi dairy characteristics.

In the last few years there has been good evidence that, too, Karadi sheep have valuable dairy traits. Karym and Al-Barzinji [17] studied 163 Karadi ewes in Halabja Province of Kurdistan Region in Iraq. The mean daily milk yield was about 613.5 ± 90.06 g/ewe/day with total yield of about 67.05 ± 11.8 kg/ewe during a lactation of about 107.8 ± 11.14 days. These results are significant since detailed dairy studies have been less frequent in the case of Karadi sheep than Awassi sheep. The results indicate that Karadi ewes could be a source of economically viable amount of milk under the northern

Iraqi production environment. The study also calculated breeding values for total milk yield (TLY) and most probable producing ability (MPLY), and a large variation was found for these two breeding values. This variation was interpreted by the authors as the potential for milk productivity improvements in the future through selection within Karadi flocks. This inbreed variation is especially useful. Breeding could be done to enhance indigenous breeds without necessarily replacing them with specialized foreign dairy breeds; very good improvement can be made by identifying and breeding the best performing animals within local populations.

Milk of this type is called karadi milk, which has relatively high solids content. Karym and Al-Barzinji [17] reported average levels of about: Total solids 16.41%; Fat 5.79%; Protein 5.43% and Lactose 4.28%, and they reported that there was strong positive correlation between total solids and individual milk components. The values indicate that Karadi milk is suitable for traditional milk processing. Extra high levels of both fat and protein can boost the nutritional value of the cheese and could lead to a higher cheese yield per kg milk. This is an economically significant point as milk volume can be misleading when evaluating dairy breeds. A moderately high milk solids-producing population can yield competitive amounts of cheese when compared to a high milk solids-producing population. Therefore, milk solids yield should be considered in future economic comparisons of Iraqi breeds along with milk volume.

The Arabi sheep too exhibit useful milk production potential as well as stronger southern Iraqi imprints. Raoof et al. [18] evaluated 122 Arabi sheep and reported daily milk production of 814.65 g, total milk production as 81.49 kg and the average lactation period as 103.53 days. The study also presented the fertility rate (78.10%) and prolificacy (1.50) indicating multipurpose productive capacity of the population.

These values show that the Arabi sheep is not simple low output animals adapted to harsh conditions. With proper management they can reproduce, produce milk and adapt in a "biologically valuable package. For a separate comparison between Awassi and Iraqi Arabi sheep, test under the same conditions was performed by Ahmed et al. [19]. Ten ewes of each breed were used and both milk composition and the effects of all important factors on the daily and total milk production were investigated. The average daily milk production of Arabi group was about 0.77 kg/day, total milk production about 87.7 kg, and average lactation length was about 95 days. The results were consistent with the production level reported by Raoof et al. [18] though the sample size was small. Ahmed et al. [19] reported several composition differences for Awassi and Arabi milks. The concentrations of whey protein were about 0.775% in Awassi and 1.181% in Arabi sheep, respectively, with about 3.683% and 4.321% in Awassi and Arabi sheep, respectively, for lactose. On the other hand, concentration of casein was greater in Awassi milk (3.680%) than in Arabi milk (3.400%). The total solids level was also greater in Awassi milk (11.148%) than in Arabi sheep (9.060%). These differences may have implications for dairy processing since casein affects cheese yield and coagulation properties. In general, cheese and fermented product manufacture is more efficient at higher levels of total solids. The results must, however, be viewed with some caution, as milk composition may differ greatly depending on the stage of lactation, nutritional status, parity, frequency of milking and analytical technique. Therefore, greater standardized breed comparisons are needed before definitive breed rankings can be done.

Several genetic and environmental factors influence milk yield of Iraqi sheep. The factors most often reported in the studies reviewed are the breed, ewe age, parity, body weight, litter size, sex of lamb, lambing season, flock, nutritional level, stage of lactation, and management system. Ahmed et al. [19] showed that milk production parameters were greatly affected by breed, ewe age, birth type, lamb sex, lambing condition and ewe body weight. Likewise, the environmental factors year and maternal age were significant in Awassi and Hamdani sheep studies. These results show how misleading the comparison of raw breed averages from unrelated studies can be. Major environmental factors need to be statistically adjusted before reliable genetic comparison can be made.

