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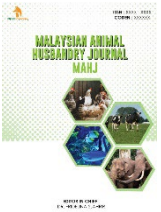

RESEARCH ARTICLE

ANALYSIS OF THE CAMEL MILK VALUE CHAIN FOR SUSTAINABLE DEVELOPMENT OF THE CAMEL BREEDING SYSTEM IN ALGERIA

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ABSTRACT

This study examines the camel milk value chain in the area of Tindouf in the southwestern Algeria, analyzing its economic, environmental and social dimensions. A holistic methodological approach was adopted, combining a literature review, field surveys of key stakeholders and analysis of local statistics. The functional approach reveals a poorly structured sector, characterized by small-scale production, the absence of organized collection, and processing limited by the low acceptability of pasteurized milk. Extensive camel farming is based on the use of natural grazing land, with a moderate environmental impact. However, sustainable grazing management is needed to prevent the risks of overgrazing and degradation of resources. The role of women in the sector remains marginal. To ensure sustainable development, the study recommends structuring stakeholders, modernizing infrastructures, improving packaging and exploring new markets, supported by an appropriate institutional policy.

KEYWORDS

Arid area, Camel milk, Camel breeding, Stakeholders, Sustainability.

1. INTRODUCTION

Camels refer to three species or subspecies of large camelids: The dromedary (Camelus dromedarius) ; or Arabian camel, one-humped, the Bactrian camel; two-humped (Camelus bacterianus) and the feral camel or wild Tartarian camel, returned to the wild (Bouron, 2024). The camel was domesticated around 4450 years ago, between northern Iran and southern Kazakhstan (Faye and Ratto, 2022). It played a crucial role in cultural and economic exchanges, notably through the Saharan roads and the Silk Road, linking the Mediterranean basin to sub-Saharan Africa, and the Chinese, Indian and European worlds.

Adapted to arid environments, wide temperature variations and high altitudes, camelids are an essential resource for human societies living in these environments. Their contribution to food security and sustainable development is significant, in particular through their products (milk, meat, leather, hair) and their economic role in marginalized regions (Bouron, 2024; Faye et al., 2014; Adamou and Faye, 2007).

The global dromedary population is estimated at 40 million head, although this number is thought to be underestimated according to (Bouron 2024). Moreover, according to the latest statistics, the number of dromedaries stood at 35 million (Faye 2020). According to recent FAO data, the world camelid population reached 42.4 million head in 2023, 84% of which are concentrated in Africa. Ten countries account for 85% of this population. Chad leads the way with 25% of the world total, followed by Somalia (18%), Sudan (11%) and Kenya (10%). Saudi Arabia and Niger each have 5% of the population, while Ethiopia and Mauritania each have 4%. Mali and Pakistan complete the list with 3% each.

In Algeria, camels are divided into three main geographical areas: the central Sahara, home to 56% of the national herd, the northern Sahara with 37%, and the Steppe, which accounts for 7% of the total herd (Moula, 2023). With a herd of 439 134 head in 2023 (FAO, 2023), Algeria ranks 15^{e} worldwide, representing 1% of the world camel population.

The regions of southern Algeria have long been deprived of dairy products, due to the distance separating them from supply centers and the lack of adequate means of transport for these perishable products. However, camel milk has played a crucial role, alongside the milk of other livestock species present in these difficult areas, in the food security of local populations (Adamou and Faye, 2007). Since time immemorial, camel milk has been the main food resource of nomadic peoples, who generally consume it raw or fermented. It is a year-round staple in most Saharan pastoral areas (Sboui et al., 2016).

The potential of dromedary meat and milk production as an economic opportunity remains largely unknown, both to the general public and to political decision-makers. This is due to the predominantly local consumption of these products and the lack of reliable data on the species.

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However, in recent years, more accurate information has begun to emerge, although the subject remains poorly documented (Faye, 2003).

