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DYNAMICS AND CONSTRAINTS OF CAMEL PRODUCTION IN MOROCCO: A REVIEW

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ABSTRACT

For centuries, pastoralism has been one of the main pillars of livelihood systems in Morocco's arid and semi-arid regions. This traditional production system is now facing increasing environmental pressures and profound transformations driven by climate variability and socio-economic change across rural areas. As these pressures intensify, the dromedary remains a vital resource owing to its unique adaptive capacity to harsh environments. It occupies a distinctive position among livestock species: its market value tends to be more resilient during times of crisis and it remains the most valuable animal within both pastoral and agro-pastoral systems. More than 90% of the national camel population is concentrated in the southern regions of the country. This review paper examines the current status and dynamics of Morocco's camel population, highlighting the main socio-economic drivers, constraints and opportunities within the sector. Available data indicate fluctuating herd trends, with a declining tendency in recent years. Although the marketing and processing of camel products remain limited, the sector is showing early signs of expansion and demonstrates considerable development potential. The camel sector continues to receive limited institutional and scientific attention and still faces major structural constraints, particularly recurrent drought, rangeland degradation and restricted market access.

Key words: Arid and semi arid zones, camel population, *Camelus dromedarius*, morocco, pastoralism, sustainable livestock development

Morocco presents a remarkable diversity of agro-ecological zones, ranging from Atlantic plains to Saharan areas, offering a wide variety of conditions for livestock production. Approximately 93% of Morocco's territory is classified as arid to semi-arid, reflecting the predominance of dry and very dry environments across the country and providing an ecological context highly favourable to pastoral systems (Dahan *et al*, 2012).

In Morocco, the livestock sector plays a crucial role in both the agricultural and rural economy. Its direct contribution to the agricultural GDP is estimated at 30–35%, while it accounts for nearly 10% of the national GDP, according to the Moroccan Ministry of Agriculture's Green Morocco Plan review report (2019). When related activities such as processing, marketing and value addition of animal products are included, the contribution of livestock to national agricultural value added exceeds 40%. Although the livestock sector has traditionally supported rural livelihoods and contributed to national food security (FAO, 2022), its stability has been severely challenged in recent years due to exceptional climatic and economic pressures. Morocco is now experiencing structural water stress, with renewable water availability falling below 730 m^3 per capita per year, well under the commonly used water-stress threshold of 1,000 m^3 (World Bank, 2020). In 2023/2024, Morocco experienced one of the most severe crises affecting pastoral and livestock systems, marked by a sharp increase in the prices of forage, compound feed and red meat. Severe and recurrent droughts drastically reduced rangeland biomass and local forage production, forcing farmers to rely heavily on commercial feedstuffs whose prices rose sharply. The study conducted in the province of Taza demonstrates that meteorological drought leads to a significant rise in straw and feed prices while simultaneously reducing animal productivity and market value (Belmahi *et al,* 2023). At the national scale, this surge in input costs was further exacerbated by global increases in cereal and soybean prices and by Morocco's structural dependence on imported feed

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components, which intensified inflationary pressures across the agri-food system. Benayad (2024) highlights that food inflation has become a major vulnerability within the ongoing transformation of the Moroccan agri-food sector. The economic burden on livestock producers is considerable: Dahmani, Julien and Sraïri (2025) report that feed costs may account for up to 80 to 87% of total production expenses in sheep systems, making these systems extremely sensitive to any rise in input prices. Taken together, these studies show how drought-induced forage scarcity, global market volatility and growing dependence on external inputs have converged to undermine the stability of the livestock sector and to drive the substantial increase in production costs and meat prices observed in Morocco in 2023/2024.

The dromedary is among the animal species best adapted to arid and semi-arid zones worldwide. While camel husbandry is highly developed in the arid lowlands of East Africa, Morocco, belonging to the Saharan and pre-Saharan zones of North Africa, offers similar ecological conditions favourable to camel breeding. Camel production systems in Morocco are largely extensive and pastoral, characterised by high herd mobility, particularly in Saharan regions (Michel *et al,* 1997). The national camel population is currently estimated at around 106044 heads, according to the most recent statistics from the Moroccan Ministry of Agriculture (MAPM, 2025). The highest concentrations of camels are found in the southern provinces, namely Guelmim-Oued Noun, Laâyoune-Sakia El Hamra and Dakhla-Oued Eddahab, which together account for more than 80% of the national herd (MAPM, 2020).

Owing to their exceptional tolerance to heat, drought and feed scarcity, dromedaries stand out as the most resilient domestic species in arid and semi-arid ecosystems, capable of sustaining the production of milk, meat and services under harsh environmental conditions (Bengoumi and Faye, 2015). Given the strategic importance of this species for pastoral communities and for the sustainable development of arid regions, a comprehensive assessment of the current state of the Moroccan camel sector is warranted. The present work therefore provides a literature review analysing national camel production, its constraints and the emerging opportunities for its future development.

