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Review article
Ανασκόπηση

# Sheep Breeds of the Middle East: Diversity, Growth Patterns, and Reproductive Performance

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**ABSTRACT:** The Middle East exhibits considerable diversity, with prevalence varying across the region. Despite their critical importance, sufficient data to describe these breeds in this region are currently unavailable, and direct comparisons among them have not yet been made. The primary recognized Middle Eastern breeds were meticulously illustrated for each major Middle Eastern country, along with a description of each breed's traits. Subsequently, two broad categories of growth and reproductive traits were taken using the available literature to compare among these breeds. To measure growth traits, average body weight was recorded at birth and at three-month intervals until maturity. Concerning reproductive traits, fertility, twinning, lambing, and survival rates were recorded. Turkey and Iran were found to have the highest ovine biological diversity. This number is drastically reduced in other regions of the Middle East, with only three breeds recorded in Iraq, Egypt, and Saudi Arabia. Comparisons across breeds showed that the Assaf had the highest average birth weight. Again, the Assaf breed showed the highest values for litter size, lambing rates, and prolificacy. Red Karaman showed the highest fertility rates, whereas the Bafra breed exhibited the highest twinning rates and prolificacy. In conclusion, the Assaf breed had the highest average body weight indices, indicating superior reproductive traits. Other Middle Eastern breeds, such as Bafra, red Karaman, and Hamdani, exhibited excellence in specific reproductive parameters, including twinning, fertility, and survival rates. This is the first comprehensive comparison of Middle Eastern sheep, providing insight into their unique characteristics and informing a better understanding of their potential for growth and reproductive success.

***Keyword:*** Growth characteristics; Middle Eastern sheep breeds; Ovine biological diversity; Prolificacy potential; Reproductive traits

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## INTRODUCTION

Sheep breeding is economically vital in the Middle East, providing primary income for many breeders due to its minimal resource requirements. Improving the growth characteristics of sheep is a key focus for researchers, as these traits are crucial for economic success. (Ajam et al., 2019; Yilmaz et al., 2007). Production traits significantly impact income and enhance the livelihoods of rural communities in tropical countries. In addition, reproductive traits, such as fertility, early embryonic mortality, twinning rate, and birth rate, play a critical role in livestock profitability. These factors influence the number of weaned births per year, highlighting the importance of prolificacy at lambing and weaning. Globally, there are more than 1,000 sheep breeds, with a total population of approximately 1.17 billion. Among these breeds, over 60 fat-tailed varieties makeup 25% of the global sheep population. Fat-tailed sheep are well-evolved to survive in arid conditions and exhibit resilience in marginal environments. (Sejian et al., 2017). Their tail fat is culturally significant in local cuisines, and these sheep have been selectively bred for meat, wool, and milk. (Mohapatra and Shinde, 2018). Characterized by coarse wool or hair, long droopy ears, and slender frames, fat-tailed sheep encompass around 50 different breeds with regional variations, reflecting a rich history of breeding and adaptation. (Kijas et al., 2012). Their distinct characteristics have made them a subject of fascination and targeted breeding efforts.

Fat-tailed or fat-rumped sheep derive their name from their capacity to store substantial quantities of fat in their tail or rump, with some breeds depositing more than 20% of their total weight as tail fat. (Yousefi et al., 2012). This evolutionary adaptation allows them to store nutrients during periods of food abundance for use as metabolic energy during food shortages, particularly during seasonal fluctuations and migration. (Atti and Mahouachi, 2011).

Sheep breeding is economically significant in the Middle East, serving as a primary source of income for many breeders. Its relevance stems from the minimal resources required for sheep farming, making it an accessible and sustainable livelihood in the region.

Sheep resilience in semi-desert and harsh climates makes them a practical choice for breeders facing resource constraints (Kilgour et al., 2008). Versatile breeds such as the Awassi sheep are particularly valuable, providing wool, meat, and milk that support breeders' livelihoods (Gürsoy, 2011). Sheep require significantly less water and feed than larger livestock, making them more viable in areas with water scarcity and limited vegetation (Schlink et al., 2010). This adaptability enhances the resilience of the sheep industry, allowing consistent income despite environmental challenges. The economic importance of sheep breeding also extends to global markets, with many Middle Eastern countries engaged in the international trade of sheep and related products (Morris, 2017). For instance, the Awassi sheep has become a crucial genetic resource and is exported to over 30 countries. As a result, improving the growth characteristics of sheep has become a primary focus for researchers, as these traits are considered the most critical economic factors in livestock (Cheng et al., 2011; Malik et al., 2016).

The Middle East is home to a wide diversity of sheep breeds, highlighting the adaptability of these animals to diverse local landscapes (Eydivandi et al., 2021). This extensive distribution is vital to the region's agricultural and economic sectors, contributing significantly to wool, meat, and milk production (Mohapatra and Shinde, 2018). The Middle Eastern climates, ranging from arid to semi-arid, support various sheep breeds, each exhibiting unique traits suited to specific conditions (Gowane et al., 2017). For example, the Awassi sheep thrives in arid environments, making it prevalent in Iraq, Syria, and Turkey (Galal et al., 2008). The distribution of these breeds is shaped not only by environmental factors but also by historical and cultural influences (Zeder, 2011). Communities in the Middle East have selectively bred sheep over centuries to meet their specific needs, resulting in local breeds with distinct characteristics that serve as valuable genetic resources. The economic significance of these breeds is considerable, as they provide livelihoods through meat, wool, and milk, supporting local economies and industries. Additionally, some breeds are exported internationally, offering income to local breeders and enhancing global sheep genetic diversity (Al Araimi, 2019). Across the Middle East, sheep breeds exhibited distinct biological diversity within each region. Accordingly, sheep breeds exhibit a variable distribution, as evidenced by the presence of different breeds across the region. Each breed differs from others in various traits important to the economy. Despite the critical importance of this topic in sheep production, no direct comparisons have been made among breeds in the Middle East, and

the only available data concern limited studies from confined regions (Al-Atiyat et al., 2018; Aljubouri et al., 2020b). Therefore, this review compares Middle Eastern sheep with respect to patterns of distribution, weight, and reproductive characteristics. To do so, various online databases were consulted to examine the distribution, characteristics, and other critical traits of Middle Eastern sheep, including Google Scholar, Scopus, PubMed, the Turkish Statistical Institute, the FAO, and FAOSTAT. All manuscripts not written in English were excluded from our consideration. Additionally, we reduced the number of manuscripts with lower indexing values in the text. Following an overview of significant breeds with respect to their names, localizations, phenotypic, and reproductive features, several direct comparisons have been conducted to prioritize them using the available literature. This manuscript represents a pioneering effort in a crucial area of expertise, offering the first comprehensive insight into the growth traits of Middle Eastern sheep populations. Through systematic comparison of these breeds, the most suitable breeds can be identified.

## SHEEP DISTRIBUTION IN THE MIDDLE EAST

The Middle East has a diverse range of sheep breeds adapted to various environmental conditions and production systems. In Turkey, the distribution of sheep breeds varies, with some being more prevalent than others. The Akkaraman breed is one of the principal local Turkish sheep breeds, comprising approximately 11 million, or about half, of Turkey's total sheep population. (Aytekin and Öztürk, 2012). The Red Karaman makes up 24.4% of the sheep population. (Aydin et al., 2024), while the Dağliç breed accounts for around 2% of the total ovine population (Aytekin and Öztürk, 2012). Other notable breeds include the Karakul, known for its unique fur; Kivircik, a prominent breed in Turkey; and Karayaka, which comprises about 4-5% of the entire sheep herd. (Aksoy and Ulutas, 2016). The Bafra breed, available primarily in the Bafra district, consists of approximately 70,000 sheep. (Sakar and Erişek, 2019). The Merino breed, though not native, is present in Turkey, accounting for 3% of the sheep population; 97% are native breeds. The Gökçeada breed, endemic to the Gökçeada region, contributes to local farming and is estimated to have a population of 70,000 (Kaymakçı et al., 2001). The Sakız breed is also found in certain areas, adding to Turkey's diverse sheep resources.

The Baluchi breed is one of the most significant Iranian sheep, known for its fat tail and medium size, making it well-suited to the harsh arid regions near the country's large deserts. It comprises over 29% of Iran's sheep population (Valizadeh, 2010). Moghani sheep are another key breed, primarily raised for meat, with a population of about 5.5 million (Jafaroghli et al., 2010a). This dual-purpose breed is medium-sized and primarily found in the West Azerbaijan province (Mohamadipoor Saadatabadi et al., 2021). The Ghezel sheep is a native, dual-purpose fat-tailed breed from northwestern Iran, while the Afshari breed, known for its large size and fat tail, originates from Zanjan province in the northwest. The Lori-Bakhtiari breed, also dual-purpose, is medium-sized and prevalent in Lorestan province, recognized for its high-quality wool and meat. The Shal and Zel breeds, which are dual-purpose and medium-sized, are found in Markazi province. The Mehraban breed, primarily raised for meat production, originates from Hamadan in western Iran and has a population of approximately 3 million (Karimi et al., 2011). The Zandi breed is another important indigenous breed that has experienced a significant decline in numbers over generations, from approximately 6,475 3,500 years ago to roughly 3,000 in recent times (Ghoreishifar et al., 2019). The Awassi breed, common throughout the Middle East, is found in countries such as Iraq, Syria, Saudi Arabia, and Jordan. Its adaptability to both nomadic and sedentary management makes it valuable for the production of meat, milk, and wool.

Hamadani sheep are a notable indigenous breed, particularly in plains, valued for their high twinning rate, large size, milk production, and fleece weight. This breed constitutes more than 20% of Iraq's sheep population. The Assaf breed, developed in Israel by crossing Awassi and German East Friesian sheep, is primarily raised for milk production but also for meat quality. It is managed under an intensive production system in Israel, with annual demand increasing. (Gootwine, 2011). In Egypt, the Barki, Rahmani, and Ossimi breeds constitute about 65% of the entire sheep population. (Sallam et al., 2022). Barki sheep thrive in the Northwestern Coastal Desert, Ossimi sheep are known for high milk production, and Rahmani sheep are recognized for their fertility. In Saudi Arabia, the Harri, Najdi, and Arabi sheep breeds are the most common indigenous breeds. They are well-suited to local conditions, are resistant to native parasitic infections, and have high meat production capacity. Table 1 presents a detailed distribution of

**Table 1.** The distribution of the most common sheep breeds in the Middle East regions.

| No. | Breed | Turkey | Iran | Iraq | Saudi Arabia | Egypt | Israel | Jordon |
|---|---|---|---|---|---|---|---|---|
| 1 | Afshari | - | ✓ | - | - | - | - | - |
| 2 | Akkaraman | ✓✓✓✓ | ✓✓ | - | - | - | - | - |
| 3 | Arabi | - | - | ✓✓✓ | ✓✓✓✓ | - | - | - |
| 4 | Assaf | - | - | - | - | - | ✓✓✓ | ✓ |
| 5 | Awassi | ✓ | ✓ | ✓✓✓✓ | ✓✓✓ | ✓ | ✓✓ | ✓✓✓ |
| 6 | Bafra | ✓ | - | - | - | - | - | - |
| 7 | Baluchi | - | ✓✓✓ | - | - | - | - | - |
| 8 | Barki | - | - | - | - | ✓✓ | - | - |
| 9 | Dağlıç | ✓✓ | - | - | - | - | - | - |
| 10 | Ghezel | - | ✓ | - | - | - | - | - |
| 11 | Gökçeada | ✓ | - | - | - | - | - | - |
| 12 | Hamdani | - | - | ✓✓ | - | - | - | - |
| 13 | Harri | - | - | - | ✓✓ | - | - | - |
| 14 | Karakul | ✓✓ | ✓✓ | - | - | - | - | - |
| 15 | Karayaka | ✓ | - | - | - | - | - | - |
| 16 | Kivircik | ✓✓ | - | - | - | - | - | - |
| 17 | Lori-Bakhtiari | - | ✓ | - | - | - | - | - |
| 18 | Mehraban | - | ✓ | - | - | - | - | - |
| 19 | Merino | ✓ | - | - | - | - | - | - |
| 20 | Moghani | - | ✓✓ | - | - | - | - | - |
| 21 | Najdi | - | - | - | ✓✓✓ | ✓ | - | - |
| 22 | Ossimi | - | - | - | - | ✓✓✓ | - | - |
| 23 | Rahmani | - | - | - | - | ✓✓✓ | - | - |
| 24 | Red Karaman | ✓✓✓ | - | - | - | - | - | - |
| 25 | Sakız | ✓ | - | - | - | - | - | - |
| 26 | Zandi | - | ✓ | - | - | - | - | - |
| 27 | Zel | - | ✓ | - | - | - | - | - |
| 28 | Shal | - | ✓ | - | - | - | - | - |

The symbols ✓✓✓✓ refer to "high availability" (> 40 %). The symbols ✓✓✓ refer to "moderate availability" (21-40%). The symbol "✓✓" refers to "low-availability" (5-20%). The symbol "✓" refers to "non-common availability" (less 5%).

the most common sheep breeds across the Middle Eastern countries of Turkey, Iran, Iraq, Israel, Egypt, and Saudi Arabia. The availability of each breed in these regions is shown, with each breed categorized into four levels. The Table highlights the varying levels of availability across breeds, reflecting factors such as breeding practices, environmental suitability, and cultural preferences within each region. Analysis of the provided data indicates that the Awassi sheep is the predominant breed, with the highest prevalence across nearly all Middle Eastern nations. In contrast, Akkaraman, Assaf, and Karakul sheep exhibit less widespread localization, owing to their presence in multiple countries within the region. Conversely, the remaining Middle Eastern sheep breeds typically demonstrate prevalence confined to their respective countries, with limited exposure to large-scale breeding systems in other Middle Eastern nations.

## DISTRIBUTION OF SHEEP IN TURKEY

Turkey has a diverse range of sheep breeds, influenced by climatic, geographic, and regional factors.

There are numerous native sheep breeds in Turkey, each adapted to survive in a particular habitat. Turkey's sheep population is largely composed of native breeds, valued for their production of wool, milk, and meat. Breed-to-breed differences exist in the relative relevance of these production qualities. The sales of meat, milk, and wool account for an average of 70, 23, and 7% of the gross output value, respectively. Turkey has 45 million sheep, with ewes making up roughly 83% of the population, according to the Turkish Statistical Institute's database. (TUIK, 2022). Between 1990 and 2002, several factors contributed to a decline in sheep populations. (Gürsoy, 2006). The introduction of government support programs is attributed to a more recent surge in the sheep population after 2010 (Aydin et al., 2024; Erturk et al., 2015). The White Karaman breed, characterized by its distinctive fat tail, is widely distributed across Central Anatolia, Turkey's largest region. Notably, among all sheep breeds in the nation, this breed has the largest population and has adapted well to arid conditions. Each breed has characteristics that make it suitable for specific regions, considering factors such as climate, vegetation, and terrain. This distribution ensures that each breed thrives in its respective environment, thereby contributing to the overall diversity and resilience of Turkish sheep farming. The morphological characteristics of the most well-known Turkish sheep breeds are drawn in Figure 1.


**Figure 1.** Typical morphology of the Turkish sheep (TAGEM, 2009; Aytekin & Öztürk, 2012; Urun and Şirin 2023; Yilmaz et al 2013; Ertuğrul et al. 2009).

## AKKARAMAN SHEEP

The Akkaraman, or White Karaman, is a native breed of sheep in Turkey, known in Turkey as Akkaraman and in Iran as Makuie. Similar to other varieties of fat-tailed sheep found in this country, it thrives in arid conditions with poor nutrient intake and erratic weather. Breeds such as Akkaraman are considered dual-purpose and appreciated for producing both meat and milk. These sheep are distinguished by their coarse fleece, and usually, the males have polled, while ewes are usually un-polled (Milas et al., 1996; Yilmaz et al., 2012a). Notably, the White Karaman sheep has the largest population of all sheep breeds and accounts for more than 50% of the Turkish sheep population. The majority of Akkaraman sheep are white, with black markings on their legs and occasionally around their eyes and nose. There may also be dark brown spots on the legs and ears. These sheep have big tails that weigh between 5 and 6 kg on average. Akkaraman sheep range in body weight from 45 to 80 kg, and nearly all of them are hornless. The Akkaraman sheep has carpet-wool-type fleece, characterized by 36–42 S-grade fibers, with a fine, short inner fleece and a coarse, long outer fleece. The meat is described as firm and dry, and the average carcass weight is between 20 and 25 kg. Lambs destined for fattening show an approximate daily live weight gain of 250 g, which aids in their general development and growth. A ewe can yield up to 30–40 kg of milk in a period of 3–5 months, not counting the nursing period. The breed yields about 120 lambs from 100 sheep, indicating low fertility. September and October are when mating takes place,

indicating the seasonal reproductive season (Aytekin and Öztürk, 2012). Of the rams, only approximately 10% have horns. Ewes typically have polled horns, though little horns are extremely uncommon. Ewes looks to be drooping. However, the main drawback of the Akkarman breed is its low production level (Akçapinar et al., 2000). The breed's largest crossbreeding operation now uses artificial insemination with semen from Mutton Merino sheep. In the early phases of this crossbreeding scheme, artificial insemination is required since White Karaman ewes' fat tail prevents Merino rams from mating with them naturally. Because of this crossbreeding endeavor, Central Anatolia is home to over a million Merino-type sheep. For experimental purposes, the White Karaman breed was crossbred with the Lie de France and Awassi breeds (BEHREM, 2021; Ozmen et al., 2020). The Akkaraman breed was initially crossbred with the Lie de France to enhance its genetic diversity and traits. Later, it was crossed with the Awassi breed to boost production performance and adaptability. Additionally, the Chios breed was introduced to enhance its prolificacy. These crossbreeding efforts led to hybrids with improved reproductive performance and milk yield (Akçapinar et al., 2000; Özcan et al., 2001). These results contributed to the development of more prolific types of Akkaraman sheep (Şen et al., 2021). Genetic improvement programs for Akkaraman have focused on characterizing its genetic diversity, and recent studies highlight its potential for further enhancement (Gungor et al., 2022; Kizilaslan et al., 2023). Therefore, it can be inferred that ongoing efforts are underway to implement genetic improvement programs for the Akkaraman breed.