In Algeria, as in other North African countries, camel breeding is enjoying a revival after a period of decline. This revival is reflected in a rise in national numbers, greater integration of camel milk into the market economy, and the emergence of mini-dairies (Bengoumi and Faye, 2015; Senoussi et al., 2023).

Dromedary products are becoming increasingly popular, thanks in particular to the dissemination of information by various media highlighting their benefits for human health, especially those of dairy products. This craze, driven by a significant proportion of the population, has led to a notable increase in demand for camel milk, driving up its price to levels well above that of cow's milk (Hacini and Rahmani, 2018; Konuspayeva and Faye, 2021; Bengoumi and Faye, 2015; Faye et al., 2003; Faye et al., 2014) and contributing to the further integration of camel milk on the local, regional and even international market (Konuspayeva and Faye, 2019). In fact, camel milk, which was once customarily offered free of charge and its sale considered taboo, has now come to be sold, in view of its therapeutic virtues (Senoussi et al., 2023, Konuspayeva et al., 2004).

Numerous initiatives have been launched to encourage the development of camel breeding and promote the camel milk sector. Among these actions, in 2017 the United Nations (UN) established an International Camelid Day, aimed at raising public awareness of the importance of these animal species (Bouron, 2024).

In Mauritania, to support the development of the camel sector, which plays a key role in food security, socio-economic development and reducing the vulnerability of populations in arid areas, the FAO has set up a center dedicated to camel breeding development in 2019. Prior to this initiative, Mauritania had already launched the camel milk development project with the creation of the TIVISKI dairy in 1989, aimed at structuring the camel dairy sector and producing various types of camel milk products (Bedda, 2020). In Dubai, United Arab Emirates, a large camel milk farm named CAMELICIOUS has also been set up. In Ndjamena, Chad, restaurants and dairy bars offer camel milk, as does Nairobi in Somalia, where some establishments serve camel milk tea. Finally, in Kazakhstan and India, doctors prescribe camel milk to convalescent patients because of its high vitamin content (Bedda, 2020).

In Algeria, the company TIDJANE, founded in 2016 in the province of El-Oued, it is one of four dairies in the country to incorporate camel milk. It specializes in camel breeding and the production of camel milk and its derivatives. It became a key partner in the international cooperation project "Camel Milk Around the Mediterranean Basin", a scientific research project as part of the PRIMA program. This project, carried out between 2019 and 2022, has enabled the company to increase its herd of dairy camels from eight to one hundred and five animals (DGRSDT Blog, 2022).

The aim of this study is to analyze the camel milk value chain in the Tindouf area, a chain that is still poorly understood. The study assesses the environmental and economic dimensions, as well as the production, collection, processing and distribution processes. It also includes a mapping of the chain's actors and flows, with the aim of identifying development levers to improve the sustainability and income of breeders while minimizing environmental impacts.

2. Materials And Methods

2.1. Choice and characteristics of study area

The target area for this study is the area of Tindouf, which ranks second nationally in terms of average camel numbers, which were around 45 734 head between 2010 and 2017 (calculated from the Ministry of Agriculture and Rural Development-MADR- data). The distribution of camel numbers highlights the relevance of this region for an in-depth analysis of the camel milk value chain.

The area of Tindouf is located in south-west Algeria. It is bordered to the west and south by Morocco, Western Sahara and Mauritania and to the east by the wilaya of Adrar (Figure 1).