Current status and evolution of camel populations in Morocco

In 2023, the global dromedary population was estimated at about 43 million head (FAOSTAT, 2023). In Africa, the camel population was estimated at about 34 million head in 2021, nearly ten times lower than the numbers of cattle, sheep or goats (Faye *et al,* 2025). In North Africa, only dromedaries are found and Morocco is among the leading camel-breeding countries of the region (Faye *et al,* 2014). In this review, the term camel production refers exclusively to the dromedary species.

In Morocco, nearly 90% of camel production is concentrated in the Saharan and pre-Saharan zones of the southern regions, namely Laâyoune-Sakia El Hamra, Dakhla-Oued Eddahab and Guelmim-Oued Noun, forming what is commonly referred to as the Moroccan camel belt (Amsidder *et al,* 2021; Kamili *et al,* 2020). This distribution is confirmed by Julien *et al* (2021), who also highlighted the importance of the Drâa-Tafilalet valley, located in the south and south-east of the country, as a complementary camel-breeding area. In these regions, camel milk is mainly consumed raw, although several initiatives are now promoting the diversification and processing of camel products (El Hatmi *et al,* 2015; Faye and Bonnet, 2012).

Estimates of the camel population in Morocco vary depending on the source (Fig 1). The national livestock inventory conducted by the Moroccan Ministry of Agriculture reported 254000 dromedaries up to 2019, while the most recent census, carried out in 2025, indicated a marked decline to 106044 head, including 91432 females. This regression has been attributed mainly to successive drought years (MAPM, 2025). According to Faye *et al* (2025), Morocco's camel population was estimated at approximately 175 505 head in 2023, with a density of 24.63 head per 100 km², 4.65 dromedaries per 1000 inhabitants and a negative annual growth rate of –1.22 % between 1961 and 2023, reflecting a trend of stagnation linked to the reduction of pastoral rangelands and the progressive sedentarisation of herders.

A certain regularity can be observed in the FAO data series presented in the Fig 1, although these are partly based on estimates (from 2008 to 2017) rather than those officially reported. Moreover, a notable discrepancy appears between the values reported by the FAO and those derived from national statistics. According to Faye *et al* (2025), the data reported by the FAO are underestimated and do not fully reflect the actual number of dromedaries present in Morocco. Consequently, all available sources indicate an irregular evolution of the camel herd, placing Morocco among the countries characterised by low or even stagnant growth in camel population numbers.

Analysis of the trend in the Moroccan camel herd shows an increase in population size between 2008 and 2012, followed by an estimated decline at 44.2 % between 2012 and 2025, (Fig 2). This fluctuating trend has been confirmed by several studies, which specifically attribute the downward phase to factors such as repeated droughts and the marginalisation of pastoral systems. However, certain regions have shown signs of stabilisation or even a slight recovery, associated with renewed mobility dynamics and local valorisation initiatives (Aayadi *et al,* 2025; Faye *et al,* 2025).

To support the livestock sector, the Moroccan government has implemented a development programme with an overall budget of about 11 billion dirhams. This funding aims to mitigate the effects of adverse climatic conditions on animal production. The resources are distributed as direct subsidies to herders, intended for the purchase of feed, the preservation of breeding stock, the reduction of farmer indebtedness and the organisation of vaccination campaigns and technical support activities. The amount of aid per beneficiary is calculated on the basis of the number of animals recorded and identified by local committees using numbered ear tags (Ibnelbachyr *et al,* 2025; MAPM, 2020).

Several local camel populations are traditionally recognised in Morocco, including Guerzni, Khouari and Marmouri, which are mainly distributed across the Saharan and pre-Saharan regions (Kamili *et al,* 2020; Piro *et al,* 2020; Boujenane *et al,* 2019). Other populations have also been identified by researchers but remain less well known, such as Harcha, Jebli (JmalJbel) (MAPMDRE, 2020; Piro *et al,* 2020). The Guerzni type is generally described as a dromedary with a robust and compact conformation, a well-developed skeletal structure, a large hump and a high load-carrying capacity, which, according to herders, has historically made it the most suitable for harsh pastoral conditions. In contrast, the Marmouri is perceived as a more slender type, with long limbs, a fine body frame and a relatively less developed hump; it is often associated with riding abilities and a better dairy potential. The Khouari is commonly described by herders as an intermediate type, exhibiting morphological characteristics close to those of the Marmouri, but with a greater degree of rusticity. It should be emphasised, however, that these distinctions are primarily based on local knowledge and empirical criteria transmitted within herding communities during our interactions with them and that they do not correspond to populations formally defined on morphometric or genetic bases.

The photographs (Fig 3) illustrate observable morphological diversity among dromedaries; however, no inference is made regarding breeds or populations, as no morphometric or genetic characterisation was performed.

A morphometric study conducted by Piro *et al* (2020) analysed the genetic variability of 227 dromedaries belonging to four local populations (Guerzni, Khouari, Marmouri and Harcha) using 16 microsatellite markers. The results revealed high genetic diversity but low differentiation among most populations, with the exception of the Harcha group, which appeared more distinct. Similarly, the study by Boujenane *et al* (2019) on 132 females from 38 herds across 8 southern provinces confirmed certain morphological differentiations.