## RED KARAMAN SHEEP

A fat-tailed sheep with some traits in common with the White Karaman, the Red Karaman, also known as the MorKaraman, gets its name from the word "Karaman." It was argued that the Red Karaman should not be viewed as just a color variation of the Karaman, but rather as a unique breed from the White Karaman (Mason, 1967; Thevenin, 2011). Red Karaman is distributed similarly to White Karaman in the northeastern provinces of Turkey, and it is also found in the Iranian port that borders Turkey. In the southeast provinces of Diyarbakir and Urfa, one can witness wandering flocks of Red Karaman during the winter. On the other hand, the Food and Agriculture Organization (FAO) reports that 11,892 thousand Red Karaman sheep made up 24.4% of Turkey's total sheep population in 1983 (Yalcin, 1986). Another source reported that there were 376,104 sheep in the city of Uşak, Turkey, in 2017 (Demirhan, 2019). In Turkey, the most prevalent sheep breeds are the Red Karaman and White Karaman varieties, which collectively constitute about 65% of the nation's total ovine population. These two breeds dominate the sheep-farming landscape due to their adaptability and their significant role in the country's agricultural economy. Their widespread presence reflects their importance to Turkish livestock production and underscores their integral role in the national sheep population (Gürsoy, 2006; Uzun et al., 2006).

Usually brown or reddish-brown, the Red Karaman's throat, head, and legs are darker. Some Red Karaman ewes and rams may have little horns, although most of them are polled (Bebek and Keskin, 2020). This breed typically has pendulous or semi-pendulous ears (Yalcin, 1986). Red Karaman sheep are known to weigh between 44 and 48 kg for ewes and 55 and 75 kg for males (İnan and Aygün, 2019). The average carcass weight is around 30-35 kg, and the meat is characterized by its hard and dry texture. Despite being a fat-tailed sheep like the Akkaraman, the Red Karaman distinguishes itself with its larger body and tail size compared to the Akkaraman. These distinctive features may limit its adaptability across conditions and uses, as it may not be suitable for all purposes. Red Karaman sheep are often raised in migratory or sedentary systems, and the prolonged winter months can be challenging to feed and care for (Yalcin, 1986). The Red Karaman's head, neck, belly, and legs have an open texture and low density, resulting in wool that is a mixed, coarse carpet type. The wool ranges from brown or reddish-brown to purple, with the head, neck, and legs in a deeper tone. The greasy fleece has an approximate yearly weight of 2.0 kg, with fiber diameters varying from 36 to 44 microns ('S). Red Karaman's unique drawback is its wool color, which can make it less desirable for certain applications, such as dyeing or blending with other colors. Ewes of the Red Karaman breed are typically milked for 4-5 months, yielding 40-45 kg of milk, excluding the suckling period. However, the fertility rate is relatively low, with an average of around 110-120 lambs obtained from 100 sheep (Aytekin and Öztürk, 2012).

## DAĞLIÇ SHEEP

Dağlıç is a breed native to western Anatolia, characterized by coarse wool. In terms of population size, Dağlıç ranks as the third-largest breed in Tur-

key (Kaymakçı et al., 2001). Turkey's lake area and central-western regions are home to the majority of this breed (Aytekin and Öztürk, 2012). Before Kivircik from Thrace arrived in Anatolian Turkey, Dağlıç most likely lived there naturally. Due to their similar appearance, Dağliç is wrongly named Gicik in some Turkish localities (Rákossy et al., 2019). Herik is a distinct species, similar to Dağliç, but it differs in that its tail lacks a median groove. Although Dağliç's fat tail appears to act as a mediator between Kivircik and White Karaman, and its range is believed to be between these two breeds, there is strong evidence of the opposite (Mason, 1967). This evidence contradicts the notion that Dağliç originated from a blend of Kivircik and White Karaman. The feeding and management techniques used by Dağlıç flocks are largely the same as those described for White Karaman sheep. This suggests that the manner in which Dağlıç sheep are handled, fed, and cared for is similar to that historically observed for White Karaman sheep. This breed, which is used to produce both meat and dairy, is distinguished by its fat tails (Yilmaz et al., 2013). Dağliç sheep display distinctive black spots on the legs and head, with males typically having spiral horns and females being predominantly polled (Albayrak et al., 2012). These sheep weigh between 35 and 60 kg in total. Dağliç can also be recognized by its carpet-wool type, which has a glossy appearance. Due to its texture, which is finer than White Karaman wool and coarser than Kivircik wool, Dağliç wool is the best choice when creating carpets (Ertuğrul et al., 2009). Dağliç sheep are known to have low fertility, with only about 105–110 lambs produced from 100 sheep. Dağlıç is regarded as producing higher-quality meat than Akkaraman, which is considered of medium quality (Aytekin and Öztürk, 2012). Despite having thick tails, this breed's tails are smaller than those of the White Karaman (Yilmaz et al., 2013). The narrow end of the Dağliç breed's tail, which hangs straight down instead of looping over the fat tail to form an S-shaped curve, is another distinctive feature. It is comparable to White Karaman in terms of wool properties. However, there is no specific information on whether the Dağlıç breed has any genetic improvement program. Accordingly, implementing genetic improvement programs for this local breed can help maintain or increase its population size and improve its long-term economic returns.

## KARAKUL SHEEP

This breed of sheep, which is regarded as medium-sized and bred for milk, meat, and fiber, is named after the Karakul town in Turkmenistan (Akçapinar et al., 2000) or the Karagöl district in the city of Bukhara, Uzbekistan (Yalcin, 1986). When the breed was introduced to Turkey from Russia in 1929, its contribution to Turkey's biodiversity began. By 1950, Central Anatolia had produced a sizeable flock of Karakuls by the upgrading of several native breeds with Karakul rams (Ertuğrul et al., 2009). Karakul sheep have been part of Anatolian agriculture for an extended period, contributing to Turkey's biodiversity. Known for their ability to withstand harsh conditions, they are primarily raised under a semi-nomadic management system. However, due to a significant decline in the total number of Karakul ewes, there is a pressing need to enhance production traits. However, the availability of this breed is not limited to Turkey. Karakul sheep constitute less than 6% of Iran's sheep population, and the Iranian Karakul breed is primarily found in North Khorasan Province, which borders Turkmenistan (Binabaj et al., 2013). The diet and husbandry techniques described for White Karaman sheep are very similar to those for Karakul sheep. Mature Karakul sheep are characterized by their gray coloration, fat-tailed conformation, and average body weights of 80–90 kg and 60–70 kg for rams and ewes, respectively. The fleece color is black in lambs, whereas in adults it becomes dark grey. The adult Karakul breed has black heads, legs, and tails; its fat tails are longer and narrower than those of White Karaman sheep. Thirty to forty percent of ewes may develop tiny horns, even if the majority are polled. Depending on size, pattern, and color, young lambs provide expensive fur that is sold on the global market and used to make designer clothing, including coats, jackets, and suits. Astrakhan fur has considerable potential, but it's not widely used in Turkey. This breed's lambs are incredibly well-suited for producing fur (Shiri, 2010). However, the coarse, low-quality wool of adult animals is significantly inferior to the beautiful, high-quality fleece of lambs. Consequently, the survival of the breed relies on the utilization of other yield characteristics (Halil and Özbeyaz, 2020). Currently, the primary reason Karakul sheep are kept is to produce meat, their first marketable output. Due to the increased demand for red meat around the world, Karakul lambs are primarily bred for meat production, which has hampered the growth of the fur industry (Mohapatra and Shinde, 2018; Nsoso and Madimabe, 2003; Sharma et al., 2016). While single lambs are common, twins are also prevalent in the Karakul breed (Mirhoseini et al., 2015). The lambing rate of Karakul is higher compared

to other fat-tailed breeds such as Akkaraman and Morkaraman (Çolakoğlu and Özbeyaz, 1999; Erol and Akçadağ, 2009; Yilmaz and Odabaşioğlu, 2006). However, the breed has a low value for litter size, similar to the Dağlıç breed (1.05) and the Karayaka (1.03-1.08) (Ünal et al., 2003). The low litter size in Karakul herds is attributed to the low rate of twin births, indicating that despite the breed's high lambing rate, it is not prolific (Halil and Özbeyaz, 2020). The average weight indices of Karakul lambs at birth, 3 months, and 6 months were found to be 4.38, 23.08, and 31.54 kg, respectively (Aljubouri et al., 2021). They stand tall, with a long, narrow body. Improving environmental and management conditions can enhance the productive traits of this breed. Insights into prospective selection programs were obtained by investigating genetic criteria for various growth traits in Karakul sheep (Mirhoseini et al., 2015). In Turkey, the Karakul breed faces the challenge of improving production traits to ensure sustainable production. Fertility, greasy fleece output, milk yield, udder measures, lamb survival rates, and growth characteristics are among the performance variables that are being studied. The Karakul breed, however, exhibits high genetic variability, which is beneficial for genetic improvement initiatives (Ismoilovich, 2019). Genetic variation in Karakul sheep has been studied using microsatellite markers, aiding the development of selection programs (Nanekarani et al., 2011). Various studies have linked genetic polymorphisms in Karakul sheep from different regions to differences in productive traits (Al-Jubouri et al., 2022; Aljubouri et al., 2020a; Aljubouri and Al-Shuhaib, 2023a, 2023b; Mirhoseini et al., 2015). This genetic diversity highlights the potential for improvement programs for the breed.

## KIVIRCIK SHEEP

The Kivircik breed is typically recognized for its dual-purpose use in meat and milk production. It has medium to coarse wool, similar to that of the Bulgarian Karnobat and Tsigai breeds. It is believed to have European origins, possibly descending from the Tsigai breed, and is also found in western Thrace, Greece (Koban, 2004). The Kivircik breed showcases a white body, known as "Belka" within the breed, with black markings on the head, around the mouth, and ears, albeit in small quantities. While black coloring can be observed within herds, flocks of the brown-colored variant are no longer present in Turkey. While ewes are hornless, rams exhibit horizontal spiral horns that extend sideways with relatively short ears that extend horizontally (Mason, 1967). The breed's body weight ranges from 35 to 55 kg, and they are known for high-quality meat, considered the best among native breeds (Aytekin and Öztürk, 2012). The tail is long, slender, and free of fat, reaching the hocks, and their wool is of superior quality compared to other native breeds (Demir, 1997). The fleece from young sheep is suitable for worsted fabric production (Sezenler et al., 2014). Kivircik males weigh 60-70 kg, and females 45-55 kg. Newborn lambs typically weigh 3.5 to 4 kg, and ewes give birth to an average of 1.2 lambs per lambing, with lambs averaging 3.6 to 4 kg at birth (Cemal et al., 2017; Öner et al., 2014; Yardibi et al., 2015). Genetic improvement programs have been implemented to enhance the breed, with studies focusing on the genetic characterization and conservation of Kivircik sheep (Öner et al., 2014). These efforts aim to enhance biological diversity and support the sustainable in situ conservation of native sheep.

## KARAYAKA SHEEP

The Karayaka breed is distinguished by its rugged wool, elongated, slender tail, and diminutive physique. Its main habitat is situated along the eastern section of the Black Sea coastline, with additional populations in Düzce within the western Black Sea Region. Although historical records on the breed are scarce, it is presumed to be native to Anatolia. The designation "Karayaka" originates from the Tokat region in Turkey. Significantly, this breed exhibits unique traits not observed in any other breeds outside Turkey. Male Karayaka specimens typically tip the scales at approximately 55 kg, whereas females typically weigh around 40 kg. The primary hue of the body fleece is predominantly white, although splashes of black and brown may appear near the eyes, mouth, ears, and limbs. Entirely white-fleeced sheep can also be identified within flocks, with a notable feature being the lengthy forelock. The population of Karayaka sheep in Turkey represents around 3.5% of the overall sheep population in the nation. Ram Karayaka sheep commonly exhibit robust, spiral horns, in contrast to the polled nature typically observed in ewes (Soysal, 2012). Karayaka sheep are recognized for their thin and long tails, with some animals exhibiting fat deposits at the base. The wool from this breed is the coarsest among indigenous breeds, making it highly suitable for mattress production (Ulutaş et al., 2010). The annual mass of oily fleece ranges from 2.0 to 2.5 kg. Although the flesh of Karayaka sheep exhibits superior quality, their

milk production is comparatively modest, as ewes can yield around 30-35 kg of milk while lactating, excluding the nursing phase. Similarly, the fertility levels are substandard, resulting in approximately 110-115 lambs from a herd of 100 sheep (Aytekin and Öztürk, 2012). The Karayaka breed has been the focus of several genetic improvement programs, and various studies have shown that the breed possesses a high degree of genetic diversity, which can benefit such improvement efforts (Kirikci et al., 2023, 2021; Kirikçi et al., 2021; Olfaz et al., 2019).

## BAFRA SHEEP

In the Bafra district, around 70,000 ruminants are raised in mountainous areas. (SAKAR and ERİŞEK, 2019). The Bafra breed, first developed at the Bafra State Farm in 1998, has gained popularity across Turkey due to its adaptability. The Bafra breed, a cross between Chios (75%) and Karayaka (25%), combines desirable traits from both breeds, resulting in high reproductive performance, higher adaptability, and quality milk and meat (Ünal et al., 2008). Bafra sheep have fine wool, large body sizes, and distinctive features, including a white fleece with black surrounding the mouth, ears, and eyes. The head, underbelly, and legs are typically bare, with rams being horned and ewes hornless. Ewes average about 60 kg, while rams weigh around 70 kg. Bafra sheep exhibit a high rate of twin births since the average litter size is 2.2 lambs, making them suitable for rapid herd growth, thanks to an inter-birth interval of eight months (Yilmaz et al., 2012b). The lactation period lasts 170 to 180 days, yielding approximately 130 L of milk. Adult sheep produce an average fleece weight of 2 kg annually (Güngör and Akçapınar, 2013; Şahin, 2023; Sönmez et al., 2009). Bafra sheep significantly contribute to lamb meat production due to their high fertility and adequate milk yield for feeding lambs (Köseman et al., 2023). Lactation milk yields for single and multiple-bearing ewes are 104.89±8.57 kg and 165.62±10.79 kg, respectively, with lactation lengths averaging 131.25±1.54 days for single-bearing ewes and 131.70±2.99 days for multiple-bearing ewes (Cam and Kirikci, 2022). Key reproductive statistics recorded for this breed include about 86.57% birth rates, 7.46% infertility rates, 1.72% stillbirth rates, and twin birth rates of about 43.96%, with an average of 1.94 lambs per ewe (Yerlikaya and Ulutaş, 2019). Although some research has been conducted on Bafra sheep across Turkey, more studies are needed to explore their reproductive traits, survival capacity, growth rates, and carcass weights in Eastern Anatolia (Köseman et al., 2023; Ünal et al., 2008; Yakan and Ünal, 2010). Improving reproductive efficiency in sheep farming can involve prioritizing fertility traits and employing methods like artificial insemination and embryo transfer (Ustaoğlu et al., 2023).

## MERINO SHEEP

According to the 2019 FAO report, Turkey has a sheep population of 42,126,781, including 3,547,033 Merino sheep, making it the eighth-largest sheep-breeding country worldwide. Merino sheep's contribution to the Turkish output rose from 4% in 1991 to 14% in 2020. Turkish domestic sheep average 1.8 kg of greasy fleece per shearing, while Merino sheep produce about 3.1 kg (Behrem et al., 2022; Yilmaz et al., 2013). The medium-sized Merino breed, characterized by white legs and face, is valued for its fine, soft wool. Originating from Spain in the 12th century (Ciani et al., 2020) Merino sheep are primarily found in Ankara, Eskişehir, and Konya, where they have been crossbred on various farms. With a predominantly white coat, long tails, and polled ewes, Merino sheep adapt well to Turkey's diverse regions (Rauw et al., 2010). Crossbreeding with indigenous breeds like Awassi, Kivircik, and White Karaman has led to new breeds with enhanced traits (Ciani et al., 2015). Researchers have focused on developing highly productive sheep for meat, milk, and wool (Atkins et al., 1998). Historically, breeds were developed primarily for meat rather than wool, which remains underappreciated despite its limited production of textiles. The annual wool output from Merino and local sheep, along with their crossbreds, is 9.453 tons and 61.134 tons, respectively (Behrem and Gül, 2022). Given the rich genetic heritage of Turkish Merino sheep, various genetic improvement initiatives aim to enhance productivity and adaptability, focusing on traits such as conception rate, milk yield, and body and fleece weights. These efforts aim to establish Merino sheep as a vital asset in Turkey's sheep sector, as described in (Ceccobelli et al., 2023).