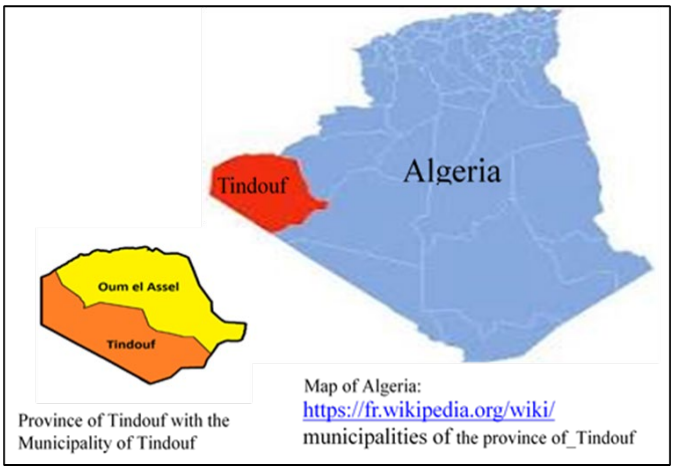

Figure 1: Location of study area

This area covers some 158 874 km^2, making it one of Algeria's largest région. With a population of 103 725 inhabitants spread across the two municipalities of the province (Tindouf and Oum Lassel). The region is predominantly desert, with landscapes of dunes, plateaus and arid valleys, with a grazing area of six million hectares, making it a région with a livestock vocation, especially as the Useful Agricultural Area remains very low, estimated at 872 ha (Province of Tindouf, 2021).

The climate in the région of Tindouf is characterized by temperatures that can reach extreme levels, often exceeding 45°C during the day in summer, and cool nights, with temperatures sometimes dropping below 5°C in winter. Annual rainfall is around 100 mm, with prolonged periods of drought. Most rainfall occurs in winter, but is infrequent and irregular. Strong, sustained winds can occur, particularly during sandstorms, affecting visibility and living conditions (Province of Tindouf, 2021).

Beyond quantity, the regularity and seasonal distribution of rainfall determine the dynamics and floristic richness of plant communities in the Tindouf hamada (Kaabèche et al., 2013). In terms of plant availability, camel range areas are represented by around nineteen plant species (Ould Safi, 2014).

3. Methodology

The methodological approach adopted for the development of the camel milk value chain is based on a holistic approach, focusing on the camel herd, milk production, the actors involved, as well as the natural environment of its production.

Mapping the camel milk value chain aims to visualize and understand the key activities and stages that contribute to bringing a product from the production stage to the end consumer (Miller and da Silva, 2007). With a three-level perspective (micro, meso and macro), this schematic representation aims to identify the generic functions encountered at value chain level, as well as the actors performing these functions and their relationships. It also looks at the different service providers at meso level who play the role of service support, and finally the different main actors at macro level who influence the overall economic context.

The study included various methods: (i) indirect information gathering based on bibliography and available local and national statistics, (ii) direct data collection from the various actors in the camel milk sector (producers, transporters, processors, distributors) based on interview guides adapted to each in order to gather the information provided in Table 1 and (iii) information and data collection from the local administration (DSA, CAW) and the inter-professional council and associations related to the activity. Data collection took place during February 2025. The number of actors and the type of information are listed in Table1.

It should be noted that data on livestock in the province of Tindouf, compiled as part of a survey conducted during the last quarter of 2022 by the agricultural services was provided to us for analysis.

Table 1 : Information sought through questionnaires and interviews

Actors	Number	Searched information
Producers	25	Status / Herd composition / Production data / Economic data / How each identified system operates / constraints encountered.
Collectors	0	Operating mode and organization
Distributors and Retailers	10	Quantity purchased/ Quantity sold/ Purchase price/ Sale price/ Source of supply
Transformers	1	Status / Volume processed / Purchase price / Sale price / Markets / Organization / Manufacturing process
Institutional actors (DSA, CAW)	7	Production data/ Economic data/ Livestock data/ Support program/ Development outlook/ Producer data/ Characteristics of existing production systems/ Constraints encountered
Interprofessional Council of the Camel sector in the province of Tindouf	2	Support program/ Development prospects/ Characteristics of existing production systems/ Constraints encountered in production/ Constraints in organization
Association (nomadic association, camel racing association)	2	The association's objectives/ Support program/ Development prospects/ Organizational constraints