This pattern indicates the presence of substantial gene flow among cohabiting zones. These findings suggest that the recognised groups correspond more to phenotypic or ecological types than to distinct breeds in the zootechnical sense, although traditional classification remains deeply rooted and highly valued among herders (Piro *et al,* 2020).

Historically, camel husbandry in Morocco was based on full nomadism, characterised by extensive movements following the availability of pastoral resources (Faye *et al,* 2017). However, recent studies indicate a gradual transformation of these practices towards hybrid forms of mobility. In the south-eastern regions, Amsidder *et al* (2021) observed that although herders still identify themselves as nomadic, their practices now combine seasonal transhumance, opportunistic movements and, in some cases, partial sedentarisation. This transformation is accompanied by multi-activity among herders, the majority of whom engage in non-pastoral income-generating activities and reside in urban areas. This observation is consistent with Kamili *et al* (2020), who, following a survey conducted in nine southern provinces covering 168 herds (representing about 10 % of the regional herd), distinguished different herder profiles according to herd size and market integration: large traditional herders, maintaining a high degree of mobility, small peri-urban herders, who are more sedentary and multi-active herders, who adapt their movements to economic and environmental constraints. These developments illustrate the growing diversity of Moroccan camel

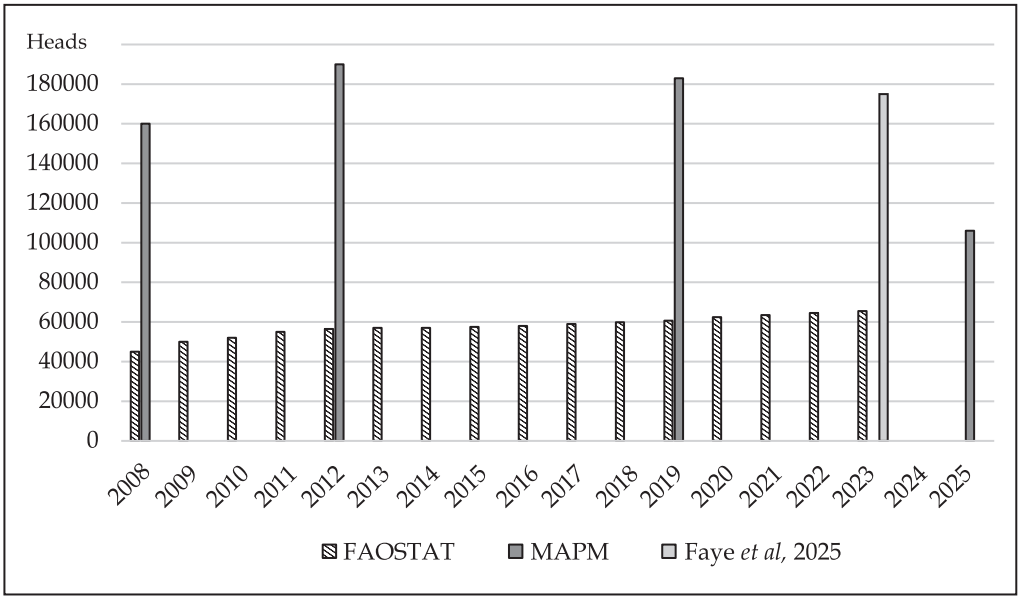

Fig 1. Camel population trends in Morocco (Data compiled by the author: MAPM, 2025; Faye *et al,* 2025; FAOSTAT, 2023 (incomplete data); MAPM, 2012).

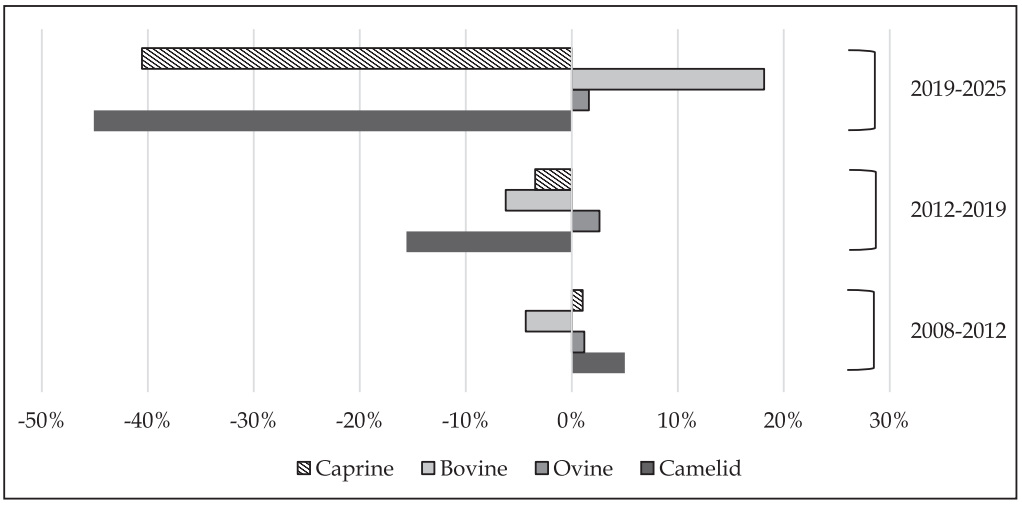

Fig 2. Evolution of camel and general livestock populations in Morocco: Percentage variation from 2008 to 2025.

production systems, which no longer correspond solely to the traditional pastoral model but include various adaptive forms. In Guelmim, El Aayadi *et al* (2024), demonstrated that movement patterns reflect a differentiated use of resources: short displacements around water points during the dry season and longer routes towards pre-Saharan areas during periods of greater forage availability.