## GÖKÇEADA SHEEP

Although the terms Gökçeada and Imroz can be used interchangeably to refer to the same breed of sheep, Gökçeada is the one that is most frequently used. This sheep breed, which is among the smallest in the nation, gets its name from the Gökçeada island in the northwest of Anatolia's Aegean Sea, where it has been acknowledged for more than a century (Atici

et al., 2017). The Gökçeada sheep breed is found in Çanakkale province, with an estimated population of around 70,000 (Kaymakçı et al., 2001). Known for its long, coarse wool, especially on the upper head, this breed is highly valued for its premium-quality meat and strong resistance to diseases and parasitic infections. Its husbandry and feeding conditions are comparable to those of the Kivircik breed raised in similar environments (Sezenler et al., 2014). White in appearance, the Gökçeada breed is distinguished by black markings around the lips, nose, and eyes, as well as on the tips of the legs and ears from time to time. The head is narrow and straight. While ewes of this breed are often polled, up to thirty percent of them may have little scurs, and rams of this breed have powerful spiral horns that extend laterally (Yilmaz et al., 2012a). Gökçeada ewes have a conception rate of 57.6%, an average litter size of 1.2, a milk yield of 89 kg, a birth weight value of 3.3 kg, and an average live weight value of 43 kg (Yilmaz et al., 2004). These data indicated that the Gökçeada sheep breed is notable for its high conception rates, modest litter sizes, and moderate milk yields. Importantly, the breed responds positively to improved feeding and management practices. Various aspects of its production characteristics have been studied (Yilmaz et al., 2009). Although specific genetic improvement programs for the breed are not detailed, Gökçeada sheep are included in efforts to enhance productivity and adaptability, similar to initiatives for the Imroz and Kivircik breeds (Yilmaz et al., 2003a). The production traits observed in the Imroz and Kivircik sheep offer valuable insights for developing genetic improvement programs for the Imroz breed. The goal is to enhance its productivity and adaptability to the local environment.

## SAKIZ SHEEP

The Sakız (Chios) sheep is an indigenous fine-wooled breed that originated in the Aegean region and was probably introduced to Çeşme, Izmir, about 150 years ago. The Sakız and Kamakuyruk sheep were initially crossed, but later imports and breeding initiatives increased the proportion of Sakız DNA. Renowned for their exquisite white fleece, Sakız sheep are speckled with black markings around the mouth, eyes, ears, and legs, with ewes typically lacking horns and males possessing long spiral horns. The Sakız sheep, averaging 40–45 kg, is one of the tallest local breeds and is recognized for its high production levels. Each ewe usually produces about two lambs per birth, with newborns averaging 3 kg. They have well-developed, circular, and pendulous udders (Sezenler et al., 2014). Unlike other local breeds, such as Kivircik, Sakız sheep are typically raised in groups of three to six to meet family needs for both meat and milk, while preventing the development of herd mentality; they are well known for their dairy traits. Their meat, particularly from suckling lambs, is highly regarded for its quality (Ekiz et al., 2009; Önenç et al., 2015). Except for the nursing phase, ewes can yield 150–200 kg of milk over a 6-7 month period of milking. Renowned for its exceptional prolificacy, early sexual maturity, and great milk production, with litter sizes ranging from three to five (Aytekin and Öztürk, 2012). Because of their excellent environmental adaptation, Chios sheep are raised for most of the year in vegetable and fruit gardens (Tsartsianidou et al., 2021). The breed's remarkable resilience enables it to tolerate harsh conditions, thereby facilitating adaptation to diverse environments (Fidan et al., 2009). The sheep are maintained and fed in basic stalls throughout the winter. Purebred Sakız sheep have had their genetic traits analyzed and compared with those of other native Turkish sheep breeds, including Gökçeada and Kivircik. The breed, valued for its distinct genetic and phenotypic traits, is important to the Aegean region's agricultural history.

## DISTRIBUTION OF SHEEP IN IRAN

Iran boasts a rich diversity of 27 distinct sheep breeds and ecotypes, each adapted to the country's varied landscapes and environmental conditions. Each of these ecotypes adapted to diverse climatic landscapes, ranging from mountainous regions to arid plains. This wide variety reflects the country's historical and geographical influences on its ovine populations. These breeds possess unique traits shaped by generations of selective breeding and environmental interaction, contributing significantly to Iran's agricultural heritage (Masoudzadeh et al., 2020; Talebi et al., 2018). Native sheep breeds in Iran can play a vital role in meeting global protein demands. However, challenges such as slow growth rates, suboptimal carcass composition, and low feed efficiency persist (Vatankhah and Zakizadeh, 2020). To address these issues, breeding programs should prioritize enhancing ewe productivity and reproductive performance to meet industry needs for meat production, growth, and carcass traits (Roudbar et al., 2018; Safaei et al., 2023).

In 2008, Iran's sheep population reached 53.8 million, ranking fifth globally, with around 50 million

sheep contributing to significant agricultural output. This diverse sheep population contributes significantly to agricultural output, producing approximately 22 million pelts annually (Ansari-Renani, 2012). Over 1.6 million Iranian sheep are actively bred, primarily by rural and nomadic communities. These indigenous breeds are dual-purpose, with wool production as a secondary focus. The sheep industry accounts for approximately 35% of Iran's total meat production (Rashidi et al., 2008). A focused breeding strategy is necessary to improve characteristics such as litter size, body structure, and lamb weight to close the gap between meat supply and demand (Ghafouri-Kesbi and Eskandarinasab, 2008; Ghoreishifar et al., 2019). Only 4% of Iranian sheep are semi-fat-tailed or tailed varieties, compared to almost 96.3% of fat-tailed breeds (Kiyanzad et al., 2003). The unique Zel breed, located in the Caspian Sea region, is the only tail breed in the country (Ansari-Renani, 2012). Iranian sheep demonstrate strong adaptation to local environmental conditions (Yilmaz et al., 2003b). The high-quality wool produced by these sheep is crucial for the traditional craft of carpet weaving, contributing to both regional livelihoods and cultural heritage (Ansari-Renani, 2012). Iranian sheep exhibit thick tails and a variety of fleece colors, ranging from white to black (Mohapatra and Shinde, 2018). The country's sheep breeds are classified into four main categories: meat, dual-purpose, fur, and dairy, with notable examples including Baluchi, Karakul, and Zel (Ghoreishifar et al., 2019; Satari, 1975; Shoridea, 2001; Tavakolian, 2000; Valizadeh, 2010). Between 1997 and 2007, the sheep population increased by only 15,400 head annually, indicating a decline in growth compared to previous decades (Valizadeh, 2010). The morphological characteristics of the most well-known Iranian sheep breeds are drawn in Figure 2.


**Figure 2.** Typical morphology of the Iranian sheep (Hosseinpour Mashhadi, 2017; Mohammadi & Edriss 2007; Talebi et al., 2025; Bakhtiarizadeh and Alamouti 2020; Mohamadipoor Saadatabadi et al., 2021; Patiabadi et al., 2024; Agricultural Research, Education and Extension Organization, 1982; Bakhtiarizadeh and Alamouti, 2020).

## BALUCHI SHEEP

Baluchi sheep are a significant Iranian breed, comprising slightly over 29% of the total sheep population, with body weights ranging from 40 to 60 kg. This breed, estimated to number 15 million, is vital to Iran's meat industry (Nazifi et al., 2015). Their substantial numbers make them vital for overall lamb and mutton output (Jafaroghli et al., 2019). Primarily raised in extensive production systems on low-quality rangelands, Baluchi sheep are native to southwestern Pakistan, eastern Iran, and southern Afghanistan, and are now primarily raised in Khorasan Province for meat production. Various surnames, including Araghi, Farahani, and Kermani, are known to them. Adapted to the harsh conditions of eastern Iran, these fat-tailed sheep have medium-grade, coarse wool, ideal for producing famous Persian carpets (Goswami, 2018). The Baluchi sheep breed is well known for its distinctive black-and-white fleece, characterized by black markings on the head and legs and a mostly black face (Yazdi, 1997). Both males and females are generally polled, with mature ewes averaging around 35 kg and rams up

to 40 kg. Baluchi sheep typically produce 40 to 50 kg of milk over 125 days and have an average fleece weight of 1.3 to 1.8 kg per year, characterized by white wool, pigmented heads and legs, and coarse, medullated fibers (Ebrahimi et al., 2017; Gholizadeh and Ghafouri-Kesbi, 2015; Yazdi et al., 1999). This breed is recognized for its strong growth characteristics and large population, making it suitable for selective programs aimed at enhancing meat output. Since the 1960s, various genetic improvement efforts have been implemented within the breed to improve its productive performance (Ghafouri-Kesbi and Gholizadeh, 2018; Yazdi et al., 1999). Although Iranian native sheep breeds are multifunctional, lamb production takes precedence. Various genetic loci, such as leptin, ghrelin, IGF-1, ADRB3, myostatin, GDF9, BMP15, GH, and STAT5A, exhibit variations associated with growth characteristics in the Baluchi breed, indicating that its genetic makeup is not uniform across these regions; instead, these variations are linked to specific growth traits (Ansary et al., 2011; Gholibeikifard et al., 2013; Kosgey et al., 2006; Moradband et al., 2011; Tahmoorespur et al., 2011, 2010).

## MOGHANI SHEEP

The Moghani sheep breed, native to northwest Iran, has been raised in the region for over a century. This area, characterized by suitable topography and population density, is among the most intensively farmed in the country, resulting in competition between crop farming and sheep herding. Moghani sheep are characterized by their large tails and coarse wool, traits suited to cold, mountainous climates (Esfandyari et al., 2011; Talebi et al., 2023). Renowned as one of the top meat breeds, Moghani sheep are recognized for their impressive size, resilience, and ability to produce heavy lambs (Shodja et al., 2001). Predominantly white with brown faces, legs, and feet, these fat-tailed sheep have a population of approximately 5.5 million and are notable for their large body size and lamb production capabilities relative to other Iranian breeds (Rashidi et al., 2011; Tavakolian, 2000). While their wool, alongside that of local Ghezel sheep, is suitable for carpet-making, it often lacks uniformity in diameter and body positions, suggesting potential for higher-quality production (Shodja et al., 2004). Traditionally, Moghani sheep are raised in a seasonal system, with their summers spent in hilly areas and their winters in lowlands. A genetic improvement program has been implemented to identify superior rams for distribution to commercial flocks. Selection criteria often include body weight indices at birth, weaning, and later stages, highlighting the commitment to enhancing the breed (Hossein-Zadeh, 2012). Usually, breeding starts at 18 months, and ewes can be used for up to eight years, while rams are utilized for a year. In this breed, male and female lambs are usually separated at six months of age, and the selection is based on overall appearance and fleece color (Javadi et al., 2014; Sattaei Mokhtari et al., 2015). Various studies have provided valuable insights into the genetic estimates of Moghani sheep. These studies have elucidated the factors affecting the breed's growth performance, highlighting both inherited genetic traits and observable physical characteristics (Jafaroghli et al., 2010b).

## GHEZEL SHEEP

The Ghezel sheep, originating from northeastern Turkey and northwest Iran, is commonly known by several names, including Kizil-Karaman, Gesel, and Kazil. Approximately 2 million Ghezel sheep are primarily found in northwest Iran, where they thrive under conventional farming methods. Ghezel sheep are characterized by their crimson fleece, often featuring patches of black, red, or light red, while females are hornless and rams typically lack horns; the breed is also recognized for its reddish-brown coloration and its dual purpose of producing meat, milk, and wool (Alizadeh et al., 2017; Esfandyari et al., 2011). Adapted to the mountainous climate, these sheep can withstand summer temperatures reaching 38.3°C (Baneh and Hafezian, 2009). Their tails are distinctively pear-shaped and circular, with an "S" shape when viewed from the side; less curvature in the tail correlates with lower popularity. Ghezel sheep experience rapid growth, averaging 200 grams per day, with weights reported at 31.83 kg, 35.49 kg, and 39.86 kg at 6, 9, and 12 months, respectively, and lambing occurring from January to April (Baneh and Ahmadpanah, 2018; Izadifard and Zamiri, 2007). This breed is noted for its strong resemblance to the Karaman sheep, particularly in the appealing pelts of newborn lambs. However, unlike Karaman rams, Ghezel rams do not have spiraling horns. Recently, there has been a shift towards prioritizing meat production due to decreased demand for wool (Cloete et al., 2002). Ghezel sheep are large and fat-tailed, with yearling weights ranging from 38.2 kg for ewes to 41.7 kg for rams (Najafi et al., 2014). Notably, their milk is used to make Lighvan cheese, a traditional delicacy in Iran's Sahand mountainous region

(Ghahri et al., 2019). Selection for growth traits is a key focus of genetic improvement in Ghezel sheep, with studies assessing genetic parameters to enhance productivity (Miraei-Ashtiani et al., 2007). Efforts to improve Ghezel sheep genetics include multivariate analyses of growth traits (Baneh et al., 2013), and crossbreeding with Grey Shirazi ewes to enhance carcass features and feed efficiency (Karimi et al., 2021). Additionally, a method for isolating and proliferating spermatogonial stem cells has been developed to enhance genetic traits (Qasemi-Panahi et al., 2018). Research on ewe productivity has utilized both linear and threshold models to inform breeding plans and improve reproductive characteristics in the Ghezel breed (Nabavi et al., 2015).

## ZANDI SHEEP

In Iran, native sheep populations mainly consist of fat-tailed and carpet-wool breeds, notably the Zandi sheep breed, accounting for approximately 5% of the entire Iranian sheep population (Ghafouri-Kesbi et al., 2011). Despite its small share, the Zandi breed is crucial to the country's meat production sector and economically significant for its meat and pelts. Predominantly raised in central Iran, Zandi sheep have adapted well to harsh conditions and poor mountainous pastures (K. Mohammadi et al., 2013). Studies indicate that single lambs outperform twins in the weight values that are recorded at 6, 9, and 12 months, as well as in the weight gain values (Ghafouri-Kesbi, 2018). The Zandi sheep is thought to be descended from the Karakul sheep breeds of Shiraz. While both breeds share morphological traits, their primary similarity is the attractive pelt of newborn lambs. Recently, the growth of the textile industry has driven a shift towards meat production and improvement of growth traits, leading to a decline in the pelt industry in response to rising meat prices in Iran (Mohammadi et al., 2014; Senemari et al., 2011). The fat-tailed Zandi sheep breed is primarily raised for mutton, with milk and wool as secondary products. At birth, they weigh around 3–4 kg, reaching 30–40 kg as adults. Natural pasture provides the main feed year-round, except during winter and mating seasons (starting in August) when supplemental feeding is necessary. Young ewes typically meet rams at about 1.5 years of age (Senemari et al., 2011). The substantial population of Zandi sheep in Iran has led to significant interest in genetic improvement for growth traits (Ghafouri-Kesbi and Eskandarinasab, 2008). Numerous studies have examined genetic variability, inbreeding characteristics, and within-breed diversity. Research has demonstrated a strong interest in enhancing growth traits (Bohlouli et al., 2013; Mohammadi et al., 2020). The analysis of genotypic and phenotypic trends for this breed has improved understanding of the factors influencing these characteristics in Zandi sheep (Khojastehkey and Aslaminejad, 2013). These studies collectively demonstrate the substantial attention to the genetic improvement of Zandi sheep in Iran, with a focus on enhancing growth traits, maintaining genetic variability, and managing inbreeding to preserve and improve this Indigenous sheep breed.

## AFSHARI SHEEP

The Afshari sheep, native to the Afshar region of the Iranian city of Khorasan, is recognized for its significant contribution to the country's livestock industry. Fat-tailed Afshari sheep are ideally suited to their environment, which may include dry and semi-arid areas; the sheep range in size from medium to giant, with varying fleece colors and patterns. But the typical feature of its wool is its dark color. The Afshari breed has notable wool potential for carpet manufacturing in Iran (Ansari-Renani, 2012). While twin births are common in the Afshari breed, known for its high prolificacy, infertility rates are rarely recorded (Ghafouri-Kesbi et al., 2009; Lotfollahzadeh et al., 2016; Mohammadi et al., 2009). The Afshari breed is one of the largest and heaviest Iranian breeds, predominantly found in the mountainous western regions (Eskandarinasab et al., 2010; A. R. Mohammadi et al., 2011). Afshari sheep are often managed under traditional husbandry systems by local shepherds and farmers. The genetic improvement program for Afshari sheep in Iran aims to enhance various traits, including growth, reproduction, and genetic variability, with a particular focus on improving meat production and adaptability to local conditions. It has been shown that genetic enhancement programs through selection are appropriate solely for body weight in Afshari sheep, as assessed by genetic criteria for growth traits (Latifi and Mohammadi, 2018). An analysis of growth and reproductive traits, as well as pedigree, was conducted for 1,714 Afshari sheep. This research concerns the monitoring of inbreeding rates and genetic progress in Iranian sheep breeds (Ghafouri-Kesbi, 2012). An additional finding suggested that calculating litter size from genetic characteristics in this breed could inform a successful genetic breeding plan (Ahrabi et al., 2020). Additional genetic evidence was provided by the observation of a significant association

between the BMP15 gene polymorphism and litter size in several Iranian breeds, including the Afshari breed (Amini et al., 2018). These studies demonstrate that genetic enhancements in Afshari sheep in Iran have focused on various aspects, including growth traits, reproduction, and genetic variability (Mahjoubi et al., 2015). Adult Afshari ewes typically weigh between 45 and 57 kg, with 65-75% lambing frequency (Mohammadi et al., 2009). Birth weights are around 3.4 kg for ewes and 4 kg for rams, while weaning weights reach 26.5 kg for ewes and 29.6 kg for rams (Latifi and Mohammadi, 2018). By leveraging genetic analysis and pedigree information, the genetic traits of the Afshari sheep breed can be readily improved.