The number of calves born is highly correlated with milk yield. The ewes which carry twins tend to be stimulated more by sucklings than the ewes which carry single lambs, and this will increase the milk secretion. The relationship exists with the several indigenous Iraqis as well as between flocks of different prolificacy, especially. The superior genetic dairy potential of twin-bearing ewes does not

necessarily mean that they produce more milk, as some of the difference may be due to greater stimulation of the mammary glands. Litter size and number of lambs reared would thus be systematic environmental effects that should be incorporated into the models used for genetic evaluation.

Breeds and production systems vary in length of lactation. The reviewed Iraqi studies showed that lactation of the different sheep breeds ranged between approximately 95 days – 100 days in some Arabi flocks, about 108 days in Karadi sheep, and 132 – 180 days or more in Hamdani sheep depending on their management and recording system. One reason for their higher dairy specialization is the ability to have longer lactations with Awassi dairy populations under specialized management. The socio-economic advantage of increased lactation exists only if milk production is not deemed to be low enough to stop feeding and milking. Selection for lactation persistency should therefore be based on lactation duration.

The most economically important of sheep milk products are milk fat and protein. Generally, the milk of sheep is more concentrated in both constituents than the milk of cow, which makes it more appropriate for cheese and fermented milk products. This high-solids characteristic is evident in the case of Karadi milk with an average of 5.79% fat and 5.43% protein contents. In the case of Awassi and Hamdani studies, the fat and protein content was relatively high, but the exact figures were influenced by the stage of lactation and management. Total kilograms of fat and protein produced per lactation might be more informative than milk volume, in future selection programs.

In the traditional systems in Iraq, a significant portion of the milk produced by ewes is not sold but used directly by the lambs. Thus, milk production is an indirect factor in meat production. The large comparative study conducted by Al-Dabbagh [14] on Awassi and Hamdani sheep included the relationships between milk production and lamb growth. The work emphasizes the significance of the characteristics of maternal milk for birth-to-weaning performance. This has significant implications for breeding aims. If commercial milking is not widely practiced, the use of better maternal milk production types for ewe selection can improve weaning weights and lamb mortality. Milk production should thus be part of maternal breeding in meat production systems.

Wool Production and Fiber Characteristics of Indigenous Iraqi Sheep:

The traditional products of indigenous Iraqi sheep are wool but in recent decades, its economic value has decreased compared with meat and milk. Traditionally, Iraqi sheep were used to make carpets, rugs, blankets, tents, mattresses, felt and other traditional household products such as carpets. Most indigenous Iraqi sheep produce coarse or carpet type wool rather than apparel type wool, which is due to their genotype and adaptation to the climatic conditions of the area. Principal wool qualities of economic and technological significance are the grease weight, clean wool yield, staple length, fiber length, fiber diameter, medullation, crimp, tensile strength, elasticity and color of the wool. There is significant variation between the different breeds of Iraq and in individual flocks, which points to a potential for selective breeding and the development of specialized local products about wool qualities.

Awassi sheep are considered to belong to the carpet-wool type. In one of the most detailed classical research projects on Iraqi Awassi wool, 268 ewes were studied, where the weight, fiber length, fiber diameter, fiber crimp and clean wool yield were characterized [20]. The average greasy fleece weight was about 3.77 lb or 1.71 kg with a remarkably high average clean wool percentage of about 84.85% reported by Sharafeldin [20]. The average staple length was about 16.47 cm, and the average fiber length was about 17.37 cm. The mean fiber diameter was about 33.32 μm , and the average number of crimps per 2 cm was about 4.18. The above properties prompted the author to rank Iraqi Awassi wool as the main source for carpet production.

There were strong correlations between wool traits values in the study. Fleece weight was positively associated with fiber length and clean wool percentage was negatively associated with fiber length. There was also a positive correlation between crimp number and fiber diameter. The associations suggest a correlated response of selection for one wool characteristic to other characteristics and should be considered when breeding. These published reviews of the Awassi breed confirm that the fleece is coarse, heterogeneous and good for carpet-type uses [4]. The weight of greasy fleece is reported as 1.86 kg for the Awassi ewe in Iraq, and the mean fiber diameter is reported as around 31.1 μm for some Iraqi population. The long staple and relatively low grease content of the breed has also been confirmed by the FAO documentation. These make the Awassi wool different from the

fine wool breeds like Merino. Therefore, the useful economic value of Awassi wool isn't related to the fineness of an apparel textile, but to its durability and structure, appropriate for carpets and heavier textile products.