The economic and demographic performance of camel herds in Morocco is closely linked to the typology of production systems. Highly mobile systems display greater adaptive capacity to climatic variability, whereas small peri-urban units, despite having better access to markets, are more vulnerable to land and feed constraints (Boujenane, 2023; Julien *et al,* 2021). Herd sizes show considerable variability, dominated by small and medium herds (Michel *et al,* 1997), although large herds still exist (Kamili *et al,* 2020).

Socio-economic importance of the dromedary in Morocco

The dromedary occupies a central place within Morocco's pastoral and agro-pastoral systems, particularly in Saharan and pre-Saharan regions, where extreme climatic constraints limit agricultural alternatives. The species also plays a key role in the valorisation of arid and desert areas, as it can exploit plant resources inaccessible to other domestic species, thereby sustaining pastoral activity in marginal lands and ensuring the livelihood security

Fig 3. Evolution photographs of dromedary camels (*Camelus dromedarius*) from Dakhla–Oued Eddahab region, Morocco (Photos by authors).

Fig 4. Dried dromedary meat (Tichtar) produced by a cooperative in Dakhla (ADA, 2025).

Fig 5. Traditional dromedary hump fat (Loudek) produced by a cooperative in Dakhla (ADA, 2025).

of local households (Julien *et al,* 2021). Thanks to its remarkable resilience to water and feed scarcity, the dromedary secures household subsistence while serving as a strategic pillar of food, economic and social security for local communities (Kamili *et al,* 2020). During drought periods, unlike cattle and sheep whose prices collapse, camel prices remain relatively stable or even increase, making the species a true store of value and a security asset for pastoral households (Amsidder *et al,* 2024; Julien *et al,* 2021). In regions such as Guelmim and eastern Morocco, the dromedary provides not only a direct source of income but also a reserve of value convertible into investment, confirming its function as a "security capital" within pastoral livelihood strategies (Alary *et al,* 2021).

Although its contribution to the national livestock population is modest, around 0.32% (Calculated on the basis of the latest 2025 livestock census), its economic and symbolic value far exceeds this proportion, especially in desert provinces where other forms of livestock farming are less viable. Camel production systems in Morocco are multifunctional, encompassing specialised herds (milk or meat), mixed systems combining dromedaries and small ruminants and integrated oasis systems where agriculture and livestock coexist in complementary ways (Kamili *et al,* 2020). This multifunctionality results in a wide range of products and services: milk, meat, fibre, fat, hides, transport, tourism, social capital and symbolic value, that reinforce the cultural embeddedness of the species.

Camel husbandry plays a major economic and social role beyond its productive activities. It constitutes both a source of income and a form of capital that can be mobilised in times of need, as well as a driver of territorial valorisation. Recent analyses have shown that camel products are used in multiple ways, integrating local food systems, traditional medicine and the marketing of live animals, giving the activity both an economic and non-economic dimension (Amsidder *et al,* 2024). Camel milk, for instance, is incorporated into local diets either through direct consumption or traditional processing, while popular medicinal practices continue to rely on its therapeutic properties (Kamili *et al,* 2020). Several studies highlight this diversity of uses and show that the highest profitability is observed in the most diversified systems. Although the sale of live animals remains the main source of income, the multifunctionality of camel products directly enhances household welfare and investment capacity (Amsidder *et al,* 2024).

Household income derives mainly from the sale of milk, meat, live animals and by-products such as hides. Camel milk, in particular, is experiencing growing demand due to its nutritional qualities and its potential for local valorisation (Ibnelbachyr *et al,* 2025). In recent years, several studies conducted in Morocco have deepened current knowledge on the composition and physicochemical characteristics of locally produced camel milk. These works highlight a nutritional profile characterised by good-quality proteins, a low fat content, a favourable mineral balance and relatively stable pH and acidity values compared with other dairy species. The main findings from these studies are summarised in Table 1, which presents the key nutritional parameters and physicochemical characteristics of Moroccan camel milk.

Since 2016, the Protected Geographical Indication (PGI) "Lait de chamelle du Sahara" has covered the regions of Guelmim-Oued Noun, Laâyoune-Sakia El Hamra and Dakhla-Oued Eddahab, thereby enhancing its recognition and commercial potential (Amsidder *et al,* 2024). Initiatives such as the International Agricultural Fair of Morocco (Salon International de l'Agriculture au Maroc, SIAM), the International Fair of Local Products of Agadir (Salon International des Produits du Terroir d'Agadir, SIPTA) and the Local Products Competition (Concours National des Produits du Terroir), organised by the Agricultural Development Agency (ADA) (Figs 4 and 5). These initiatives have encouraged cooperatives and small-scale producers of camel-derived products, thereby contributing to market development.