Source: Made by the authors

4. Results And Discussion

4.1 Identifying the different links in the camel milk value chain

4.1.1 Input supply

Camel breeding relies mainly on local natural resources, with little use of modern inputs. The main inputs are:

- Feed consists of subsidized barley, sometimes supplemented by concentrated feed. The forage area in the province of Tindouf, which amounts to 37 ha (MADR, 2022), is very limited, even insignificant, and does not cover the needs of the livestock. The same applies to cereal crops, which are not grown in the region (MADR, 2022).
- Veterinary care: limited, due to the unavailability of approved veterinary products for camels and the use of traditional natural treatments.
- Breeding equipment: enclosures (Zriba), rudimentary troughs and feeders.

4.1.2 Production

Camel farming in Tindouf is mainly extensive and transhumant. Camels are kept in H'mila, a free-range grazing system based on the exploitation of natural resources. Urban and peri-urban breeders, on the other hand, practice semi-intensive management, keeping some camels in enclosures (Zriba) for more regular milking (Figure 2).

Figure 2.a: Extensive breeding (H'mila)

Figure 2.b: Breeding in enclosure (Zriba)

Figure 2: Camel breeding system (Photos taken by the authors)

In areas where extensive livestock rearing predominates, practiced mainly by nomads, the situation differs. Nomads who keep dairy camels do not generally seek to sell their milk. They keep a small number of milking camels, around five, close to the kheimas (camps), to meet their daily milk requirements. The majority of the herds are “H'mila” herds. This extensive system has no significant impact on the camel milk value chain, as it does not produce milk for sale. In nomadic societies, the sale of camel milk is often considered taboo. The distribution and consumption of milk therefore remains primarily a family affair.

In the study area, camels are milked manually on all farms, with twice-daily milking (morning and evening) and milk production varying between three and ten liters per day, depending on breed, physiological stage, feed and season. The camel's calf presence at the udder is an important factor in initiating milk let-down and maintaining the mother's milk production activity the duration of which varies between eight and eighteen months and seems to depend on certain practices, in particular milking and suckling frequencies (Faye, 2003).

Analysis of the results of a survey carried out by the agricultural services on livestock farming in the Tindouf region, involving a sample of 748 camel herders, reveals the following breakdown of the number of camels per herder:

- Less than 20 camels: 47%
- Between 20 and 50 camels: 39%
- Between 50 and 100 camels: 11%
- More than 100 camels: 3%
- Furthermore, 86% of the herd is made up of camels.

If we consider the data that the rate of lactating camels in the total dromedary population is 20% and the milk production in Africa per camel and per lactation varying from 1000 to 2700 liters and on the basis of a dromedary number of 45 734 heads, we estimate that the theoretical milk production in the province of Tindouf varies between 9 800 and 25 400 tons/lactation (Bengoumi and Faye, 2015; Faye et al., 2025; Faye, 2003; MADR, 2017). This remains significantly higher than the quantities actually produced due to the farming methods used (particularly Hmila). This is because the milk produced is not collected and the farms are located far from urban areas.

4.1.3 The Milk collection

The milk collection segment is absent in Tindouf. Most milk is consumed directly by herders or sold without intermediaries.

4.1.4 The Processing (Dairy)

Camel milk is supplied to the dairy by seven to ten informal herders. Milk is delivered in the morning, containing the evening and morning deliveries in 30-liter metal tanks, totaling approximately 1000 liters.

The milk received undergoes pasteurization, degassing, homogenization, cooling and finally bagging in 0.5-liter bags.

Shelf life is 6 days, with local distribution (municipality of Tindouf) by the dairy itself in a refrigerated truck to grocery stores and supermarkets at a rate of 1 900 bags/day.

Despite these efforts, the dairy went out of business related to camel milk after only four months (from July to October 2017) due to the low acceptance of pasteurized milk by consumers, the absence of an organized distribution circuit and the impossibility of selling milk outside the department, due to the very long distances involved (over 800 km) combined with a shelf life limited to 6 days.