Fiber size is one of the major factors affecting wool value as it plays an important role in the wool's softness, processing qualities and final product suitability. Awassi wool is medium to coarse and not like specialized fine wool breeds. There is considerable variation, however, between fibers in the same fleece as Awassi wool is made up of fine fibers, coarse fibers, medullated fibers, permanent fibers and kemp. Descriptions of Awassi wool publishing in various sources, show a high degree of variation in fiber type and medullation [4, 20]. This heterozygosity is characteristic of many of the indigenous fat-tailed sheep and helps to ensure their durability for carpet production. Moderate decrease in fiber diameter may provide an opportunity to enhance the commercial versatility of Awassi wool from a breeding point of view. Too strong a selection for some very fine wool, however, would likely be unsuitable since wool is not the most important economic characteristic of the breed and such selection may be detrimental to adaptation or other economic goals.

Awassi and some other Iraqi sheep breeds are known to have long staple length. The Awassi ewe from Iraq has an average staple length of about 16.5 cm while this would be much shorter in many fine-wool breeds. Long fibers are better for spinning carpet as it adds to the strength and durability of the yarn. Genotype, age, nutritional state, body region and shearing interval affect the length of fiber. While nutritional restriction can decrease wool growth, sufficient protein and energy nutrition can help increase wool growth, and further, severe nutritional restriction can decrease wool fiber growth and fleece weight.

Clean wool percentage is the percentage of clean wool, that is, the fleece that is obtained after the removal of grease, dirt, vegetable matter and other contaminants. High clean wool percentage (CWP) percentages, about 84.85%, were reported for the historical population of Iraqi Awassi sheep, which are relatively low contamination and grease in the sheep. This trait is desirable for processing because there is a greater percentage of usable fiber from the sheep's fleece. However, true clean yield may greatly vary depending on conditions of grazing, dust exposure, rainfall, housing and fleece contamination.

Karadi sheep are one of the best documented sheep breeds of Iraqi indigenous breeds for their wool traits. Ghoneim et al. [21] studied 168 wool samples from commercial Karadi flocks from five provinces in north of Iraq. The study proved that the sheep of the breed Karadi have long type carpet. The mean staple length was about 19.3 cm, and the mean fiber length was about 23.5 cm, which were significantly higher than those reported in sheep of Iraqi Awassi breed. The mean fiber diameter was about 48.1 μm which substantiated the relatively coarse fiber characteristics of Karadi wool. The proportion of medullated fibers was about 19.45% of the fleece. Karadi wool is easily recognized for its long fibers, coarse diameter and thick medullation, which make it ideal for carpet and rug production, but not for next-to-skin clothing. The traits may be due to breeding and to the selection pressures from the traditional local production systems of the Kurds and in northern Iraq, where wool was utilized in the manufacture of rugs and other durable cloths.

It is a significant characteristic of Karadi sheep that there is a lot of variation in the breed itself. Factors which can lead to differences in fiber diameter, staple length, fleece weight and medullation are age; sex; nutrition; sampling body region; season; flock management; genetic background. This variation holds two implications. Firstly, published breed averages must not be taken as a fixed value which is true for all Karadi flocks. Second, the presence of variation offers the possibility for selective breeding should wool quality become an important production goal. Selection might also be able to shorten the excessive fiber diameter or medullation and retain the long staple fiber value that is useful in carpet production.

Compared to Awassi and Karadi sheep, the information on detailed measurements of fleece and fiber characteristics of Hamdani sheep is limited, particularly for the cooler northern Iraqi environment where the sheep exist. In the traditional classification of wool, Hamdani wool is coarse or carpet wool and has been utilized for household textiles, carpets and rugs. Hamdani sheep have larger body size than other breeds, which may lead to higher total fleece production but is not necessarily accompanied by higher clean wool production or superior fiber quality. The following characteristics should be measured when studying Hamdani wool: annual greasy fleece weight, clean fleece

percentage, staple length, fiber diameter, coefficient of variation in diameter, medullation, fiber strength, elasticity and staple strength. Comparative studies with standardized research on Hamdani and Karadi sheep would be very useful, as they are both used in northern environment of production in Iraq, but they have different body shapes and historical breed identity.

In southern Iraq, Arabi sheep are kept as multipurpose animals, and their contribution to the economic return is less than meat and, in some systems, milk. There is little quantitative data about the characteristics of Arabi fleece published. The wool is generally coarse and not very suitable for high value clothes production. Fleece characteristics may be affected significantly by the harsh conditions of the South. Factors such as high temperatures, dust, saline conditions, feed shortages and nutritional stress during the appropriate seasons can have an impact on wool growth, fiber diameter, tensile strength, and contamination. Thus, future investigations should involve an investigation of Arabi wool under various nutritional and environmental conditions. Such data would help to define whether specific southern breeds are adapted more to heat or have lower fleece density.