The social impact has accompanied this growth: the number of jobs related to the camel sector increased from 798 to 2 219 in the Dakhla-Oued Ed-Dahab region and from 740 to 990 in Laâyoune-Sakia El Hamra between 2008 and 2019 (MAPM, 2020). These data confirm that, far from being limited to a traditional pastoral role, the camel sector has become a driver of economic and social development in Saharan regions, with a growing potential for diversification, particularly in milk and meat processing. However, a significant data gap persists concerning the economic value of this activity, which mainly develops in arid and semi arid areas. This shortfall can be explained by the lack of in-depth studies on local dynamics and the micro-actors involved in the sector (Amsidder *et al,* 2024). As a result, a significant share of the economic benefits, particularly those generated at the household level, remains unquantified and unaccounted for an official assessment.

Marketing and valorisation of the dromedary in Morocco

The marketing of dromedaries and their derived products in Morocco reveals a sector that is both historically rooted and undergoing profound transformation. The added value of the camel sector increased from approximately 221 to 439 million dirhams (MDH) between 2008 and 2019 (MAPM, 2020). Regional data show that the sector's economic performance has improved markedly in the main active Saharan regions, particularly Dakhla-Oued Ed-Dahab and Laâyoune-Sakia El Hamra. In the former, turnover rose from 45.4 million dirhams in 2008 to 122.5 million in 2019, while added value more than tripled, from 18 to 60 million dirhams. In the latter, the growth has been even more striking: the camel dairy sub-sector's turnover increased exceptionally from 142 million dirhams in 2008 to nearly 484 million in 2019, representing a rise of over +240 % (MAPM, 2020). These results underline the key economic role of the camel sector in regional economies and confirm its structuring and diversification potential beyond traditional pastoralism.

This economic momentum is closely linked to changes in herd size and production levels. In Dakhla-Oued Ed-Dahab, the total herd increased from 9 700 head in 2008 to 24 600 in 2019 and to 40 000 according to the latest figure reported by the Moroccan Minister of Agriculture, while meat production rose from 702 to 900 tonnes over the same period (MAPM, 2020). This growth was also supported by a budget envelope of nearly 99.27 million dirhams allocated to the development of the camel sector within the framework of the Green Morocco Plan (Plan Maroc Vert). The funding was intended to boost milk production by 150 %, targeting 10 million litres by 2020. Although milk production did not reach this figure, it increased from 4 to 6 million litres, reflecting enhanced productivity and local valorisation.

In the Laâyoune-Sakia El Hamra region, which constitutes the country's main camel dairy hub, the milking herd doubled from 50 705 to 105 000 head between 2008 and 2019, raising milk output from 50 to 60.7 million litres (MAPM, 2020). These structural changes have been supported by investments in pasteurisation and packaging units, as well as by the emergence of local milk-collection cooperatives. In this region, beyond the sale of live animals and meat, camel milk production and processing now contribute

increasingly to the sector's overall turnover. The Ministry of Agriculture reports that the camel milk and dairy derivatives sub-sector alone generates a turnover of around 55 million dirhams, or 11% of the region's total camel-sector revenue, with an added value close to 32 million dirhams (MAPM, 2020). This highlights the specific economic role of milk within the broader camel value chain.

At the transboundary level, the dromedary remains one of the most traded species in Morocco's southern provinces, particularly Laâyoune, Guelmim and Tarfaya. Local experts estimate that several thousand dromedaries are exchanged annually, mainly through informal cross-border channels (FAO, 2019). Regional technical services also report that thousands of camels move each year towards neighbouring countries, with a substantial share passing through unregulated trade routes, limiting statistical traceability (DRAG, Personal communication, 2024). The most active informal routes connect Morocco with Mauritania and Algeria (Kamili *et al,* 2020).

At the national level, camel meat marketing remains limited. This weakness is due to the restricted consumption of camel meat outside Saharan areas, where it is traditionally appreciated, as well as to the lack of structured distribution networks. Consequently, informal slaughtering remains widespread, providing local supplies but bypassing sanitary controls (Ait El Alia *et al,* 2023).

The Moroccan camel value chain therefore relies primarily on the sale of live animals and local or informal slaughtering, while showing increasing potential for processed products. Recent initiatives demonstrate a trend towards diversification: in Boujdour, a camel milk cooperative comprising about 40 members processes nearly 400 000 l/year, whereas in Laâyoune, a pasteurisation unit achieves a capacity of 1.5 tonnes/day of camel milk (ONCA, 2020). Other pilot initiatives have emerged, such as the first camel-milk cheese unit inaugurated in Dakhla in 2023, which has developed a range of innovative cheeses and yoghurts. The creation of the "Fromage de chamelle du Sahara" agricultural label in 2018 (MAPM, 2018) and the Protected Geographical Indication (PGI) "Lait de chamelle du Sahara" in 2017 (OMPIC, 2023; Arrêté du MAPM, 2017) confirm the growing institutional recognition of the sector's potential and its integration into terroir-based market strategies targeting urban and tourism markets.