## MEHRABAN SHEEP

The western Iranian region of Hamadan is home to the indigenous Mehraban sheep breed. With more than 3 million heads, it is the most prevalent breed in that area. The Mehraban sheep breed is recognized for its high fertility, multiple births, exceptional survival rates from birth to weaning, and notable litter size indices and productivity values (Atashi et al., 2013; Hojjati and Ghavi Hossein-Zadeh, 2018; Pezhman and Zamani, 2012; Yavarifard et al., 2015; Zamani and Mohammadi, 2008). Primarily raised for meat, it is also considered a dual-purpose breed (for meat and milk production) and is well suited to the cold, rocky regions of western Iran, particularly Hamedan (Talebi et al., 2018). Recognizable by its fat tail, large frame, and light brown, cream, or grey wool with a dark neck and face, Mehraban sheep average 3.88 kg in pre-weaning weight gain and 21.58 kg in body weight at 90 days (Mohammadi and Edriss, 2007). The Mehraban population has declined from 2.2 million to 0.7 million (Bathaei and Leroy, 1998), underscoring the urgent need for conservation efforts to prevent the breed from becoming endangered. The absence of a Mehraban sheep society is the primary factor contributing to the sharp decline in the population of these sheep. Furthermore, few investigations have examined this breed's genetic makeup (Zamani et al., 2011). Though matured more slowly than females, males exhibited heavier body weight indices at maturity, with 81.04 kg for males vs. 62.95 kg (Bathaei and Leroy, 1996). Average birth weights were 4.1 kg for males and 3.8 kg for females, with mature males weighing 65–75 kg on average. Annual wool production was 1.8–2 kg for rams and 1.5 kg for ewes. The Mehraban sheep is renowned for its light-brown carpet wool, which is highly favored in the production of Persian carpets. A comparative investigation indicated that the Afshari and Mehrabani breeds display coarser fleeces regarding fiber diameter and lower fiber density than the Baluchi and Lori breeds (Ansari-Renani et al., 2011). The high-quality wool of the Mehraban sheep has a historical significance in Persian carpet manufacturing. Like other Iranian breeds, Mehraban sheep showed an average litter size of 1.1 (Pezhman and Zamani, 2012). Studies have shown that Mehraban sheep exhibit low genetic diversity among subpopulations, indicating potential for response to selection or crossbreeding with other breeds (Zamani et al., 2011). Genetic improvement programs for Mehraban sheep in Iran have focused on reproductive and growth traits. A study conducted over 18 years (1994–2011) found that selecting for litter weight indices at weaning significantly improves the reproductive performance of Mehraban ewes (Yavarifard et al., 2015). The typical approach in genetic improvement programs involves systematically enhancing desirable traits through selective breeding, a crucial step in developing effective breeding strategies for Mehraban Sheep.

## LORI-BAKHTIARI SHEEP

The Lori-Bakhtiari sheep is one of the most prevalent local breeds in southwestern Iran, with a population exceeding 1.7 million heads. This breed is particularly notable for having the largest fat-tail size compared to other Iranian breeds, making it a significant livestock resource in the region (Roudbar et al., 2018). The animals are primarily raised in communities and semi-intensive systems. Iran has realized the value of boosting sheep production's efficiency (output) through enhancements to milk yield, growth characteristic quantity and quality, and other economically important features (Matika et al., 2003; Vatankhah et al., 2008). The Lori-Bakhtiari breed thrives in the cold weather of southwest Iran, where it is raised on mountain pastures. The breeding program aims to improve growth and reduce tail size. However, enhanced prolificacy is also considered crucial for the breed's future. The heritability of litter size in Lori Bakhtiari sheep is estimated at 0.08 ± 0.02, reflecting minimal heritability and gradual genetic progress (Vatankhah and Talebi, 2008). Lori Bakhtiari sheep are highly valued for their wool, which constitutes a significant component of the Iranian textile and carpet industries. The breed is known for its predominantly white fleece, making

it a key resource in these sectors, although a small percentage of dark brown and pale brown fleece is sometimes observed. Some Shal sheep exhibit black spots on their fleece, which reduce wool quality. Interestingly, it has been demonstrated that various genetic variants significantly impact reproductive traits like ovulation rate and litter size (Davis, 2005; Moradi et al., n.d.).

## SHAL SHEEP

The Shal breed is one of the most popular sheep breeds in Iran, primarily raised for meat production. Originating in Qazvin province, the Shal breed is vital to the country's sheep farming industry due to its large size, adaptability across diverse climates, and ability to produce twin lambs (Mohammadi et al., 2013). This sheep is relatively heavy and has significant early growth. Therefore, the Shal sheep breed has adapted over time to its environment and has a long tail that helps it withstand periods of drought and hunger. The Shal sheep breed has a slightly long head, large, prominent eyes, a thick muzzle, and a flat, short forehead. Its large ears are distinctive, and the breed features tassels under the throat and on the ears, with a convex nose. Both ewes and rams lack horns. Initially black at birth, their wool color transitions from sugar white to gray. This breed is characterized by a fat tail, a large body, a black spot on the forehead, and a predominantly sugary greyish fleece, with some individuals exhibiting black-and-white coloration (Salehi, 2005). Notably, both rams and ewes in the Shal breed are horned. Various metrics are crucial in shaping the economic viability and success of this breed, as they directly affect the efficiency and financial outcomes of sheep farming operations (Mohammadi et al., 2013). The Shal sheep, a large, fat-tailed breed primarily raised for meat, is found in Iran's Qazvin Province. Known for its black or brown fleece with white head spots, it adapts well to harsh climates. With a population exceeding 600,000, this breed is a key protein source in Iran and provides farmers with their primary income through surplus lamb sales (Hashemi and Ghavi Hossein-Zadeh, 2020). Lambing occurs between mid-January and mid-March, and the percentage of twinning in Shal ewes is about 40% (Posht-e-Masari et al., 2013). On average, the weight of the ram in this breed is 70-80 kg, and its height is 75-80 cm. Also, the weight of the ewe in the Shal sheep breed is 52-58 kg, and its height is 70-75 cm (Vatankhah and Zakizadeh, 2020).

## ZEL SHEEP

The Zel sheep, native to the Mazandaran province in northern Iran near the Caspian Sea, thrive in an environment characterized by high rainfall and dense forests. With a population of approximately 2.5 million, this breed is recognized as an ancestor of Merino sheep and is the only local breed suitable for dairy production in the region (Gholami and Kianzad, 2014; Valizadeh, 2010). Known for its resilience in humid, wet environments, the Zel breed is valued for both meat and milk. This non-seasonal, small-tailed breed exhibits peak sexual activity during the summer and autumn months. It is typically characterized as a single ovulatory breed, though low reproductive efficiency is prevalent across various sheep production systems in Iran, primarily due to the diminished productive performance of ewes (Asadpour and Joozani, 2012; Esmailizadeh et al., 2009). The breed generally weighs between 40 and 45 kg and is unique in Iran for having thin tails measuring 10–12 cm long, rather than thick tails (Afshar and Aboozari, 2018; Farhadi et al., 2021). Zel sheep typically have predominantly white fleece but may display black, brown, or pied variations on the head and legs (Valizadeh, 2010). Females are either naturally hornless or polled, while males have horns. They are renowned for their high-quality carpet wool, historically used in Persian carpet production (Ansari-Renani, 2012). In terms of productivity, Zel sheep can lactate for up to seven months, producing about 50 kg of milk over 120 lactation days, with an average daily output of approximately 300 ml and a fat content of 8–9%. The breed has a litter size of about 1.23 and an average twinning rate of 15%. Ewes can breed in both spring and fall (Afshar and Aboozari, 2018). Recent whole-genome sequencing projects on Zel sheep and related Iranian native breeds have created valuable resources for genomic investigations, aiding studies on livestock adapted to hot, dry climates (Saadatabadi et al., 2023).

## DISTRIBUTION OF SHEEP IN IRAQ

The distribution of sheep breeds such as Awassi, Karadi, Hamdani, and, to a lesser extent, Arabi in Iraq reflects the country's diverse agricultural and climatic landscape. The presence of these breeds varies across regions due to differences in climate, vegetation, and cultural traditions, with each breed exhibiting traits that make it well-suited to specific environments and purposes. The Awassi breed is the most prevalent, representing 58.2% of the entire sheep herd, and thrives in central and southern Iraq,

where its adaptability to arid and semi-arid climates is advantageous. In contrast, Hamdani and Arabi sheep account for around 20% of the sheep population and have more localized distributions influenced by grazing conditions and historical breeding practices. While not as widespread as the Awassi, the Hamdani sheep still contribute to Iraq's overall sheep diversity (Mustafa et al., 2022; Oramari et al., 2014). The morphological characteristics of the most well-known Iraqi sheep breeds are drawn in Figure 3.

## AWASSI SHEEP

The Awassi sheep is one of the key breeds in the Middle East and Iraq, playing a vital role in the global sheep industry (Almahdawi and Altalib, 2020; Al-Shuhaib et al., 2019; Galal et al., 2008). It is the most prevalent breed in Iraq, significantly contributing to the local livestock sector. In addition to Iraq, Awassi sheep are found in southeastern Turkey and in Lebanon, Syria, and Israel, particularly in the Hatay, Adana, Gaziantep, and Urfa provinces of Turkey (Mason, 1967). In 1983, an estimated 1.1 million Awassi sheep were recorded in Turkey, accounting for 2.3% of the country's total sheep population. Awassi sheep are noted for their distinctive appearance, characterized by white wool, red-brown facial markings, semi-pendulous ears, and a short, fat, round tail (Said et al., 1999). The breed exhibits a distinctive color pattern, with brown tones on the head, neck, and legs and a white body, sometimes with a white tuft on the forehead. Males typically have spiral horns and an arched front, while females are usually hornless, with horned ewes being rare (Al-Sabea et al., 2020). The average body weight of Awassi ewes is between 50 and 55 kg, and their fleece is coarse with long, glossy fibers, measuring 40 microns in diameter with a staple length of 11-20 cm (Shrestha and Fahmy, 2007). As a triple-purpose breed, Awassi sheep are prized for their meat, milk, and wool and are particularly known for their ability to produce twins (Thamer R S Aljubouri et al., 2021; Haile et al., 2019; Shinde and Naqvi, 2015). They thrive in dry and semi-arid regions and adapt well to diverse natural pastures. Research indicates that young Awassi sheep adapt effectively to harsh climates (Renaudeau et al., 2012), and their reproductive parameters reflect climate-related stress in ewes (Dobson et al., 2012). The breed demonstrates resilience in extreme environments, maintaining milk production even in high temperatures (İnal et al., 2021). Primiparous Awassi sheep acclimated to arid conditions do not suffer negative impacts when exposed to colder climates (Haile et al., 2017). Awassi sheep are notable for their strong reproductive performance, with fertility rates ranging from 73% to 95% and a low litter size of 0.8 to 1.12 (Aljubouri et al., 2020b; Alkass et al., 2021). Under good farm conditions, they produce an average of 181 to 202 kg of milk (Yarkin and Oztan, 1968). The lambing season can vary, with lambing rates reported between 76.38% and 92.3% in different studies. The breed's birth and weaning weights are reported as 4.54 kg and 19.34 kg, respectively, with a pre-weaning weight gain of 0.264 kg (Haile et al., 2019). In Iraq, male Awassi lambs have birth weights of 3.85 kg and weaning weights of 20.87 kg, while females show weights of 3.54 kg and 18.81 kg, respectively. The Awassi breed exhibits various variants or subpopulations, enhancing its diversity and adaptability. One notable variant is the Naiemi, found in Kuwait, Iraq, and Syria, characterized by fine white wool and light fleece. These subpopulations may have distinct traits that address specific regional needs, underscoring the importance of studying Awassi genetics for


**Figure 3.** Typical morphology of the Iraqi sheep (Alkass & Juma, 2005; Galal *et al*., 2008).

selective breeding (Alkass and Juma, 2005). Efforts are underway to improve Awassi sheep traits, including growth, reproduction, and milk production. The breed's ability to withstand steppe climates has made it a focus of breeding programs in Israel and Turkey, where selective breeding has enhanced milk production, often yielding more than 500 liters per ewe annually. The "Improved Awassi" strain, developed through selective breeding, has produced successful crossbreeds, such as the Assaf dairy breed, which is known for its higher fecundity and twinning potential (Al-Nafie et al., 2022; Al-Thuwaini et al., 2023b, 2023a, 2022; Imran et al., 2020; Khazaal et al., 2022; Mohammed et al., 2021, 2022). Large-scale selection programs addressing inbreeding concerns are supported by molecular genetics tools, enhancing breeding strategies and uterine capacity (Gootwine, 2011).

## KARADI SHEEP

Karadi sheep are distributed mainly in the northern regions of Iraq and account for approximately 18–20% of the national sheep population (Alkass & Juma, 2005; Mustafa et al., 2022; Yousif et al., 2023). They are characterized by a predominantly white fleece, whereas the head, neck, and sometimes part of the shoulder are typically black or brown; in some animals, darker pigmentation may extend over additional parts of the body (Alkass & Juma, 2005; Mustafa et al., 2022). The wool is long, coarse, and of carpet type, with relatively high hair content and lower suitability for fine textile production (Alkass & Juma, 2005; Aziz & Hama, 2008; Mustafa et al., 2022). Both sexes are generally polled, and the breed is regarded as one of the large-bodied native Iraqi sheep breeds (Alkass & Juma, 2005; Mustafa et al., 2022). Mature rams usually weigh about 70–80 kg, although larger individuals may occur, while ewes generally weigh about 60–70 kg; fleece production is commonly reported to range from approximately 2.5 to 4.0 kg (Alkass & Juma, 2005; Mustafa et al., 2022; Zinalabidin & Öztürk, 2017). Karadi sheep also possess a large fat tail, long and broad ears, strong relatively short legs, and a large head with a convex forehead (Alkass & Juma, 2005; Mustafa et al., 2022).

Several local types or strains have been reported within the Karadi sheep population, including Kurdi, Jaf, Herki, Hamdani, and Dzaie/Dizayi, reflecting geographic distribution and production traditions in northern Iraq (Yousif et al., 2023; Zinalabidin & Öztürk, 2017). Some of these populations have historically been associated with seasonal movement in search of feed resources, whereas others are maintained under more sedentary systems (Alkass & Juma, 2005; Mustafa et al., 2022).

## HAMDANI SHEEP

Hamdani sheep are considered among the most important and largest native sheep breeds of northern Iraq (Alkass et al., 2025; Alkass & Juma, 2005). The breed is generally described as having a white body, a long dark head with fine bone structure, very pendulous ears, and the absence of horns in both sexes (Alkass et al., 2025; Alkass & Juma, 2005). Adult body weight is relatively high, with rams commonly reported at about 80–100 kg and ewes at about 60–80 kg (Alkass et al., 2025; Alkass & Juma, 2005). Hamdani sheep are valued by breeders for their large size, milk production, and reproductive performance, and their milk is widely used in traditional dairy processing, especially under favorable spring grazing conditions (Alkass et al., 2025). Fleece yield is generally reported to range from 3 to 4 kg (Alkass et al., 2025).

This breed is also noted for good fertility and a twinning rate considered higher than that of Awassi sheep in regional reports (Alkass et al., 2025). Reported productive traits indicate an average birth weight of approximately 3.5–5.0 kg, a weaning weight of around 21 kg, and body weight at one year of age ranging roughly from 40 to 50 kg, depending on flock, management, and study conditions (Alkass et al., 2025).

## ARABI SHEEP

Arabi sheep are distributed mainly in southern Iraq and represent an important indigenous sheep breed of that region; they are often reported to constitute around one-fifth of the Iraqi sheep population (Alkass & Juma, 2005; Yousif et al., 2023). The breed is generally regarded as one of the smaller native Iraqi sheep breeds and is well adapted to harsh environmental and climatic conditions (Alkass & Juma, 2005; Taherpour et al., 2012). The fleece is predominantly white, although colored animals also occur within the population (Taherpour et al., 2012). Compared with Awassi and Karadi sheep, Arabi sheep produce relatively finer and shorter-stapled wool, which is suitable for local woven products and yarns (Alkass & Juma, 2005; Taherpour et al., 2012). Greasy fleece weight is commonly reported at around 1.5–1.7 kg (Taherpour et al., 2012).

Rams are horned, typically with large spiral

horns, whereas ewes are usually polled (Alkass & Juma, 2005; Taherpour et al., 2012). Mature rams generally weigh about 50–55 kg and ewes about 40–45 kg, and the breed is characterized by relatively small body size and a small fat tail (Alkass & Juma, 2005). Some local descriptions also mention related local subtype designations; however, such classifications are less consistently standardized in the accessible literature than the main breed descriptions themselves (Alkass & Juma, 2005).

## DISTRIBUTION OF SHEEP IN EGYPT

Sheep play a vital role in Egyptian agriculture, comprising about 30% of the country's total livestock and significantly contributing to daily protein intake and food security. With a population of 5.69 million, sheep outnumber other livestock such as cattle (5.06 million), goats (4.35 million), and buffaloes (3.37 million) (Elshazly and Youngs, 2019). The main sheep breeds—Barki, Ossimi, and Rahmani - make up 65% of the total sheep population and are well-suited to Egypt's native environment (Shafey et al., 2020). In 2017, FAOSTAT estimated that Egypt had approximately 5.7 million sheep (Abousoliman et al., 2020a), with the three breeds numbering approximately 990,000, 514,000, and 470,000, respectively (Hammoud, 2019). Livestock, especially sheep, is essential to rural communities in Upper Egypt and contributes significantly to the income of Bedouin people. The distribution of the three main breeds is as follows: Barki in the northeastern coastal regions, Ossimi in Middle Egypt, and Rahmani in the northern Delta. Despite the importance of these sheep breeds to Egypt's cultural and genetic history, research and selection processes remain limited (Othman et al., 2016). In 2016, sheep accounted for about 7.42% of Egypt's red meat supply (FAOSTAT, 2018). However, inbreeding due to small flock sizes and selective breeding practices poses challenges, as it leads to the accumulation of harmful recessive alleles. Studies indicate that higher levels of inbreeding result in lower birth and weaning weights in offspring (Mokhtari et al., 2014; Van Wyk et al., 2009). Egyptian sheep, which have small to medium frames and coarse wool fibers, exhibit lambing rates between 105% and 130% (Elshazly and Youngs, 2019; Khattab et al., 2021). The morphological characteristics of the most well-known Egyptian sheep breeds are drawn in Figure 4.