Little has been done to characterize the Guraishi sheep in relation to their wool. The recent phenotypic evidence confirms that the Guraishi sheep are a recognized large-bodied population, however, there is currently insufficient reliable quantitative data available on: fleece weight; staple length; fiber diameter; clean wool yield; medullation; tensile strength; and color characteristics. However, due to the lack of data, it is not possible to classify the Guraishi wool with respect to Hamdani, Karadi and Awassi sheep. Thus, the latter must be sampled from representative Guraishi flocks to provide a national characterization project. This research could lead to the discovery of new properties of fibers not previously identified which are of commercial significance.

Fleece weight, length of fleece, fiber diameter and quality of wool can be affected by age. Sheep yield finer fibers as they are younger, and fibers may become coarser as they get older. But this cannot consistently be the case across breeds. Interestingly, the classical Iraqi Awassi investigation revealed that there was no significant age effect on the characteristics of wool evaluated. This finding suggests that breed-specific responses must be determined in an empirical fashion, not assumed. The main differences in fleece production between the sexes are related to body size, hormonal status and nutrient distribution. Rams tend to have heavier fleeces due to larger mature size, but the fiber quality may be different, with rams, than that of ewes. Wool data should thus be reported separately by age and sex in future studies.

Nutrients are critical to wool growth especially dietary protein and sulfur containing amino acids (methionine and cysteines). In extensive production, shortage of feed can cause loss of fleece weight and fiber strength during the seasons. Under severe nutrition restriction animals can develop weak areas in fibers which can lead to processing failures. This nutritional effect is particularly important for flocks migrating to or living semi-nomadically in northern parts of the country, where forage quality varies greatly from season to season. This could mean that, if wool was selected in the absence of nutritional supplementation, it could be improved by strategic supplementation during nutritionally critical periods.

Fleece is also an important trait for wool production but has a role in thermoregulation. Fleece is thick and insulated during winter in northern Iraq and can be a source of high heat load in summer. Fleece adaptations of indigenous populations are compatible with climate and shearing season. This 'adaptive' function might mean that selecting only for fleece weight might be detrimental. The density of the wool could be more expensive if it is grown to increase the density and was not considered by considering the thermal tolerance. If the density of the wool is increased without considering the thermal tolerance, it could be more expensive in already hot environments. Breeding objectives should therefore be balanced in the direction of the commercial characteristics of the fleece and the physiological adaptation to the climate.

The low price of coarse fleece is one of the biggest challenges in wool production in Iraq. Traditional wool use has been phased out in a lot of industrial products, making shearing less profitable. For some production systems, the value of the fleece is only just greater than the shearing and transportation costs. This can have several consequences: loss of farmers interest in wool quality; farmers may not shear at regular intervals or at all; loss of traditional textile industries; less selection pressure for fleece characteristics. But with the fading away of the commodity wool market, it does

not mean that indigenous wool has no economic future.

Iraqi woollens have a high potential to be re-positioned as a specialized product. Applications may be handmade carpet, Kurdish or Arab traditional rugs, felts and felt products, blankets, acoustic insulation, building insulation material, biodegradable packaging, horticultural mats, erosion-control materials, artisanal textiles. The long and coarse fibers of Karadi wool might be more appropriate for heavy duty carpets while Awassi wool may be more suitable for various carpet and upholstery applications. Geographic branding also has the potential of providing value. Specific identification of the products as Karadi wool, Iraqi Awassi wool or Kurdistan indigenous wool may bring textile production in relation to cultural heritage and conservation of indigenous livestock.

In some instances, the direct market value of fleece is relatively low, but the wool characteristics are still useful as phenotypic markers. Fiber diameter, pigmentation, staple structure, medullation and fleece distribution can be useful for distinguishing populations and can be used for breed characterization. So, wool traits should also remain part of a conservation program even if they are not main selection targets. Future production requirements may vary; hence the importance of recording both economically important and breed distinguishing characteristics as recommended in the FAO phenotypic characterization guidelines [6]. In other markets and/or technologies, traits of minimal present value could be important.