The range of camel products marketed in Morocco is highly diverse, encompassing fresh, processed and dried meats (Qadid, Loudek, lahmiss, Tichtar, Aflou), dairy products (pasteurised milk, fermented milk 'Lefrik', cheeses, yoghurts), as well as hump fat, which is traditionally used in many dishes and cosmetics and, to a lesser extent, derivative products such as soaps and camel milk-based creams. The main production and processing sites are concentrated in the Saharan provinces , Laâyoune, Boujdour, Dakhla and Guelmim, while consumer markets are expanding towards major urban centres such as Agadir, Marrakech and Casablanca, where specialised retail outlets are beginning to emerge (Amsidder *et al,* 2024; Ait El Alia *et al,* 2023).

Challenges and constraints of the camel sector in Morocco

Although the dromedary holds a strategic position in Saharan and pre-Saharan regions, both for its ecological role and its contribution to food security and pastoral livelihoods, it has long been marginalised in research and development policies. Institutional efforts have historically prioritised the cattle and sheep sectors, to the detriment of the camel subsector, which explains the relative scarcity of updated data on its production and diseases

Table 1. Key nutritional parameters and physicochemical characteristics of Moroccan camel milk.

Study area (Morocco)	Fat (%)	Lactose (%)	Ash (%)	Acidity (°D	pH	Total solids (%)	Protein (%)	Density	Vitamine C (mg/L)	Source
Southern Morocco	-	3,4 à 5,6	-	-	6,55 à 6,65	-	3,5 à 4,5	-	-	Bengoumi & Faye (2015)
Southern Morocco	2,72	-	0,87	19	6,47	-	2,55	1,026	-	Alaoui Ismaili *et al* (2019)
Dakhla / Errachidia / Fès–Meknès	3,41	4,98	0,81	-	6,51	15	3,24	1,029	27,53	Bouhaddaoui *et al* (2019)
Southern Morocco	2,65	4,05	0,83	17,7	6,61	10,8	3,25	1,032	-	Kouniba *et al* (2005)

(Kamili *et al,* 2020). Until recently, the dromedary remained poorly studied by researchers and largely overlooked in development programmes (Faye *et al,* 2014). Limited information is available regarding its production systems, health problems and product quality, compared with other livestock species (Boujenane *et al,* 2019). This situation has resulted in the underdevelopment of the camel sector in Morocco, despite the species' high ecological and economic potential.

The camel farming system is exposed to recurrent droughts, rangeland degradation and overexploitation and a progressive reduction of grazing areas in Draa-Tafilalet region of Morocco caused by irrigated agriculture expansion and urbanization (Boujenane, 2023). Desertification represents a major concern, affecting over 90% of the national territory, particularly in arid and semi-arid zones (Laamouri and Khattabi, 2025). In the area studied by Boujenane (2023), herders reported a progressive reduction in grazing land, shrinking year by year due to the encroachment of cropland over pastoral areas. Institutional responsibilities related to the development and monitoring of the camel sector are fragmented across multiple bodies (ministries, regional agencies, ONSSA, ONCA), with limited coordination, hampering the implementation of targeted and coherent policies (Ibnelbachyr *et al,* 2025). Furthermore, the vast spatial extent over which camel herding systems operate spanning remote arid and semi-arid zones with high mobility of herds across cross-regional corridors greatly complicates surveillance, data collection and timely policy response. This mobility is described as a major logistical and institutional constraint, since tracking herd movements, health status and market flows across such a broad territory exceeds the current coordination capacity of institutional actors (Alary *et al,* 2021; Amsidder *et al,* 2021). Together, these structural and logistical bottlenecks represent significant obstacles to both productivity enhancement and reliable market supply of animals.

Limited access to specialised veterinary services also represents a significant obstacle: camel-specific diseases remain poorly managed, increasing the sector's vulnerability to animal health risks. A study by Drif *et al* (2018) highlighted the presence of viral circulation within camel herds, while Kamili *et al* (2020) and Aït Lbacha *et al* (2017), respectively documented skin diseases and Anaplasmataceae infections, illustrating the lack of specialised veterinary coverage. At the African scale, El-Alfy *et al* (2024) reported an average prevalence of 35 % for Anaplasma infections in dromedaries and 10–12% for Babesia and Theileria, based on data from several North African and Sahelian countries, including Morocco. These findings confirm the high exposure of camel herds to vector-borne diseases, highlighting the urgent need for adapted veterinary monitoring. The productivity of Moroccan camel herds remains modest, with a low average reproductive rate (around one viable calf per three females), reflecting significant demographic and zootechnical constraints (Julien *et al,* 2021).

Camel milk, in particular, continues to face serious health and hygiene challenges. According to Ibnelbachyr *et al* (2025), the physicochemical parameters of the marketed milk are satisfactory; however, its bacteriological quality shows a non-negligible level of contamination, probably due to poor hygiene conditions. This conclusion aligns with other recent studies reporting high bacterial diversity and indicators of poor hygienic practices in samples of raw camel milk collected in southern Morocco (Kadri *et al,* 2021; Ismaili *et al,* 2019). These studies point to insufficient microbiological quality in many camel milk samples. Although the camel value chain holds strong valorisation potential, its development remains constrained by sanitary vulnerabilities, including inadequate collection and processing practices, lack of cold-chain infrastructure and the absence of well-structured supply chains (Ibnelbachyr, *et al,* 2025).