The dairy, which produces other products including pasteurized cow's milk made from subsidized milk powder, did not see fit to continue camel milk production in view of the constraints encountered. Furthermore, other products made from camel milk, sush as cheese, were not considered by the dairy because they were note part of the population's dietary habits. (Our interviews revealed that no processing is carried out by the local population. However, an introductory training course on processing camel milk into cheese was organized by the public authorities, without any entrepreneurial initiatives being taken on the ground by the stackholders).

4.1.5 The Marketing

The sale of camel milk is limited by cultural and logistical barriers. The milk is mainly sold informally by the herders themselves, or in certain butchers' shops. It is packaged in recycled plastic bottles. This analyzing this aspect in Djibouti (Faye et al., 2003). The price of milk varies between 250 and 450 DA/liter depending on supply and demand, with a notable rise during the month of fasting.

4.1.6 The consumption

Camel milk is mainly consumed raw and fresh at any time of day, without any particular constraints, making it an integral part of the daily dietary habits of local populations, especially nomads. It is renowned for its nutritional and medicinal benefits, and demand increases on certain occasions, notably Ramadan and religious and social holidays. Based on the quantities theoretically produced, we estimate that the estimated average consumption in the province of Tindouf is 0.48 liter/day/inhabitant.

Furthermore, the acceptability of pasteurized camel milk remains low, as consumers do not recognize the specific taste and smell of camel milk, this has also been highlighted by other authors (Konuspayeva and Faye, 2016; Faye et al., 2003).

4.2 Characteristics of actors in the camel milk value chain

4.2.1 The producers

Dromedary breeders are divided between nomads, transhumants and urban sedentary. Their production system is based on traditional practices, with little veterinary intervention and limited use of modern inputs. Herd management generally requires the mobilization of two workers, at a monthly wage cost of between 30 000 DA and 40 000 DA per worker.

In the absence of comprehensive data listing camel breeders, an estimate based on the total herd and the average number of animals per breeder puts their number at around 1 300 herders. This estimate is also supported by data provided by the Chamber of Agriculture (CAW) of the province of Tindouf.

According to the CAW, producers are generally breeders from father to son, deriving their income mainly from livestock farming. Those whose income comes from other activities are rare; they are generally retired people who return to breeding.

The results of the livestock survey carried out in the province of Tindouf in 2022 by the services concerned show a clear dominance of mixed sheep/goat/camel breeding systems (41%), followed by exclusively camel breeding (35.67%), reflecting the strong adaptation of these species to arid conditions. Systems integrating cattle or horses remain marginal, reflecting their lesser suitability to the local context (Figure 3).

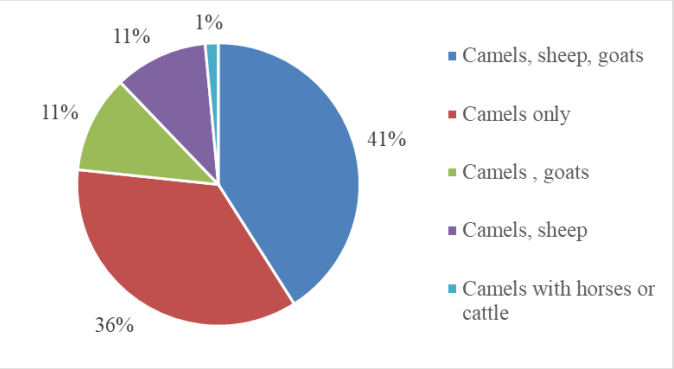

Figure 3: Farming systems associated with camels in the province of Tindouf

4.2.2 Collectors

There are no collectors. This link is non-existent in Tindouf, and there is no structured collection circuit for camel milk.