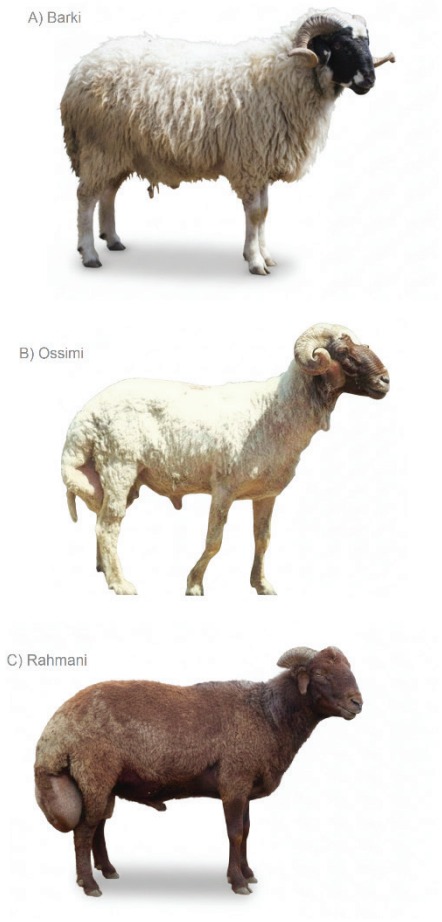


**Figure 4.** Typical morphology of the Egyptian sheep (Elsayed, 2013; Elshazly and Youngs, 2019).

## BARKI SHEEP

Barki sheep are well-known for their ability to thrive in the harsh desert conditions of North Africa, where food and water are scarce. This breed has evolved remarkable adaptations that enhance its resilience in arid environments, making it particularly valuable in regions with extreme climates. The breed's name originates from the historic Barka region, extending from western Alexandria in Egypt to eastern Libya, reflecting its association with the region's arid landscapes (Elshennawy, 1995; Fereig et al., 2023). Barki sheep are small to medium-sized, with coarse white fleece, and are distinguishable by their semi-pendulous ears and triangular, fatty tail. Rams have horns, while ewes are hornless. The breed typically has brown or black heads with white wool covering the body. Barki sheep yield coarse wool of high quality and greater weight compared to Rahmani and Ossimi sheep, although they are smaller in size (Elshazly and Youngs, 2019; Germot et al., 2022). For instance, male Barki lambs weigh 3.64 kg at birth, 19.56 kg at weaning, and 32.05 kg at 12

months (El-Wakil et al., 2008). The mating season usually begins in July, with lambing starting in December. However, one of the breed's challenges is low milk production in ewes, which results in high lamb mortality rates due to inadequate nutrition in early life. To improve both milk and meat production, genetic improvement programs have been initiated. In 1963, the Desert Research Centre established a Barki sheep flock to select for body weight. Since then, research has targeted growth performance, milk production, and meat quality (Abousoliman et al., 2020a; Elsayed, 2013; Germot et al., 2022; Mahrous et al., 2015; Potočnik et al., 2007; Sallam, 2023). Genetic studies have identified candidate genes for growth- and milk-performance traits, thereby aiding selective breeding (Ghanem et al., 2022; Ibrahim et al., 2023). These breeding strategies aim to enhance mutton productivity and improve the overall performance of the Barki breed (Gad and El-Wakil, 2013).

## OSSIMI SHEEP

Ossimi is among the most favored breeds in the Nile and Delta sheep populations, gradually displacing other breeds. The Ossimi breed has a population of 1 million head, contributing to the rapid increase in Egypt's sheep population, which now stands at approximately 4.6 million head (Shaat et al., 2004). The Ossimi falls between the two types of Egyptian breeds that preceded it (Germot et al., 2022). Distinguished by its lengthy legs and coarse fleece, often containing kemp, the Ossimi sheep is primarily recognized as a carpet wool breed, with a focus on meat production (Elshennawy, 1995). The breed is characterized by a white body and a brown head, with a convex profile. There may be dark coloring or patches on the short neck, and there is usually little wool on the neck, legs, and abdomen. Its elongated body accounts for approximately 2.5–4.0% of its total weight. It has an oval or spherical, fatty tail and a semi-pendulous ear. While females are either inherently hornless or polled, males typically have horns (Elshazly and Youngs, 2019). Ossimi sheep are Egypt's most popular breed, with a population of over 1,000,000. Middle Egypt has a greater production than Southern Egypt (Almadaly et al., 2023; Elshazly and Youngs, 2019). Research has focused on genetic variation in the Ossimi breed and its association with productive traits, examining its effects on various characteristics (El Fiky et al., 2017). Identifying polymorphisms in candidate genes associated with Ossimi sheep growth and milk performance has been the focus of research (Mahrous et al., 2016). Research has examined the genetic diversity of the Myostatin gene and its impact on productive performance in the Ossimi breed (Osman et al., 2021). Additionally, crossbreeding programs have been implemented to enhance the breed's fecundity, lambing rates, and productivity (Marai et al., 2009).

## RAHMANI SHEEP

Rahmani sheep, along with Ossimi and Barki, are key contributors to Egypt's ovine economy. They stand out among Egyptian breeds for their higher body weight and faster growth rates, making them a valuable meat breed. Approximately 250,000 Rahmani sheep are found in the northern and middle Nile Delta, although their population is declining, possibly due to the increasing popularity of the Ossimi breed (Elshennawy, 1995) (Hammoud and Salem, 2017; Madkour and Mohammed, 2021; Shaat et al., 2004). Rahmani sheep are easily recognizable by their red fleece, small ears, convex head, and fat, oval tails. Males have helical horns, while females may have small horns or none at all. Their distinctive reddish-brown color fades as they age. The breed has short wool on the abdomen and bare legs below the knee (Elshazly and Youngs, 2019). Research on the genetic diversity of Rahmani sheep has employed microsatellite markers (Ghazy et al., 2013). The breed is also involved in crossbreeding programs aimed at improving fecundity and lambing rates in native Egyptian sheep. Rahmani sheep are crossed with breeds such as Ossimi, Finn, Romanov, Chios, and D'Man to enhance indigenous breeds and develop new ones (Darwish et al., 2010; Khattab et al., 2021). In addition to the core breeds, Egypt has several subsidiary breeds, including Saidi sheep, which have dark brown fleece and long, fat tails, and Sohagi sheep, found in southern Egypt, similar in size to Barki sheep. Fallahi sheep are also notable for their brown fleece and tapered fat tails (Germot et al., 2022).

## DISTRIBUTION OF SHEEP IN SAUDI ARABIA

Remarkably, sheep meat is the top preference among Saudi citizens, followed closely by camel meat. Due to limited indigenous production, Saudi Arabia relies on imports, with Australia its primary supplier of sheep meat (Suliman et al., 2021). Sheep play a vital role in the Saudi Arabian agribusiness economy, with Najdi sheep being the most popular indigenous breed, numbering over 7.2 million (Ayadi et al., 2014). Overall, sheep account for 53% of the

country's livestock population, totaling 17.5 million, and significantly contribute to the economy by providing milk, meat, and other products (Bahadi et al., 2023). In central Saudi Arabia, Najdi sheep are preferred, while Naeimi sheep are also popular. In the West, the favored breed is the Herri (Mahmoud et al., 2020). Therefore, it is necessary to compare breeds to investigate their unique characteristics and talents (Suliman et al., 2021). Saudi Arabia is home to around 5.2 million sheep, according to the Ministry of Agriculture. Local breeds, such as Harri and Najdi, are well adapted to the environment and meet the needs of local consumers. The Najdi is the leading breed in the eastern province, whereas Awassi sheep, which originated in the eastern Mediterranean, have been exported to more than 30 countries, including Saudi Arabia (Galal et al., 2008). Renowned for their high milk production, indigenous sheep breeds are valuable for their adaptation to harsh environments, nutritional fluctuations, and disease resistance (Al-Atiyat et al., 2018). Nevertheless, 20% of domesticated animal breeds are at risk of extinction, and global biodiversity is declining. Sheep breeds, in particular, have faced significant losses, with some becoming extinct (Adam et al., 2015; Bahadi et al., 2023). At the same time, Arab sheep are characterized predominantly by a uniform black coat. Some flocks may contain occasional individuals exhibiting color variants that remain close to the base phenotype, such as greyish (ash-colored) or white animals; however, these variants are described as rare in contemporary populations and, when present, are typically valued only if they also express other highly desirable conformation features. Beyond coat color, Arab sheep are frequently distinguished in local husbandry accounts by a suite of functional and adaptive traits. The morphological characteristics of the most well-known Saudi sheep breeds are drawn in Figure 5.


**Figure 5.** Typical morphology of the Saudi sheep (Zeitoun, 2021; Alkass & Juma, 2005).

## HARRI SHEEP

Harri sheep, native to Saudi Arabia, are well adapted to the country's harsh, arid, and semi-arid environments. Known for their fat tails, which store energy during periods of food and water scarcity, these sheep are also resistant to extreme temperatures and common parasitic diseases in the region. Their strong immune systems add to their resilience, making them a valuable breed in challenging conditions (Suliman et al., 2021). Harri sheep are recognized for their high-quality meat, which is lean, tender, and flavorful, making them highly desirable among Saudi consumers (Murshed et al., 2022). Their distinct physical features include long, spiral-shaped horns, coarse wool, and predominantly white coloration, though they can also be brown or black. They are primarily found in the mountainous regions of the Hijaz (Hussein and Khattab, n.d.). Some women may give birth to twins up to three times in their lifetime, thereby further enhancing their economic value. These sheep have evolved to efficiently utilize scarce resources, which enhances their survival in Saudi Arabia's desert climate. Their high-quality meat, reflecting natural grazing habits and the region's unique vegetation, contributes to

their popularity (Mahmoud et al., 2020). However, more comprehensive studies are needed to compare Harri sheep with other native breeds to improve digestive performance and ensure sustainable breeding practices.

## NAJDI SHEEP

The Najdi breed is the primary local sheep breed in central Saudi Arabia, adapted to desert climates but with somewhat lower drought tolerance than the Awassi variety. Predominantly raised in Saudi Arabia, Najdi sheep are also found in Kuwait, Oman, and Jordan. This breed is highly valued in its native region for its quality, making it one of the country's most esteemed varieties. Najdi sheep are characterized by their fat tails, long faces with Roman noses, tall stature, and drooping ears. They typically have black fleece with white faces, legs, and tails, and their coarse wool is well-suited to the region's climate. The Najd region, where these sheep originate, experiences extreme summer temperatures averaging 45°C, with occasional peaks of 54°C, conditions that can negatively impact animal production (Alamer and Al-hozab, 2004). At one year old, rams weigh approximately 56 kg and ewes approximately 45 kg. The breed is traditionally used for both meat and milk production by Bedouin herders, with ewes generally being hornless while rams may have small horns or be polled. Najdi sheep are commonly slaughtered between 7 and 12 months of age (Musthafa et al., 2012). Genetic improvement programs are underway to enhance milk quality, and molecular genetic methods are being used to support these efforts through direct genotyping (Madeja et al., 2004; Mahmoud et al., 2014).

## ARABI SHEEP

Arab sheep (Al-ʿArab) are widely regarded as one of the oldest sheep types historically associated with the Arabian Peninsula. They have been present in the region since early times. They are often described by pastoral communities as the primary stock of nomadic Bedouins, particularly in the eastern parts of the Peninsula and in some areas surrounding Najd. In traditional production systems, these communities practiced seasonal mobility, moving in search of spring pasture and reliable water sources to enable their sheep and camels to graze under favorable conditions. Within this cultural and ecological context, Arab sheep were not merely a subsistence animal but a major component of household livelihood and economic security. They are described as exceptionally tolerant of climatic extremes, with a notable ability to withstand intense heat typical of eastern Arabian environments and, at the same time, to remain robust during winter periods when temperatures drop substantially. In practical terms, they are considered to require fewer supportive interventions to cope with thermal stress compared with many other sheep populations raised in similar settings. The Arabi breed is also commonly portrayed as highly resistant to a range of diseases, a property particularly valued in extensive and semi-extensive systems where veterinary inputs may be limited, and animals must remain productive under variable field conditions. In addition, breeders often highlight the rapid response of Arab sheep to improved finishing feeding, noting that when nutrient supply is increased, these animals can achieve efficient fattening and competitive performance relative to other meat-oriented sheep, including some lines developed through commercial crossbreeding. Arab sheep are also described as having desirable maternal performance, including comparatively good milk availability and a tendency toward twinning, together with a rapid reproductive response to mating when the flock is supported by abundant nutrition. Breeders' narratives further emphasize that these flocks were maintained with limited mixing with other sheep populations, and that co-rearing occurred mainly alongside local goats rather than through systematic interbreeding with external sheep lines. Furthermore, Arabi sheep, native to southwestern Iran, southern Iraq, and northeastern Saudi Arabia, are primarily raised for meat but also produce wool (Aljubouri and Al-Shuhaib, 2021). They are characterized by long, pendulous ears, a thick, fat tail, and an average wool diameter of 26.2 micrometers. While typically white, Arabi sheep can also be black, brown, or a mix of both. Rams have horns, while ewes are usually hornless. Mature rams average 53.5 kg in weight and 81.2 cm in height, while ewes weigh 38.2 kg and stand 71.6 cm tall, producing about 1.6 kg of wool per shearing. At birth, rams weigh around 4.4 kg, and ewes weigh 4.0 kg, with slightly more than one lamb produced on average per breeding cycle (Al-Jassim and Al-Saigh, 1999). Arabi sheep are known for their adaptability to harsh weather and demonstrate greater tolerance to high temperatures than the more prevalent Awassi breed in Iraq (Al-Thuwaini et al., 2020). Summer temperatures in southern Iraq, Kuwait, and Saudi Arabia can reach 41 °C, whereas winter temperatures are lower and precipitation is below 400 mm. The Arabi population increased from 1.4 million to 1.5

million between 1990 and 2000 (Shokrollahi and Baneh, 2012). Furthermore, in the province of Khuzestan, there are about 4 million sheep, with approximately 30% being Arabi breeds, primarily along the Iran-Iraq border. In their management, flocks graze on grassland for four to six months, and during winter, they are fed barley, hay, and crop residue. Lambs receive milk for approximately four months, with a total milk production of 150–550 kg used exclusively for their growth. Lamb mortality rates range from 5% to 30%, and shearing is performed annually in early spring by hand using blades (Taherpour and Salehi, 2003). While wool production is regarded as secondary, every portion of the Arabi sheep's body, except for the legs, is covered in wool. Efforts to improve local livestock breeds, including the Arabi breed, are ongoing (Bingöl and Bingöl, 2018a). A study by Al-Rsitmawi et al. (Al-Rsitmawi and Kassim, 2019) reported that the pubertal weight of female Arabi lambs reached 33.97 kg, highlighting the breed's potential in southern Saudi regions.

## DISTRIBUTION OF SHEEP IN ISRAEL

Israel, with its diverse climate and agricultural landscape, has developed various sheep breeds to meet the needs of its livestock industry. In addition to the Awassi breed, Israel raises Dorper, Romanov, Suffolk, and Assaf sheep. Dorpers, known for their excellent meat quality, are hardy and adaptable to different environments (Schoeman, 2000), while Romanovs, prolific breeders from Russia, are used in crossbreeding to enhance lambing rates. Suffolks, originally from England, contribute to meat production through crossbreeding for improved meat characteristics (Rosov and Gootwine, 2013). The Assaf breed, however, is the most important, offering superior productive traits compared to other breeds in the region. The morphological characteristics of the most well-known Israelite sheep breed are drawn in Figure 6.

## ASSAF

The Assaf breed, developed in Israel in the 1950s and 1960s, is a cross between Awassi and East Friesian sheep. This crossbreeding aimed to combine the Awassi's adaptability to harsh climates and good milk production with the East Friesian's prolificacy and superior productivity in both milk and meat. Controlled mating between Awassi ewes and East Friesian rams created the F1 generation, which was evaluated and backcrossed to refine desired traits such as milk yield, reproductive performance, and

**Figure 6.** Typical morphology of the Israelite synthetic sheep (Gootwine, 2009).

adaptability (Gootwine et al., 2008). Through selective breeding, a stable population with consistently improved traits was established (Gootwine, 2020). Assaf sheep are medium-sized tails, with ewes weighing 60-70 kg and males 80-100 kg (Gootwine and Goot, 1996). They are typically white, sometimes with a brown face, and lack wool on the legs and face. Known for their adaptability to various climates, they also excel in milk and meat production. In Israel, Assaf sheep have largely replaced Awassi sheep as the dominant dairy breed. An average Assaf ewe produces 334 liters of milk over a 173-day lactation, with a litter size of 1.57 and a 272-day lambing interval. The breed matures sexually between 6-7 months, and its high growth rate and carcass quality, combined with strong milk production, make it a dual-purpose breed, ideal for maximizing both milk and lamb outputs (Pollott and Gootwine, 2004).