Product valorisation is also hindered by structural constraints, particularly the remoteness of markets, which still limits the sector's full economic potential (Ibnelbachyr *et al,* 2025). Moreover, camel marketing remains largely informal: animals are sold in traditional souks rather than in specialised markets, reducing market visibility and limiting herders' ability to plan production strategies (Kamili *et al,* 2020). The lack of reliable information on trade flows, prices and sales mechanisms constitutes a major barrier to the professionalisation of actors. Recent findings from the camel-milk project confirm the weak structuring of the supply chain. Furthermore, the production system is not fully market-oriented and herders often bring animals to market without prior preparation or price knowledge, mainly to meet immediate financial needs or to cull certain animals (Julien *et al,* 2021).

Globally, the development of camel products has been fuelled by the consumer perception of camel milk as a superfood. This has contributed to the emergence of a niche demand in Morocco,

although retail prices remain very high outside production zones. For example, Amsidder *et al* (2024) reported farm-gate prices ranging from 10 MAD/L to 30 MAD/L in dairy-oriented systems of southern and southeastern Morocco. However, these remain well below the prices of processed camel milk sold in urban markets, where retail observations during the same period indicated prices between 80 and 100 MAD/L. Such high prices may be partly justified by logistical and cold-chain costs and the distance from production zones, yet they remain excessive for most consumers. So, the camel sector in Morocco is constrained by a strong cultural and commercial lock-in, as camel products (milk, meat) are often perceived as functional or medicinal foods, with vendors emphasising their curative value. Reliable data on market prices and outlets remain scarce and most available observations do not originate from peer-reviewed academic studies.

In addition to price barriers, the taste of camel milk, which is less familiar to urban Moroccan consumers accustomed to cow's milk, constitutes another challenge. As a result, camel milk marketing remains largely confined to Saharan regions, where consumers are already familiar with its flavour (Ait El Alia *et al,* 2023). The combination of high prices, limited taste acceptance and restricted availability of processed products continues to hamper market expansion and delay the establishment of structured distribution channels.

Potential and opportunities of camel production in Morocco

The camel milk and meat markets are currently experiencing rapid expansion, both in Morocco and internationally. This growth is driven by rising demand from Gulf countries and by the increasing global interest in animal products with high nutritional and functional value (Smits *et al,* 2023; Suliman, 2023). Morocco holds significant strategic advantages owing to its proximity to Sub-Saharan Africa and the Middle East, two regions where the consumption of camel-derived products is expanding rapidly (African Union, 2011). Moreover, the dromedary represents a more stable asset for herders than other livestock species, as its market value is more resilient to droughts and price fluctuations (MAPM, 2020). These characteristics make it an economically secure species, well suited to the changing conditions of Morocco's arid zones.

From an economic and industrial perspective, camel milk processing represents a major opportunity. The adoption of the national standard NM 08.4.300:2016 for pasteurised camel milk marked an important step towards sector structuring (FAO, 2016). Several processing units have been established in southern regions, notably in Boujdour and Laâyoune, producing pasteurised milk, cheese and fermented milk (Ait El Alia *et al,* 2025; ONSSA, 2025). Research and development programmes such as CAMILK and Camel4Milk aim to enhance quality, safety and traceability of camel milk while exploring new market opportunities. These efforts have also enhanced the sector's visibility at both national and international levels. Beyond the participation of camel cooperatives in the International Agricultural Fair of Morocco (SIAM), Morocco has hosted major scientific events that further promoted the camel sector, notably the ISOCARD Conference in Laayoune in 2018 and CAMILDS in 2024, which showcased scientific advances and innovations related to camel production and camel-derived products.

The potential of camel milk extends beyond its nutritional value. It is rich in proteins, unsaturated fatty acids, vitamins and minerals and contains bioactive compounds such as lactoferrin, antioxidant peptides and immunoglobulins, which provide antidiabetic, anti-inflammatory and immune-boosting properties (Ayoub *et al,* 2024; Alhassani *et al,* 2024). These properties open avenues for developing high-value bioproducts, including nutritional supplements, functional foods and natural cosmetics (Boubal *et al,* 2025). The development of such bioproducts represents a promising field of innovation, potentially positioning Morocco as a competitive player in the health and wellness markets, akin to what has been achieved with argan oil.

From a social and cultural perspective, the dromedary retains a central place in the lives of Saharan communities. It remains a source of income, a means of transport, a symbol of prestige and a key element of local heritage (Volpato, 2015). This strong cultural and identity dimension facilitates the transmission of traditional knowledge related to camel breeding and strengthens the sustainability of camel-based systems (Smits *et al,* 2023; Mercha *et al,* 2020). The integration of camels into Saharan tourism, through rides, gastronomy and local products, also offers an opportunity for rural economic diversification (Ibnelbachyr *et al,* 2025).