The quality of the evidence for Iraqi sheep wool is very uneven. While there are classical quantitative descriptions available for Awassi and Karadi wool, their detailed contemporary information is still lacking, especially for Guraishi and Hamdani sheep. A national standardized fleece-characterization program for the measurement of greasy fleece weight, clean wool percentage, staple length, fiber length, mean fiber diameter, coefficient of variation (COV) of fiber diameter, medullated fiber percentage, kemp percentage, fiber strength, elongation, crimp, fleece pigmentation and economic processing characteristics should therefore be established for future research. These can be complemented by DNA sampling to assess if there is a correlation between the wool phenotype and breed level genomic structure [22]. In addition, studies addressing physiological, nutritional, and bioactive factors can provide complementary information for understanding animal performance, health status, and biological variability in local sheep populations [23], [24].

Conclusions and Recommendations

Indigenous Iraqi sheep breeds constitute an important genetic and productive resource for the national livestock sector, with clear differences in growth, body size, carcass characteristics, milk production, wool traits, and environmental adaptation. Awassi sheep remain particularly valuable for milk production and adaptability to semi-arid conditions, while Hamdani and Karadi sheep show strong potential for meat production because of their relatively larger body size and favorable growth characteristics. Arabi sheep are well adapted to the hot environments of southern Iraq and maintain useful reproductive and milk-production performance, whereas Guraishi sheep remain insufficiently characterized in several productive traits. The available evidence also indicates substantial variation within breeds, providing considerable opportunities for selection and genetic improvement without compromising indigenous adaptability. However, productivity is still limited by poor nutrition, degradation of rangelands, climatic stress, disease pressure, insufficient performance recording, and the lack of coordinated breeding programs. It is therefore recommended that future development programs establish standardized national systems for phenotypic and productive recording, expand molecular and genomic characterization, improve nutrition and health management, and strengthen structured within-breed selection. Greater attention should also be given to under-studied traits and populations, particularly wool characteristics and Guraishi sheep, while conservation measures should be integrated into breeding strategies to prevent the loss of valuable local genetic diversity. Future research should prioritize large-scale comparative studies under standardized management conditions, combining reproductive, growth, milk, meat, wool, and genomic data to support evidence-based breeding decisions and enhance the long-term sustainability, productivity, and resilience of Iraqi sheep production systems.