## A COMPARATIV EVIEW OF GROWTH TRAITS IN MIDDLE EASTERN SHEEP

Due to insufficient information on accurate measurements of growth traits for most ovine breeds in the investigated region, critical data have not been compared across these breeds. However, a comparative analysis was conducted to elucidate the extent of differences in their weight indices from birth to maturity, spanning intervals of three, six, nine, and twelve months, as well as at maturity. This comparison has yielded significant insights that can aid in determining the genuine superiority of certain breeds over others. Awassi sheep are the most extensively measured breed with respect to body weight across age intervals. Following the Awassi breed, weight in-

dices for other breeds, such as Baluchi, Assaf, Mehraban, and Zandi, have also been recorded. However, body weight measurements have been conducted less frequently in the remaining breeds (Table 2).

Due to the insufficient data covering the phenotypic traits of various sheep breeds in the Middle East, only limited data were available for comparison among them. Consequently, reliance on a single read-

**Table 2.** Body weight indices of the Middle Eastern sheep breeds of sheep.

| Breed | Body weight (kg) | | | | | | References |
|---|---|---|---|---|---|---|---|
| | Birth | 3 months | 6 months | 9 months | 12 months | Adult | |
| Afshari | 4.82 | 28.35 | 34.56 | - | - | 57 | (Khorsand et al., 2014; Mohammadi et al., 2009) |
| Akkaraman | 4.055 | 19.5 | - | - | - | 50 | (AKTAŞ et al., 2014) |
| Akkaraman | 4.14 | - | 37.35 | - | - | 67. 29 | (Behrem, 2021; YAĞCI and BaŞ, 2021) |
| Akkaraman | 4.08 | 16.5 | 31.85 | - | - | - | (AKTAŞ and DOĞAN, 2014) |
| Akkaraman | 4.2 | 20.25 | 31.9 | - | - | - | (Unal et al., 2006) |
| Arabi | 3.8 | 24.05 | 30.765 | - | - | 40 | (Kassim and AL-Hellou, 2018; Shokrollahi and Baneh, 2012) |
| Assaf | 4.65 | - | 54.7 | - | - | 90 | (Gootwine et al., 1992; Rosov and Gootwine, 2013) |
| Assaf | - | 25.9 | - | - | - | - | (Cohen-Zinder et al., 2017) |
| Assaf | 5.09 | 28.51 | 44.86 | 68.44 | - | - | (Lyutskanov et al., 2020) |
| Assaf | 5.42 | 23.8 | - | - | - | - | (Darcan and Güney, 2001) |
| Assaf | 6.01 | 20.4 | 32.08 | - | - | - | (Aljamaeen et al., 2023) |
| Awassi | 3.52 | 19.74 | 25.63 | 26.69 | - | 54.8 | (Al-Jalili et al., 1988; Al-Khuzai and Al-Khazraji, 2019) |
| Awassi | 4.36 | 20.76 | 28.34 | - | - | - | (Thamer R S Aljubouri et al., 2021) |
| Awassi | 4.3 | 20.49 | 28.6 | 34.5 | 40.31 | 49.5 | (Aljubouri and Al-Shuhaib, 2023a) |
| Awassi | 4.737 | 23.079 | 30.32 | 36.418 | 43.424 | - | (Alwan et al., 2023) |
| Awassi | 4.48 | 17.13 | - | - | - | 61.2 | (Galal et al., 2008; Jawasreh et al., 2018) |
| Awassi | 4.205 | 17.44 | - | - | - | - | (Obeidat et al., 2019) |
| Awassi | 4.15 | 16.39 | - | - | - | - | (Şahin, 2022) |
| Awassi | - | 16.8 | 27.8 | 28.3 | 37.9 | 66.2 | (Emsen, 2005; Galal et al., 2008) |
| Awassi | - | 24.31 | - | 50.52 | - | 55.6 | (Alamer and Al-hozab, 2004; Gaili, 1993; Suliman et al., 2021) |
| Awassi | - | 23.5 | 40.2 | - | - | - | (Alshamiry et al., 2023) |
| Awassi | 4.255 | 19.15 | - | - | - | 45.6 | (Haile et al., 2019; Iniguez and Hilali, 2009; Zarkawi and Al-Daker, 2018) |
| Awassi | 4.35 | 18.4 | - | - | - | 55.45 | (Haile et al., 2019; Kassem, 2005) |
| Bafra | 3.58 | 18.08 | 22.07 | - | - | - | (Güngör, 2020) |
| Bafra | 3.65 | 23.51 | 33.62 | - | 41.50 | 65 | (Güngör, 2020) |
| Bafra | 3.93 | 22.80 | | - | - | - | (Köseman et al., 2023) |
| Baluchi | 4.344 | 24.15 | 31.91 | 35.59 | 40.63 | 44 | (Gholizadeh and Ghafouri-Kesbi, 2016) |
| Baluchi | 4.1 | 22.4 | 28.51 | 32.01 | 36.2 | - | (Gholizadeh and Ghafouri-Kesbi, 2016) |
| Baluchi | 4.31 | 23.1 | 32.33 | - | 39.34 | - | (Gholizadeh and Ghafouri-Kesbi, 2016) |
| Baluchi | 4.25 | 22.19 | 31.39 | 34.34 | 38.94 | - | (Jafaroghli et al., 2013) |

**Table 2.** Body weight indices of the Middle Eastern sheep breeds of sheep.

| Breed | Body weight (kg) | | | | | | References |
|---|---|---|---|---|---|---|---|
| | Birth | 3 months | 6 months | 9 months | 12 months | Adult | |
| Baluchi | 4.33 | 21.9 | 30.34 | 33.2 | 39.26 | - | (Nejad et al., 2017) |
| Barki | 3.445 | 14.455 | - | - | 23.81 | 37.15 | (El-Wakil et al., 2008; Moustafa et al., 2004) |
| Dağlıç | 3.54 | 23.25 | 32.5 | 36.5 | - | 49.5 | (Çelikeloğlu et al., 2021; KARABACAK and BOZTEPE, 2007) |
| Ghazel | - | 24.01 | 34.88 | - | - | 47.19 | (Baneh et al., 2013; Ghahri et al., 2019) |
| Ghazel | - | 22.01 | 31.49 | - | - | 45.89 | (Akhlaghipour et al., 2022; Baneh et al., 2013; Ebrahimi et al., 2022) |
| Ghezel | 4.27 | 23.37 | 31.83 | 35.49 | 39.86 | - | (Baneh and Ahmadpanah, 2018) |
| Gökçeada | 3.28 | 23.67 | 24.15 | - | 30.27 | 51.5 | (Sezenler et al., 2014; YILMAZ et al., 2012a) |
| Gökçeada | 3.3 | 19.8 | - | - | - | 50.49 | (ÇÖREKÇİ and EVRİM, 2001; Yilmaz et al., 2004) |
| Harri | - | 24.7 | - | 44.51 | - | 49.68 | (Gaili, 1993; Suliman et al., 2021) |
| Harri | 2.25 | 25.8 | - | - | - | - | (Abdelmoneim et al., 2017) |
| Hamdani | 4.055 | 16.78 | 25.78 | - | - | 46 | (ALADDIN OMAR, 2016; Al-Jalili et al., 1988; HAMA KHAN et al., 2019) |
| Hamdani | 4.055 | 16.78 | 25.78 | - | - | - | (HAMA KHAN et al., 2019) |
| Hamdani | 3.845 | 20.035 | | - | - | - | (Al-Dabbagh et al., 2019) |
| Karakul | 3.35 | 21.52 | 30.34 | - | - | 53 | (Halil and Özbeyaz, 2020) |
| Karakul | 4.19 | 22.81 | 30.37 | 36.24 | 40.86 | | (Aljubouri et al., 2020a) |
| Karakul | 5.2 | 24.37 | 33.23 | 39.68 | 47.32 | 51 | (Farid and Mokarechian, 1977; Mirhoseini et al., 2015) |
| Karayaka | 3.65 | 16.67 | 29.23 | - | - | - | (Şirin et al., 2017) |
| Karayaka | 4.1 | 19.9 | 31.2 | - | - | 50 | (Akçapinar et al., 2005; Yıldırım et al., 2013) |
| Kivircik | 4.005 | 29.925 | - | - | - | 57.5 | (SELVİ and ÜSTÜNER, 2021; YILMAZ et al., 2012a) |
| Kivircik | 4.1 | 28 | - | - | - | | (YILMAZ et al., 2012a) |
| Kivircik | 3.64 | 31.01 | 32.87 | - | 39.01 | 44.2 | (Ozturk et al., 2023; Sezenler et al., 2014) |
| Lori-Bakhtiari | 3.73 | 21.73 | 31.79 | - | - | 64.5 | (Mohammadi et al., 2015) |
| Lori-Bakhtiari | 5.286 | 31.68 | 39.292 | 46.479 | 50.467 | - | (Mohammadi et al., 2022) |
| Lori-Bakhtiari | - | - | 41.48 | 51.1 | 55.91 | - | (Almasi et al., 2021) |
| Makuie | 4.3 | 19.84 | 27.24 | 28.49 | 33.03 | 49.25 | (Jafari and Hashemi, 2014; Jafari and Manafiazar, 2016) |
| Mehraban | 3.88 | 21.58 | 33.27 | - | - | - | (Mohammadi and Edriss, 2007) |
| Mehraban | 4.39 | 19.13 | 37.78 | 47.47 | 54.27 | 60 | (Atashi and Izadifard, 2016; Gamasaee et al., 2010) |
| Moghani | 4.57 | 24.53 | 36.35 | 41.84 | 42.595 | 62 | (Hossein-Zadeh, 2012; Seyedsharifi et al., 2018b) |
| Moghani | 4.67 | 25.08 | 34.63 | - | - | - | (Savar-Sofla et al., 2011) |

**Table 2.** Body weight indices of the Middle Eastern sheep breeds of sheep.

| Breed | Body weight (kg) | | | | | | References |
|---|---|---|---|---|---|---|---|
| | Birth | 3 months | 6 months | 9 months | 12 months | Adult | |
| Najdi | - | 24.68 | - | 48.54 | - | 58 | (Hussein and Khattab, n.d.; Suliman et al., 2021) |
| Najdi | - | - | 33.11 | 48.15 | - | - | (Abouheif et al., 2015) |
| Najdi | - | 22.87 | 28.2 | 35.2 | - | - | (Hussein, 2014) |
| Ossimi | 4.21 | 16.57 | 23.4 | 34.55 | 46.16 | 49.16 | (El-Asheeri et al., 2006) |
| Rahmani | 4.13 | 14.76 | 22.69 | 35.92 | 48.26 | 50.26 | (El-Asheeri et al., 2006; Khalifa et al., 2013) |
| Red Karaman | 3.59 | - | - | - | - | - | (Kopuzlu et al., 2014) |
| Red Karaman | 3.3 | 17.48 | - | - | - | 60 | (Özyürek and Türkyilmaz, 2020; YILMAZ et al., 2022) |
| Red Karaman | 3.3 | 16 | - | - | - | 56.48 | (Alpak et al., 2009; Emsen and Yaprak, 2006) |
| Sakız | 3.25 | 21.49 | 31.636 | - | 39.4 | 45.2 | (Ceyhan et al., 2009) |
| Sakız | 3.91 | 25.44 | 26.95 | 30.95 | - | - | (Sezenler et al., 2014) |
| Zandi | 4.24 | 21.44 | 33.32 | 33.55 | 34.51 | - | (Mohammadi and Latifi, 2020) |
| Zandi | 4.13 | 20.14 | 31.145 | 32.635 | 34.765 | - | (Ghafouri-Kesbi, 2018) |
| Zandi | 4.14 | 20.13 | 32.96 | - | 34.15 | 36 | (Khojastehkey and Aslaminejad, 2013; Senemari et al., 2011) |
| Zandi | 4.12 | 20.72 | - | 32.22 | 34.12 | - | (Ghafouri-Kesbi and Eskandarinasab, 2008) |
| Zel | 3.5 | 20 | 32.5 | 36.5 | 40 | 49 | (Afshar and Aboozari, 2018) |
| Shal | 4.13 | 22.19 | 33.10 | - | - | 52 | (Shirzeyli et al., 2013) |
| Shal | 3.46 | 22.65 | 34.14 | 46.36 | 55.46 | - | (Hashemi and Ghavi Hossein-Zadeh, 2020) |
| Shal | 4.31 | 20.90 | 34.13 | 47.42 | 60.46 | - | (H. Mohammadi et al., 2013) |
| Shal | - | - | - | - | - | 72 | (Patiabadi et al., 1999) |

ing occurred when no other records were available. Nonetheless, a comprehensive understanding can be derived by comparing these breeds using body-weight indices at multiple time points until maturity. At birth, newborn lambs of the Assaf breed exhibited the highest average weights, at 5.292 kg, compared to other breeds in the Middle East. Following these values, Afshari, Moghani, and Lori-Bakhtiari lambs exhibited average weights of 4.83 kg, 4.62 kg, and 4.508 kg, respectively. At the same time, Harri sheep showed the lowest average birthweight indices with only 2.25 kg per lamb. Because Assaf's weight data were unavailable at three months of age, Kivircik sheep had the highest average weight (29.645 kg), followed by Afshari and Lori-Bakhtiari at 28.35 kg and 26.705 kg, respectively. In contrast, the Egyptian Barki and Rahmani sheep exhibited the lowest three-month weight indices, with each lamb weighing an average of 14.46 kg. The superiority of the Assaf breed was also evident in the age intervals of six months (43.88 kg) and nine months (68.44 kg). As in the case of the 3-month age interval, the Egyptian Ossimi and Rahmani sheep also exhibited the lowest six-month weight indices, with averages of 23.4 kg and 22.69 kg, respectively. Furthermore, detailed records regarding the weights of Assaf sheep at 12 months of age were likewise unavailable, leaving a gap in the dataset. Consequently, Shal sheep were observed to possess the highest average weight indices of 57.96 kg, followed by Lori-Bakhtiari sheep with average weight indices of 53.188 kg. The Egyptian Barki breed has also exhibited the lowest 12-month weight index, averaging 23.81 kg. Upon reaching maturity, the Assaf breed once again demonstrated its clear superiority in average weight indices, exhibiting the highest average weight records of 90 kg. This breed significantly surpassed those of other breeds in the region, none of which

exceeded an average weight record of 65 kg (Figure 7). In contrast, the Iranian Zandi and the Egyptian Barki breeds showed the least body weight indices with 36 kg and 37.15 kg, respectively.

In addition to the body weight comparison, other available phenotypic data were retrieved and compared to assess the superiority of breeds over their counterparts across several traits. Despite insufficient data to conduct this comparison, we were able to retrieve averages for several reproductive traits across most Middle Eastern breeds, including fertility rates, litter sizes, lambing rates, twinning rates, survival rates, and prolificacy indices. Similarly to body weight measurements, the literature describing other productive indices of Awassi sheep far surpasses that of other breeds. The extensive documentation of productive traits in Awassi sheep is followed by relatively limited literature on these traits in Bafra and Akkaraman breeds. At the same time, reproductive traits collected from other breeds provided less reliable information for accurately determining their reproductive performance. This deficiency arises from numerous gaps across several traits, thereby reducing the efficiency of comparisons among them. Insufficient reproductive data were notably identified in Saudi Harri, Turkish Dağlıç, and Saudi Arabi sheep, as only a scant number of reproductive records were available for them (Table 3).

The diversity in milk production potential and udder morphology among Middle Eastern sheep breeds reflects a complex interplay among genetics, adaptation to local environments, and production objectives. These traits are particularly relevant in dairy management, as udder conformation is closely linked to milk yield, lactation persistency, and suitability for hand or machine milking.