This evolution is taking place within a favourable policy environment. The Génération Green 2020-2030 national strategy emphasises the modernisation of livestock value chains, traceability

and the valorisation of local products. Since 2010, the Ministry of Agriculture has supported the creation of over fifteen modern units dedicated to the production and processing of camel products (MAPM, 2020). Furthermore, Morocco's accession to the African Continental Free Trade Area (AfCFTA) (African Union, 2022) enhances prospects for regional integration and export to African and Middle Eastern markets. Partnerships with institutions such as the FAO, CIRAD, INRA, IAV Hassan II, ASARI and Phosboukraa Fondation, contribute to strengthening applied research and professionalising the sector. Several initiatives have been supported by the foundation, including the organisation of caravans and forums aimed at improving camel husbandry practices, the implementation of camel health campaigns that have provided care to more than 200 000 of dromedaries across the southern provinces and the development of training and capacity-building programmes for herders and cooperatives, in partnership with regional research and innovation institutions (Phosboucraa Foundation, personal communication, 2025).

Overall, Morocco benefits from a coherent set of opportunities for developing camel production: a species perfectly adapted to its environment, a strong cultural foundation, a favourable regulatory framework and a growing market demand. The main challenge lies in structuring a supply system capable of meeting this demand through better organisation of herders, quality upgrading and continuous technological innovation. If these conditions are met, the Moroccan camel sector could become, in the coming years, a regional model of sustainable development, combining climate adaptation, economic valorisation and preservation of pastoral heritage.

Indeed, in other arid or semi-arid regions comparable to those of Morocco, several camel value chains demonstrate that the modernisation of camel milk production and processing is feasible. In the United Arab Emirates, the Emirates Industry for Camel Milk and Products (EICMP, Camelicious brand) represents one of the most well-documented cases of semi-intensive camel dairy farming. This system is characterised by mechanical milking, stall-based herd management and well-controlled feeding practices (Nagy and Juhász, 2016). Studies conducted within this farm report long lactation periods, good lactation persistence and milk yields significantly higher than those observed in traditional extensive systems, thereby illustrating the dairy potential of the dromedary under controlled conditions (Nagy, 2022).

Furthermore, recent research highlights that camel milk produced in modernised units exhibits nutritional and technological properties that are favourable for diversified industrial valorisation, including the production of milk powders, fermented milks and high value-added functional products (Konuspayeva and Faye, 2022; Seifu, 2023). Although it does not constitute a model that can be directly transposed, the Camelicious experience demonstrates that a value chain structured around intensive farming, processing technologies adapted to the specific properties of camel milk and product diversification can achieve international recognition while remaining embedded in a desert environment. This case therefore provides a relevant point of comparison for discussing potential development pathways of the Moroccan camel sector, provided that any intensification strategy respects pastoral systems, genetic diversity and the socio-cultural functions of the dromedary.

Conclusion

Morocco has long been recognised as a camel-rearing country and although the national herd remains modest compared with other livestock species, regional trends show considerable variability depending on sources and census data. As elsewhere, official statistics tend to underestimate the true population. Despite its smaller contribution to the national economy compared with cattle or sheep, camel husbandry generates substantial income, primarily through meat sales and increasingly via the marketing of camel milk and derived products. For many pastoral households, the dromedary helps secure and diversify livelihoods, providing a more stable economic resource than other species in arid environments.

Nevertheless, the camel sector faces numerous challenges. These include recurrent drought, rangeland degradation, limited veterinary services, technical knowledge gaps in camel management and restricted market access. Commercialisation remains constrained by inadequate infrastructure and a lack of organised distribution networks.

At the same time, new opportunities are emerging. Increasing aridity reinforces the value of the dromedary as a resilient species. Demand for camel milk and meat is rising on the domestic market and attracting growing international interest. Local and regional initiatives are beginning to promote the valorisation of camel products in food, health and even cosmetic applications. Morocco's strategic

proximity to Europe and the Gulf countries also constitutes a major advantage for the sector's future development.

In this context, an integrated and proactive approach is essential. The sustainable development of the camel sector in Morocco requires a clear and participatory governance framework, capable of bringing together institutional, professional and scientific actors around a shared vision. Strengthening herders' capacities, organising professional associations and establishing structured markets are key priorities for improving the profitability and competitiveness of the sector.

Applied research must also play a leading role, particularly in genetic selection, feed optimisation for arid zones, milk and meat processing and the valorisation of by-products such as leather, fibre and cosmetics. The transfer of knowledge to herders and local entrepreneurs remains vital to link scientific innovation with field practices. Ultimately, the sustainability of Moroccan camel pastoralism will depend on the country's ability to fully integrate the dromedary into its national strategies for livestock development and rural economy enhancement.

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Conflicts of interest

The study was carried out without any conflict of interest.

Statement of authors' contributions

AH participated in study design and planning; FG collected the data and drafted the first version of the manuscript; BEA, HM, MM and AH, participated in manuscript review. All authors have read and approved the final version of the manuscript and agree to its submission for publication.

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