References

- [1] M. A. Zeder, "Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact," *Proc. Natl. Acad. Sci. U.S.A.*, vol. 105, no. 33, pp. 11597–11604, 2008, doi: 10.1073/pnas.0801317105.
- [2] B. Chessa et al., "Revealing the history of sheep domestication using retrovirus integrations," *Science*, vol. 324, no. 5926, pp. 532–536, 2009, doi: 10.1126/science.1170587.
- [3] J. E. Alkass and K. H. Juma, "Small ruminant breeds of Iraq," in *Characterization of Small Ruminant Breeds in West Asia and North Africa*, L. Iñiguez, Ed. Aleppo, Syria: ICARDA, 2005, vol. 1, pp. 63–101.
- [4] S. Galal, O. Gürsoy, and I. Shaat, "Awassi sheep as a genetic resource and efforts for their genetic improvement—A review," *Small Ruminant Research*, vol. 79, nos. 2–3, pp. 99–108, 2008, doi: 10.1016/j.smallrumres.2008.07.018.
- [5] Food and Agriculture Organization of the United Nations, "FAOSTAT: Livestock stocks," Rome, Italy. Accessed: Sep. 30, 2026. [Online]. Available: <https://www.fao.org/faostat/>
- [6] Food and Agriculture Organization of the United Nations, *Phenotypic Characterization of Animal Genetic Resources*, FAO Animal Production and Health Guidelines No. 11. Rome, Italy: FAO, 2012.
- [7] A. S. Rajab et al., "Phenotypic survey of local sheep breeds in Iraq," *Iraqi Journal of Agricultural Research*, vol. 28, no. 1, 2024, doi: 10.65814/ijar.2024.28.1.57.
- [8] G. M. Karim and C. M. Karym, "Prediction of body weight from body dimensions in Karadi sheep," *Journal of Zankoy Sulaimani, Special Issue*, pp. 135–142, 2018, doi: 10.17656/jzs.10660.
- [9] A. Y. Ayied, M. F. Al-Hello, and E. F. Al-Jassim, "Growth patterns of Arabi sheep in South of Iraq," *Journal of Tikrit University for Agricultural Sciences*, vol. 11, no. 2, pp. 384–391, 2011.
- [10] C. A. M. Yateem, J. E. Alkass, and K. N. Mustafa, "Effect of different energy levels on growth, carcass traits, body composition and digestibility of nutrient in Awassi lambs," *Iraqi Journal of Agricultural Sciences*, vol. 52, no. 6, pp. 1382–1390, 2021, doi: 10.36103/ijas.v52i6.1478.
- [11] C. A. M. Yateem, K. N. Mustafa, and J. E. Alkass, "Effect of different protein levels on growth performance, carcass trait, digestibility and some blood biochemical parameters in Awassi lambs," *Iraqi Journal of Agricultural Sciences*, vol. 52, no. 5, pp. 1070–1076, 2021, doi: 10.36103/ijas.v52i5.1444.
- [12] D. A. O. Al-Sherwany and J. E. Alkass, "A comparative study on growth, carcass traits and body composition of Awassi and Karadi lambs raised under two levels of feeding and slaughtered at different weights: 1—Growth performance and carcass traits," *Iraqi Journal of Agricultural Sciences*, vol. 52, no. 5, pp. 1101–1108, 2021, doi: 10.36103/ijas.v52i5.1448.
- [13] J. M. Al-Khaza'leh and B. S. Obeidat, "Influence of sex on growth performance, carcass attributes, meat quality, and blood metabolites of Awassi lambs," *Iraqi Journal of Agricultural Sciences*, vol. 55, no. 1, pp. 392–401, 2024, doi: 10.36103/tryb9y64.
- [14] S. F. Al-Dabbagh, "Study of the relationship between the production of milk and some of its components with the growth of lambs in two breeds of Iraqi sheep," *Iraqi Journal of Veterinary Sciences*, vol. 33, no. 2, pp. 87–95, 2019, doi: 10.33899/ijvs.2019.163172.
- [15] J. E. Alkass, K. N. S. Mustafa, H. M. K. Hidayet, and I. A. Baker, "Performance of Hamdani sheep in Iraq: A review," *Zanin Journal of Science and Engineering*, vol. 1, no. 2, pp. 10–17, 2025, doi: 10.64362/zjse.36.
- [16] Y. M. S. Al-Barzinji and S. A. S. M. Arab, "Genetic characterization of three specific genes affecting milk traits in Hamdani ewes by molecular technique," *ProEnvironment/ProMediu*, vol. 15, no. 51, pp. 358–367, 2022.
- [17] C. M. Karym and Y. M. S. Al-Barzinji, "Evaluation of milk characteristics of Karadi sheep breed in Halabja Province, Kurdistan Region of Iraq," *Uttar Pradesh Journal of Zoology*, vol. 45, no. 1, pp. 8–17, 2024, doi: 10.56557/upjz/2024/v45i13849.
- [18] S. O. Raoof, D. Birkhader, S. S. Yahya, and Y. A. S. Mohamad, "Role of sex chromatin on performance in the Arabi sheep," *Iraqi Journal of Veterinary Medicine*, vol. 41, no. 1, pp. 145–150, 2017, doi: 10.30539/iraqijvm.v41i1.97.
- [19] A. J. Ahmed, R. J. Kadhim, and Q. A. Obaid, "Comparison study of milk components and effect of some factors on the production of milk in Al-Awassi and local Iraqi (Arabi) sheep," *Plant Archives*, vol. 19, no. 2, pp. 4486–4491, 2019.

- [20] M. A. Sharafeldin, "Wool characteristics of Iraqi Awassi sheep," *The Journal of Agricultural Science*, vol. 65, no. 2, pp. 223–225, 1965, doi: 10.1017/S0021859600083957.
- [21] K. E. Ghoneim, N. T. Kazzal, and R. Kh. Abdallah, "Some wool characteristics of Karadi sheep in northern Iraq," *The Journal of Agricultural Science*, vol. 83, no. 1, pp. 171–174, 1974.
- [22] Food and Agriculture Organization of the United Nations, *Molecular Genetic Characterization of Animal Genetic Resources*, FAO Animal Production and Health Guidelines No. 9. Rome, Italy: FAO, 2011.
- [23] Z. Palani, H. E. I. Kutaibani, and F. A. M. Amin, "Changes in some blood biochemical indicators in Kurdi rams response of selenium and zinc supplements," *SJAR*, vol. 5, no. 4, pp. 87–96, 2018.
- [24] M. H. A. Al-Obaidy, Z. M. R. Palani, K. Sirwan, and K. Hameed, "Effect of adding different percentages of glycerin in rations on some blood serum biochemical and antioxidants traits in male lambs Awassi breed sheep," *Biochemical & Cellular Archives*, vol. 20, no. 1, p. 2253.