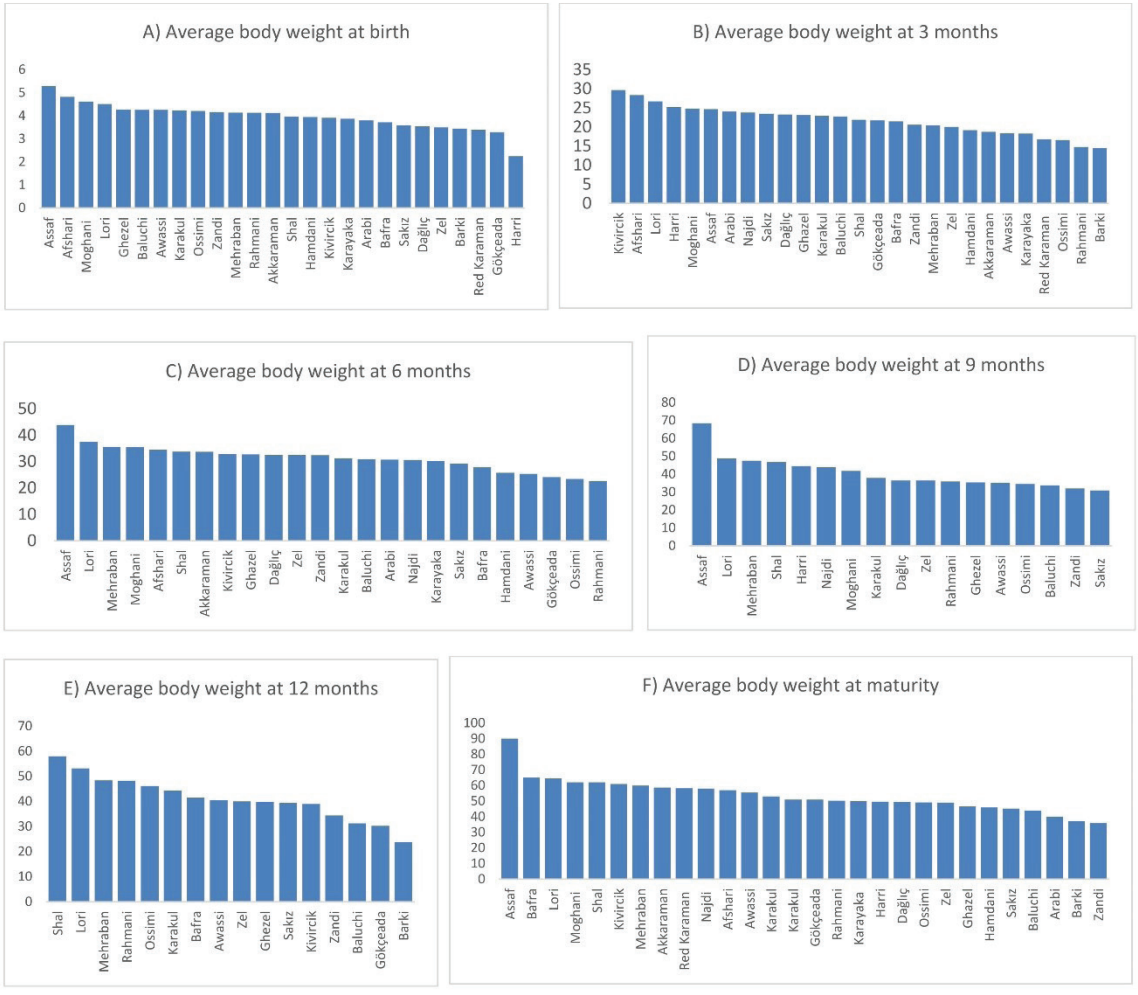


**Figure 7.** Average body weights of various Middle Eastern breeds of sheep recorded in various age intervals.

**Table 3.** The reproductive traits of sheep breeds in the Middle East.

| Breed | Country | Fertility Rate (%) | Litter Size | Lambing Rate (%) | Twinning Rate (%) | Survival rate (%) | Prolificacy | Reference |
|---|---|---|---|---|---|---|---|---|
| Afshari | Iran | 86 | - | 86.33 | 11 | - | - | (Safdar et al., 2016) |
| Afshari | Iran | - | 1.149 | - | - | - | 1.20 | (K. Mohammadi et al., 2011) |
| Afshari | Iran | 90 | - | 100 | - | - | 1 | (Akarim Alamdar et al., 2022) |
| Akkaraman | Turkey | 75 | 1.32 | 96.53 | - | 91.33 | 1.32 | (Büyüktekin and Öztürk, 2018) |
| Akkaraman | Turkey | 92 | 1.35 | 124 | 65.2 | 91.9 | 1.35 | (BEBEK and KESKİN, 2021) |
| Akkaraman | Turkey | 89 | 1.35 | 120 | - | - | 1.35 | (Şen et al., 2021) |
| Akkaraman | Turkey | - | 1.47 | 79 | 47 | - | 1.47 | (Kocakayaa, 2019) |
| Akkaraman | Turkey | - | 1.26 | 79.8 | - | 95.3 | 1.26 | (Unal et al., 2006) |
| Akkaraman | Turkey | 91 | 1.13 | 103 | - | - | 1.06 | (Aksoy et al., 2023) |
| Arabi | Iraq | 62 | - | - | 0 | - | - | (Kassim and AL-Hellou, 2018) |
| Arabi | Iraq | 70.06 | 1.14 | - | - | - | 1.14 | (Al-Dabbagh et al., 2013) |
| Assaf | Israel | - | 1.57 | - | - | - | 1.60 | (Pollott and Gootwine, 2004) |
| Assaf | Israel | - | 1.92 | - | - | 88.30 | 1.92 | (Reicher et al., 2012) |
| Assaf | Israel | 95 | 2.03 | - | - | 85.66 | - | (Gootwine et al., 2008) |
| Assaf | UAE | 84 | 1.72 | 143 | - | - | 1.72 | (Zaher et al., 2020) |
| Awassi | Iraq | - | 1.06 | - | 21.55 | 94.53 | - | (Khazaal et al., 2022) |
| Awassi | Iraq | 79 | 1.02 | 81 | 26.53 | | 1.02 | (Abdulkareem et al., 2023) |
| Awassi | Iraq | 80 | 1.12 | 90 | 12.5 | 97.8 | 1.12 | (Zebari, 2021) |
| Awassi | Jordan | - | 1.16 | - | - | - | 1.16 | (Al-Najjar et al., 2022) |
| Awassi | Jordan | 78 | 1.05 | 78 | - | - | 1.0 | (Kridli et al., 2018) |
| Awassi | UAE | 72 | 1.09 | 78 | - | - | 1.09 | (Zaher et al., 2020) |
| Awassi | Turkey | 90 | 1.30 | 117.5 | 30.50 | - | 1.30 | (ÜSTÜNER and OĞAN, 2013) |
| Awassi | Turkey | 89 | 1.37 | 121 | - | - | 1.37 | (Şen et al., 2021) |
| Awassi | Turkey | - | 1.32 | 87.8 | 28.30 | 83 | 1.32 | (Emsen and Yaprak, 2006) |
| Awassi | Saudi | 82.2 | 1.15 | 79.1 | 10.05 | 92.37 | - | (Ali et al., 2020; Galal et al., 2008) |
| Bafra | Turkey | - | 1.66 | - | 57.28 | 80 | 1.66 | (IŞIK and AKSOY, 2015) |
| Bafra | Turkey | - | 1.67 | 91.4 | 44 | 97.7 | 1.67 | (Akçapinar et al., 2005) |
| Bafra | Turkey | 93.1 | 1.67 | | 51.7 | 86.2 | 1.67 | (Güngör and Akçapınar, 2013) |
| Bafra | Turkey | - | 1.67 | 55.25 | - | 96.81 | 2.2 | (Güngör, 2020) |
| Bafra | Turkey | - | 1.60 | 92 | - | 87.50 | - | (Ünal et al., 2008) |
| Bafra | Turkey | 87.16 | - | 90.00 | 80.00 | 97.74 | 2.20 | (Gungor et al., 2022) |
| Bafra | Turkey | 92.54 | 1.94 | - | 65.61 | 97 | - | (Yerlikaya and Ulutaş, 2019) |
| Baluchi | Iran | - | 1.00 | - | - | 98.11 | - | (Nikkhah et al., 2022) |
| Baluchi | Iran | - | - | 75 | - | - | - | (Didarkhah et al., 2020) |
| Baluchi | Iran | - | 1.42 | - | - | - | 1.42 | (Esmaeili-Fard et al., 2021) |
| Baluchi | Iran | - | 1.27 | - | - | - | 1.27 | (Jafaroghli et al., 2019) |
| Baluchi | Iran | - | 1.21 | - | - | - | - | (Yazdi et al., 1999) |
| Barki | Egypt | 85 | 1.05 | 95 | - | - | 1.05 | (Abdalla et al., 2014) |
| Barki | Egypt | 75.0 | - | - | 6.6 | 87.5 | - | (El-Malky et al., 2019) |
| Barki | Egypt | 89 | 0.88 | 78 | - | - | 1.07 | (MM et al., 2013) |
| Barki | Egypt | 88 | - | - | 5 | 92 | - | (Elshazly and Youngs, 2019) |
| Dağlıç | Turkey | - | 1.05 | - | - | - | - | (ÜNAL et al., 2003) |
| Ghezel | Iran | - | 1 | 83 | 10.6 | - | 1.07 | (Atashi et al., 2013; Hajibemani et al., 2023) |

**Table 3.** The reproductive traits of sheep breeds in the Middle East.

| Breed | Country | Fertility Rate (%) | Litter Size | Lambing Rate (%) | Twinning Rate (%) | Survival rate (%) | Prolificacy | Reference |
|---|---|---|---|---|---|---|---|---|
| Ghezel | Iran | 72.85 | 1.06 | - | - | - | 1.06 | (Atashi and Izadifard, 2016) |
| Ghezel | Iran | 79.20 | - | 64.71 | 10 | 94.84 | 1 | (Hasani et al., 2020) |
| Gökçeada | Turkey | 76.3 | 1.27 | 96.9 | - | - | 1.27 | (Yalcin et al., 1980) |
| Gökçeada | Turkey | 77.60 | 1.26 | 97.77 | 26.36 | - | 1.26 | (ÇÖREKÇİ and EVRİM, 2001) |
| Harri | Saudi | - | 1.55 | - | 1.72 | - | - | (Hussein and Khattab, n.d.) |
| Hamdani | Iraq | 78 | 1.07 | 84 | 7.69 | 100 | 1.07 | (Zebari, 2021) |
| Karakul | Turkey | 94 | 1.02 | 96.3 | - | 95.2 | 1.02 | (Halil and Özbeyaz, 2020) |
| Karakul | Iran | 83 | 1.0 | 83 | - | - | - | (Safdarian et al., 2006) |
| Karakul | Iran | - | - | 80.6 | 16 | 93.6 | - | (Ayaseh et al., 2021) |
| Karayaka | Turkey | 91 | 1.12 | 102 | - | - | 1.12 | (Şen et al., 2021) |
| Karayaka | Turkey | 93.52 | 1.00 | 93.52 | 14.62 | 83.85 | 1 | (Tozlu Celik et al., 2021; YÜCEL and KILIÇALP, 2021) |
| Kivircik | Turkey | 72 | 1.32 | 92.20 | 30.60 | 88.80 | 1.04 | (SELVİ and ÜSTÜNER, 2021) |
| Kivircik | Turkey | - | 1.56 | 89.60 | - | 94.70 | 1.38 | (Koyuncu, 2005) |
| Kivircik | Turkey | - | 1.50 | 85.20 | - | - | 1.50 | (Arslan et al., 2021) |
| Kivircik | Turkey | 83.72 | 1.21 | 83.72 | 21.56 | 94.00 | 1.02 | (Ceyhan et al., 2011) |
| Lori | Iran | 72.73 | 1.17 | 68.18 | 13 | 96 | 1.07 | (Mohammadi et al., 2015; Samadian et al., 2023) |
| Mehraban | Iran | - | 1.12 | - | - | - | 1.12 | (Yavarifard et al., 2015) |
| Mehraban | Iran | - | 1.10 | - | - | - | 1.13 | (Pezhman and Zamani, 2012) |
| Mehraban | Iran | 76.05 | 1.07 | 80 | - | - | - | (Atashi and Izadifard, 2016) |
| Mehraban | Iran | 58 | - | 62 | - | 82 | 1.10 | (Farahavar et al., 2020) |
| Moghani | Iran | - | 1.25 | - | - | 96 | 1.25 | (Abdollahy et al., 2012) |
| Moghani | Iran | - | 1.27 | 80 | 12.3 | - | - | (Rashidi et al., 2011; Vahedi et al., 2023) |
| Moghani | Iran | 77.3 | - | 93 | - | - | 1.24 | (Javadi et al., 2014; Kiyanzad, 2005) |
| Najdi | Iraq | 41.6 | - | - | 0 | - | - | (Kassim and AL-Hellou, 2018) |
| Najdi | Saudi | 60 | 1.42 | 82.89 | 15.06 | 85.66 | 1.42 | (Ali et al., 2020) |
| Najdi | Saudi | - | 1.42 | 82.89 | 15.06 | 85.66 | - | (Hussein and Khattab, n.d.) |
| Ossimi | Egypt | - | 1.25 | - | - | - | - | (Ali, 2007) |
| Ossimi | Egypt | 95 | - | - | 13.33 | 100 | - | (El-Malky et al., 2019) |
| Ossimi | Egypt | 69 | 1.19 | 81.43 | 19.30 | 88.57 | 1.19 | (Mahmoud and Hussein, 2019) |
| Ossimi | Egypt | 90 | - | - | 14.3 | 94 | - | (Elshazly and Youngs, 2019) |
| Rahmani | Egypt | 86 | 1.03 | 88.14 | - | - | 1.03 | (Abd-Allah et al., 2011) |
| Rahmani | Egypt | 95 | - | - | 25.30 | 92.30 | - | (Elshazly and Youngs, 2019) |
| Rahmani | Egypt | - | - | 74 | - | - | 1.21 | (Abdel-Mageed et al., 2006) |
| Red Karaman | Turkey | - | 1.20 | 91.7 | 8.60 | 88 | 1.22 | (Emsen and Yaprak, 2006) |
| Red Karaman | Turkey | 92 | 1.13 | 96 | - | - | 1.13 | (Li et al., 2021) |
| Red Karaman | Turkey | 96 | 1.113 | 91.3 | 11.3 | 95.5 | 1.113 | (YILMAZ et al., 2022) |
| Sakız | Turkey | 93 | 1.29 | 121 | 29 | - | 1.29 | (İlhan et al., 2020) |
| Sakız | Turkey | 76 | 1.787 | 128 | - | 84 | - | (Ceyhan et al., 2009) |
| Zandi | Iran | - | 1.12 | - | - | - | 1.12 | (K. Mohammadi et al., 2013) |
| Zandi | Iran | - | - | 48.58 | 0 | - | - | (Masoudi, 2021) |
| Zandi | Iran | 60 | - | 50 | - | - | 1.20 | (Arjmandi et al., 2021) |
| Zel | Iran | 72 | 1.23 | 85 | - | - | 1.23 | (Afshar and Aboozari, 2018) |

**Table 3.** The reproductive traits of sheep breeds in the Middle East.

| Breed | Country | Fertility Rate (%) | Litter Size | Lambing Rate (%) | Twinning Rate (%) | Survival rate (%) | Prolificacy | Reference |
|---|---|---|---|---|---|---|---|---|
| Zel | Iran | 85.44 | - | - | - | 97 | 1.12 | (Kiyanzad et al., 2003) |
| Zel | Iran | 85 | 1.18 | 100 | - | - | 1.18 | (Papi et al., 2021) |
| Shal | Iran | - | 1.13 | | 35 | - | - | (Posht-e-Masari et al., 2013) |
| Shal | Iran | 84.64 | 1.04 | 93.64 | - | 97.90 | 1.12 | (Kiyanzad et al., 2003) |

High-milk-producing breeds such as the Assaf sheep clearly demonstrate the outcomes of long-term selection for dairy performance. The Assaf breed exhibits a markedly elevated milk yield, exceeding 330 kg per lactation, combined with an extended lactation length of approximately 173 days. This superior performance is supported by favorable udder morphology, including relatively deep, well-attached udders and moderately sized teats with optimal placement, characteristics that collectively enhance milking efficiency and reduce mechanical stress during milking operations (Ángeles Pérez-Cabal et al., 2013). Similarly, Iranian breeds such as Ghezel and Mehraban display moderate to high milk yields, with strong positive correlations reported between early postpartum udder dimensions, particularly udder depth and circumference, and total lactation yield. These findings underscore the predictive value of early udder measurements as indirect selection criteria for milk production in traditional systems (Izadifard & Zamiri, 1997). The Merino breed exhibits low milk production, with an average yield of about 70 kg per lactation and a lactation length of approximately 140 days, consistent with its primary selection for wool rather than dairy performance. Udder morphology is generally moderate, with mid-lactation udder circumference ranging from 42 to 45 cm, udder length around 22 cm, and udder width of 14–15 cm, while teat length averages about 2.7 cm with a diameter of 1.4–1.8 cm. These traits vary with parity and management conditions, reflecting functional but non-specialized mammary development (Ewes and Koyuncu, 2011). In contrast, widely distributed indigenous breeds such as Awassi, Akkaraman, Karayaka, and Karakul exhibit moderate milk yields, reflecting their dual-purpose or multipurpose nature. The Awassi sheep, one of the most economically important breeds in the Middle East, exhibits moderate milk production and a relatively short lactation period, accompanied by a moderately developed udder with balanced circumference, depth, and teat dimensions. Notably, udder size in Awassi ewes increases with age, indicating cumulative physiological adaptation across parities (Karakuş & Ilyas, 2020). The Akkaraman and Karayaka breeds exhibit comparable milk yields, with udders described as moderate in size and structurally functional. However, milk output per day remains limited when compared to specialized dairy breeds (Yardımcı & Özbeyaz, 2001; Cam & Kirikci, 2023). In Karakul sheep, udder dimensions decline progressively as lactation advances, while teat-to-floor distance increases, reflecting structural changes associated with milk withdrawal and advancing lactation stage (Erol et al., 2020).

The Kıvırcık breed exhibits moderate dairy potential with a reported milk yield of approximately 85.85 kg per lactation and a lactation length of about 153.5 days, reflecting its primary classification as a meat-oriented rather than a specialized dairy breed. Udder morphology is moderate, with an average circumference of around 35.1 cm, udder width of 12.4 cm, udder length close to 22.1 cm, and teat length of approximately 2.68 cm, indicating a functional udder suitable for lamb rearing but not optimized for intensive milk production (Cemal et al., 2018).

The Lori-Bakhtiari breed shows moderate milk production, with an average yield of approximately 148.15 kg per lactation and a relatively long lactation period of about 184 days. Udder morphology undergoes marked changes throughout lactation, characterized by a progressive reduction in udder height, width, and circumference, alongside an increase in teat length and a narrowing of teat angle. Additionally, udder attachment strength and cistern dimensions decline as lactation advances, indicating dynamic structural adaptation associated with milk secretion and withdrawal rather than stable dairy-type conformation (Sadeghi et al., 2013).

Several breeds originating from harsh or semi-arid environments, including Baluchi, Barki, Hamdani, Najdi, and Rahmani sheep, exhibit relatively low to moderate milk yields but possess udder charac-

teristics adapted to extensive management systems (Bingöl & Bingöl, 2018). The Baluchi breed, for example, has a small, compact udder with uniform teats, a morphology that likely confers resilience under conditions of limited nutrition and environment (Qadir et al., 2017). Najdi sheep show a wide range of milk yield values, with udder depth, width, and teat distance positively correlated with milk production, indicating that even within low-input systems, morphological variation can significantly influence productive performance (Seyedsharifi et al., 2018; Matar et al., 2024). In Rahmani sheep, the udder is described as functionally balanced with strong suspension and symmetry, attributes that support udder health; however, slight increases in udder depth and teat length in subclinical mastitis-positive animals suggest a potential trade-off between production traits and disease susceptibility (Mousa & Shetaewi, 1995; Abd Allah et al., 2011).