4.2.3 The dairy

Created in 2017 with a capacity of 5 000 liters/hour, based on a private initiative, the local dairy named Sekaya, aimed to structure the sector and offer better-quality pasteurized milk. The local dairy stopped processing camel milk after just four months. Its failure was due to the low acceptance of pasteurized milk by consumers and the absence of outlets outside the province (Figure 4).

Figure 4: SEKAYA Dairy

4.2.4 Traders

Milk is sold mainly in butchers' shops and sometimes in mini-markets. Sales remain informal and unregulated, with no sanitary controls. Indeed, the absence of a hygienic culture among producers makes control difficult at the start of the value chain (Faye et al., 2003).

4.2.5 Consumers

Camel milk is mainly consumed raw by the local population, without processing. Demand increases during certain periods, notably Ramadan and traditional festivals. However, despite its growing, recognition as a food with potential health benefits, its consumption remains limited among populations in arid and semi-arid regions (Ait El Alia et al., 2025).

4.2.6 Institutional support actors

The camel sector has long been marginalized in Algeria and, as a result, did not benefit from any structured development program until the early 2000s. It was within the framework of the National Agricultural Development Plan (PNDA) that the government initiated the first measures to support this sector, notably by introducing a subsidy of 20 000 DA granted to breeders for each camel birth.

In 2003, the Integrated Rural Development Proximity Project (PPDRI) also contributed to supporting camel breeding by enabling nearly 1 000 breeders to benefit from livestock supplies, in the form of four pregnant female camels and one breeding male per beneficiary.

With a view to boosting national milk production, the government has introduced a system of incentives for the production, collection, and integration of raw milk. These subsidies, which apply to all dairy sectors (cattle, goats, camels, etc.), provide for a subsidy of 12 to 14 DA/liter for farmers, 5 DA/liter for collectors, and 4 to 6 DA/liter for dairies involved in processing. However, the payment of these premiums is subject to the signing of a tripartite agreement between the farmer, the collector, and the dairy. In the case of camel milk, the lack of a specialized operational dairy has prevented effective access to these subsidies, which have therefore never been received in this sector.

In line with its commitment to structure and develop the camel sector, the government has implemented several measures to improve pastoral infrastructure, including the construction and equipping of boreholes, the rehabilitation of pastoral wells, and the installation of solar- or wind-powered pumping systems. In terms of animal feed, breeders have also benefited from a program to distribute subsidized barley at a rate of 2 kg per camel per day.

4.3 Mapping the camel milk value chain: a multitude of disconnected actors

Horizontal links in the value chain are virtually absent; farmers work in isolation, with no structured organization to improve productivity or marketing. The absence of cooperatives or professional associations limits the scope for pooling resources and costs.

Vertical links in the value chain are also weak, with marketing based on a short, informal circuit between producers and consumers. The absence of collection and processing structures prevents any move upmarket (Figure 5).

The analysis reveals a fragmented value chain with disconnected actors. Breeders, most of whom come from a family tradition, work in isolation, without any cooperative organization. This lack of structure prevents any move upmarket and limits opportunities for large-scale marketing.

The attempt to set up a dairy to add value to camel milk, which operated for a very short period, created certain dynamism in this value chain by strengthening links with certain actors and creating new markets. This dairy could have played a driving role and constituted a strategic lever for the development of this value chain. This dairy could have been a driving force and a strategic lever for the development of this value chain (Figure 6).