Turkish breeds such as Bafra, Dağlıç, Gökçeada, Kıvırcık, Red Karaman, and Sakız illustrate considerable intra-regional variability. Bafra sheep show relatively high milk yield and long lactation length, supported by a large udder circumference and favorable teat dimensions, suggesting suitability for semi-intensive dairy production (Şeker et al., 2024). Gökçeada sheep possess a well-developed, pendulous, bezel-shaped udder, a conformation often associated with higher milk yield and compatibility with machine milking systems (Çörekçi & Evrim, 2000). In contrast, Red Karaman and Dağlıç breeds exhibit more moderate udder development and lower milk yields, reflecting their primary selection for meat or adaptation rather than dairy specialization (Özbey & Akçan, 2000; Koçak et al., 2018).

Some breeds, including Afshari, Barki, Moghani, Ossimi, and Zel, lack detailed descriptions of udder morphology despite available milk-production data (Abousoliman et al., 2020a, 2020b). This absence highlights a significant gap in phenotypic characterization, particularly given the importance of udder traits for genetic improvement programs. For instance, although Afshari and Moghani sheep demonstrate moderate milk yields and, in the case of Moghani, extended lactation length, the lack of morphological data limits the ability to relate structure to function or to design targeted selection strategies (Amanlou et al., 2020; Asadi et al., 2025) (Seyedsharifi et al., 2018).

The Sakız breed shows variable milk production, ranging from approximately 67.83 to 150 kg per lactation, with a lactation length of about 155 to 170 days, indicating moderate dairy potential under suitable management conditions. Udder morphology is moderately developed, with udder length between 38.7 and 43.0 cm and width around 15 cm, accompanied by relatively short but well-positioned teats measuring 4.3–4.7 cm in length and 2.6–2.7 cm in diameter. These characteristics support efficient milk removal and reflect a functional udder conformation rather than a highly specialized dairy type (Ünal et al., 2002).

The Zel breed is characterized by low milk production, with an average yield of approximately 50 kg per lactation and a lactation length of approximately 120 days, reflecting its adaptation to extensive, low-input production systems. However, detailed descriptions of udder and teat morphology are unavailable for this breed, limiting understanding of the structural and functional determinants underlying its lactational performance. The absence of such information highlights a clear gap in phenotypic characterization and restricts comparative evaluation of milk synthesis traits in Zel sheep (Yousefi et al., 2013) (Table 4).

It is also important to emphasize that not all investigated sheep breeds have been reported with sufficient or detailed information regarding milk synthesis–related traits. For several breeds, available studies primarily focus on overall milk yield or lactation length, while omitting key physiological and morphological parameters directly associated with milk synthesis, such as mammary gland development, secretory tissue activity, or detailed udder and teat measurements. This lack of comprehensive reporting limits the ability to draw robust comparisons among breeds and constrains the interpretation of productive potential from a mechanistic perspective. Consequently, the existing literature reflects an uneven level of characterization across Middle Eastern sheep breeds, underscoring a clear need for more integrative studies that simultaneously document milk yield, lactation dynamics, and the morphological and functional traits underlying milk synthesis.

Despite these gaps, it is still possible to form an impression of the reproductive performance for the majority of the described breed by comparing the collected traits with those of other breeds. Although it is unsatisfactory to lack certain reproductive traits in the presented table, other retrieved traits related to the particular missing trait may help fill in these gaps. Similar to the measured body traits, signifi-

**Table 4.** Milk production and udder morphological traits of various Middle Eastern sheep breeds.

| Breed | Milk yield (kg) | Lactation length (days) | Udder / Teat morphology | References |
|---|---|---|---|---|
| Afshari | 184.8 | - | No data available | (Amanlou et al., 2020; Asadi et al., 2025) |
| Akkaraman | 99,57 | 133,12 | Moderate, milk yield ≈0.492 kg/day | (Yardımcı and Özbeyaz, 2001) |
| Assaf | 334±0.97 | 173±0.31 | relatively deep and well-attached udders, with moderate-sized teats and teat placement/udder dimensions compatible with good milking performance. | (Ángeles Pérez-Cabal et al., 2013) |
| Awassi | 98.07 ± 0.03 | 101.08 ± 0.04 | a moderately developed udder (40.6 cm circumference, 19.8 cm depth) with teats 2.8–3.0 mm long, 16.9 mm diameter, and udder/teat heights 42.9/20.3 cm; udder size increases with age and varies slightly by udder type. | (Karakuş and Ilyas, 2020) |
| Bafra | 156.86 | 177.75 | relatively large udder, with a circumference of 40.95 cm, width 12.36 cm, and depth 16.24 cm. Teats measure about 2.8 cm in length and 1.4–1.5 cm in diameter, with an inter-teat distance of 15.35 cm and udder height from the floor of 31.88 cm. | (Şeker et al., 2024) |
| Baluchi | 95.1±11.122 | 123.60±8.44 | small, compact udder, with average measurements of 7.86 cm in height and 11.83 cm in circumference. Teats are typically uniform, measuring about 2.99 cm in length and 1.03 cm in diameter. | (Qadir et al., 2017) |
| Barki | 89.80± 8.9 | 92 | No data available | (Abousoliman et al., 2020b; Koçak1 et al., 2018) |
| Dağlıç | 71.55 | 143.7 | Moderate udder; depth 15.25→14.76 cm, circumference 40.94→34.79 cm, right teat length 2.77→2.66 cm, diameter 1.58→1.44 cm (60→90 days). | |
| Ghezel | 148.8 ± 6.1 | 173.0 ± 5.0 | right udder depth (r = 0.75) and udder circumference (r = 0.72) measured two weeks postpartum showed the strongest correlations (P < 0.01) with total lactation yield | (Izadifard and Zamiri, 1997) |
| Gökçeada | 90 - 102 | 160 - 102 | Well-developed, pendulous, bezel-shaped udder, often associated with higher milk production and suitable for machine milking. | (ÇÖREKÇİ and EVRİM, 2000) |
| Hamdani | 83.96 ± 11.55 | 170.98 ± 10 | well-developed udders with long teats, and are considered good milking animals | (Bingöl and Bingöl, 2018b) |
| Karakul | 104.85 ± 3.73 | 159.01 ± 1.70 | moderate udder size (UC≈44.2 cm at day 45) with declining udder width, depth, and circumference as lactation advances, while teat-floor distance increases. Teat length (≈3.3 cm) and teat diameter (≈1.4–1.8 cm) vary with lactation number, and the distance between teats decreases later in lactation. | (Erol et al., 2020) |
| Karayaka | 101.176±6.36 | 112.8±1.53 | Moderate udder with depth 12.57 cm, circumference 36.46 cm, width 9.93–9.95 cm; right/left teat length 2.40–2.29 cm, diameter 1.33–1.36 cm, teat-floor distance 30.25–30.50 cm, and teat distance 15.30 cm; udder and teat traits influenced by udder type, with Type 4 showing longer, wider teats and shorter teat distance. | (Cam and Kirikci, 2023) |

**Table 4.** Milk production and udder morphological traits of various Middle Eastern sheep breeds.

| Breed | Milk yield (kg) | Lactation length (days) | Udder / Teat morphology | References |
|---|---|---|---|---|
| Kivircik | 85.85 | 153.5 | moderate udder size (UC ≈ 35.1 cm), udder width ≈ 12.4 cm, udder length ≈ 22.1 cm, and teat length ≈ 2.68 cm | (Cemal et al., 2018) |
| Lori-Bakhtiari | 148.15+31.3 | 184.17+35 | marked decline in udder size across lactation, with udder height (24→15 cm), width (18→15 cm), and circumference (49→32 cm) decreasing, while teat length increases (2.3→3.3 cm) and teat angle narrows (109→97°). Udder attachment weakens, and cistern depth/height declines steadily. | (Sadeghi et al., 2013) |
| Mehraban | 141.8 ± 5.7 | 177.0 ± 5.0 | udder circumference two weeks after weaning (r = 0.58) and heart girth two weeks postpartum (r = 0.59) showed the highest correlations (P < 0.05) with lactation yield. | (Izadifard and Zamiri, 1997) |
| Merino | 70 | 140 | moderate udder (mid-lactation UC ≈ 42–45 cm, length ≈ 22 cm, width ≈ 14–15 cm, rear udder depth ≈ 7.3 cm); teat length ≈ 2.7 cm and teat diameter ≈ 1.4–1.8 cm; traits vary with parity and management. | (Ewes, n.d.) |
| Moghani | 78 | 210 | No data available | (Seyedsharifi et al., 2018a) |
| Najdi | 67.5 - 125 | 90 | Medium, healthy udder; teats 3.2×1.7 cm, angled 35.7°; udder depth, width, angle, and teat distance decreased over lactation, teat length unchanged; milk yield positively correlated with udder size and teat distance. | (Matar et al., 2024) |
| Ossimi | 44.18 - 65.9 | 79.6 - 84 | No data available | (Mousa and Shetaewi, 1995) |
| Rahmani | 70.57 ± 9.651 | 96.96 ± 6.014 | a functionally balanced udder, with moderate depth (≈6.9–8.4 cm), width around 10–11 cm, and stable symmetry and attachment scores (≈1.3–3.5). The udder cleft and suspension remain strong (score 4), while teats show a functional angle (≈3.0) and medium length (≈1.1–2.1 cm). Slightly greater depth and teat length in SCM-positive animals suggest increased mastitis susceptibility. | (Abd Allah et al., 2011) |
| Red Karaman | 65 – 96.37 | 145 - 164 | moderately developed udder (34.5 cm circumference, 21.0 cm length) with short teats (1.9 cm) of 1.5 cm diameter, udder width 10.0 cm, and height from ground 71.5 cm. | (Özbey and Akçan, 2000) |
| Sakız | 67.83 - 150 | 154.63 - 170 | moderately developed udder (38.7–43.0 cm length, 15 cm width) with short teats (4.3–4.7 cm, 2.6–2.7 cm diameter) and functional placement/depth scores for efficient milking. | (ÜNAL et al., 2002) |
| Zel | 50 | 120 | No data available | (Yousefi et al., 2013) |

cant efforts have been made to compile averages of reproductive traits, aiming to compare reproductive performance among Middle Eastern sheep breeds. It has been inferred that a direct comparison of retrieved data can help compensate for missing data, yielding more reliable insights into the reproductive performance of Middle Eastern ovine breeds.

Based on the retrieved data, the average fertility rates were remarkably similar across breeds. This is exemplified by the Red Karaman breed, which demonstrated the highest average fertility at 94%. Following closely were Karayaka, Bafra, and Rahmani breeds, with fertility rates of 92.26%, 90.93%, and 90.5%, respectively. Similarly, the Assaf breed

displayed an average fertility rate of 89.5%. On the other hand, the Iranian Zandi sheep exhibited the lowest average fertility rate, at 60%. Furthermore, in addition to its superiority in body weight, Assaf sheep showcased the highest average litter size, with 1.81, closely followed by Bafra sheep with 1.7. Conversely, Barki sheep displayed the lowest litter sizes, averaging 0.965. Moreover, the superiority of the Assaf breed was evident in the lambing rate indices, with an average of 143%, followed closely by the Sakiz breed at 124.5%. In contrast, the Iranian Zandi breed exhibited the lowest lambing rate, at 49.29%. Because clear data on twinning rates in the Assaf breed were unavailable, the Bafra breed had the highest average twinning rate (59.718%), followed by the Akkaraman breed (56.1%). In contrast, both the Iranian Zandi and the Saudi Arabi breeds showed no possibility of twinning. Remarkably, the average survival rates were similar across Middle Eastern sheep breeds, ranging from 100% in the Hamdani breed, 98.11% in the Baluchi breed, and 97.9% in the Shal breed to 96% in both the Lori-Bakhtiari and Moghani breeds. In contrast, the Mehraban breed exhibited the lowest survival rate at 82%. Regarding prolificacy averages, both the Bafra and Assaf breeds significantly surpassed other breeds in the region, showing average values of 1.88 and 1.746, respectively (Figure 8). Conversely, the breeds of Iraqi Hamdani and Iranian Karakul had the lowest prolificacy indices, at 1.02 and 1.04, respectively.

Due to insufficient data on productive measurements among the majority of sheep in the Middle East, comprehensive comparisons have not been made. This review presented the main ovine breeds in the Middle East and conducted a straightforward comparison among them using the available literature. A comparative analysis of weight indices from birth to maturity has yielded valuable insights, with Awassi sheep being the most extensively studied breed. The Assaf breed consistently demonstrated superiority in weight indices and reproductive traits. Notably, the Assaf breed exhibited high fertility rates, litter sizes, and lambing rates compared to

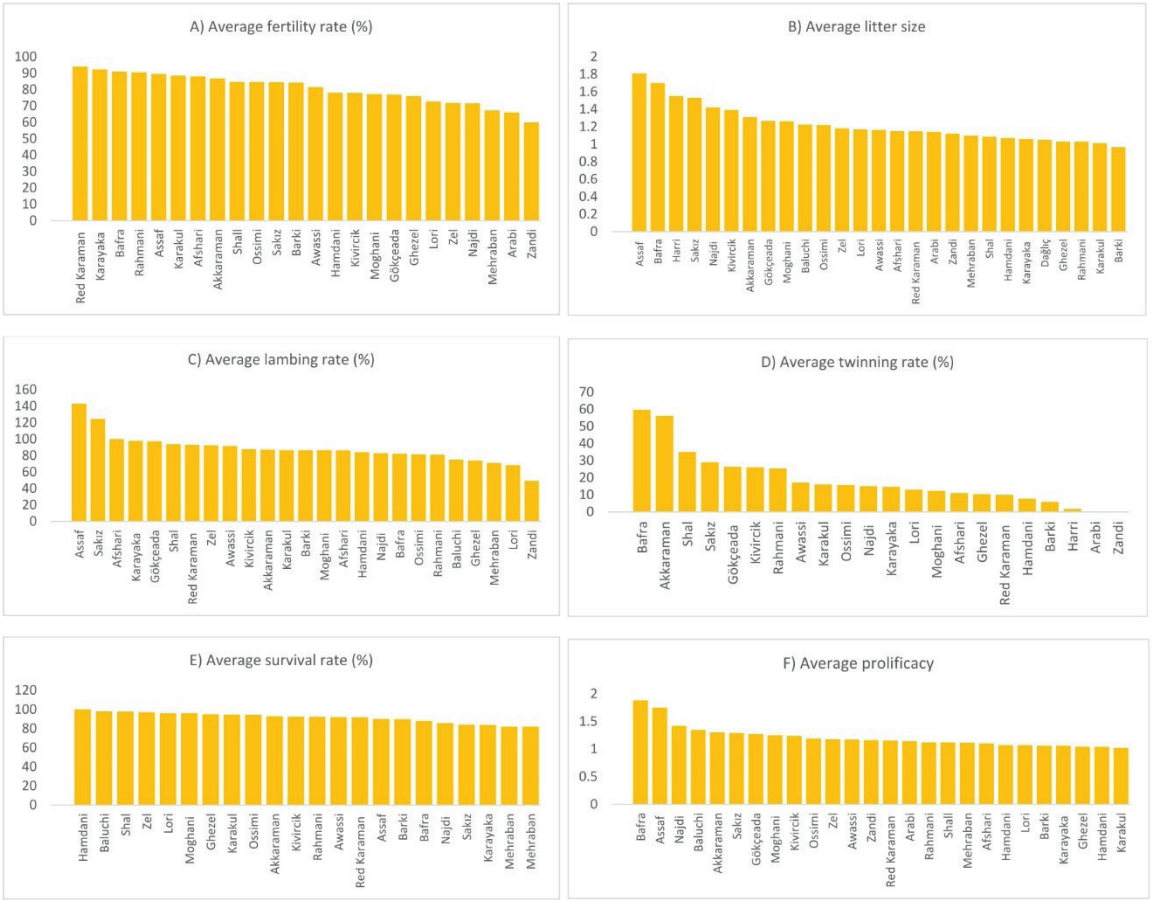


**Figure 8.** The averages of the main reproductive traits in various Middle Eastern breeds of sheep.

other breeds, while the Iranian Zandi breed consistently showed lower indices. On the other hand, the Egyptian sheep, particularly of the Barki breed, exhibit relatively lower weight indices compared to other breeds at various age intervals. Additionally, there is insufficient data on body weight measurements for Egyptian breeds, hindering comprehensive comparisons with other Middle Eastern sheep breeds. Efforts should be intensified to collect accurate, comprehensive data on growth and reproductive traits across all Middle Eastern sheep breeds. Priority should be given to researching breeds with limited available data, such as the Egyptian Barki and Rahmani sheep, as well as those with significant gaps in reproductive data, including Saudi Harri, Turkish Dağlıç, and the Saudi Arabi sheep. Consequently, it is imperative to conduct further research and collect additional data to deepen our understanding of the characteristics and performance of Middle Eastern sheep breeds. This is essential for refining our understanding of these breeds' traits and capabilities, which remain incomplete. Expanding our knowledge through rigorous research and comprehensive data collection endeavors will enable us to gain a more nuanced understanding of the intricacies inherent in Middle Eastern sheep breeds. Such efforts are crucial for informing strategic breeding programs and implementing effective management practices to optimize the productivity and sustainability of the region's livestock industry.

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## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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