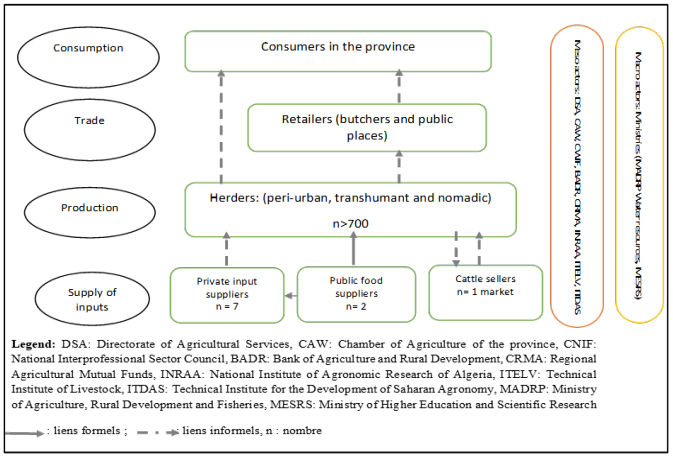

Figure 5: Camel milk value chain map in the province of Tindouf

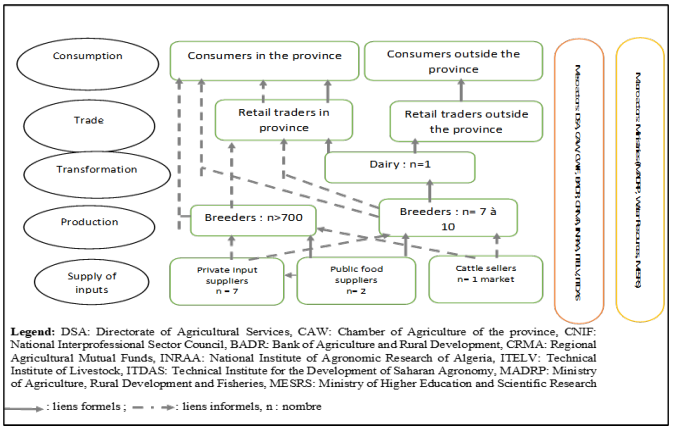

Figure 6: Camel milk value chain map in the province of Tindouf with dairy operational in 2018.

4.4 Economic analysis: Camel milk as a source of income for farming families

The camel milk value chain in arid zones is essentially based on short circuits and an informal local economy that favors certain flexibility but remains fragile in the face of hazards. The income generated is often modest but regular, providing important economic support for the families of herders.

In the camel milk value chain, the seasonal nature and yield of milk production, as well as the extensive and intensive farming methods used, make the analysis of price formation in the value chain somewhat complicated,

The selling price of raw camel milk from producers averages 330 DA/liter, varying between 250 and 400 DA/liter. This price variation is explained by the law of supply and demand, influenced by several factors, notably the season, when production is generally higher during the summer period.

The structure of production costs shows that operating expenses are the main expenses, represented by labor and feed, with 65% and 28% respectively. This corroborates the results obtained, who report a rate of 30 to 40% for feed and 40 to 50% for labor (Faye and Konuspayeva, 2020). According to these authors, these two items represent 60 to 80% of expenses. In our study, these two items account for 93% of total expenses, which can be explained by an extensive breeding method based on rudimentary methods, whereas in the previous study the method was intensive, requiring investment and modernization of practices.

Milk sold by producers at an average price of 330 DA/liter and is offered to end consumers by butchers and other marketing outlets at an average price of 400 DA/liter.

The average cost of a liter of milk for sedentary herders, amounting to 236 DA/liter, allows producers to make profits of 94 DA/liter (figure 7).

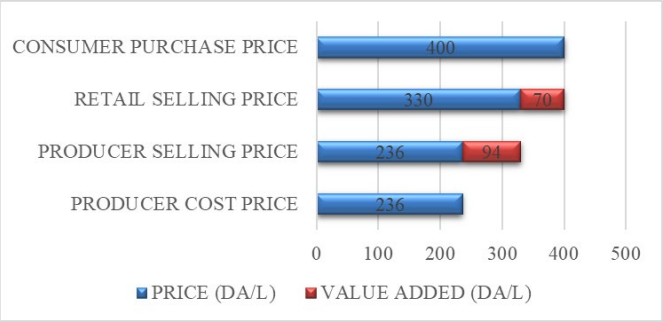

Figure 7: Distribution of value added along the value chain (DA/l)

Source: Realized by the authors based on surveys

4.5 Environmental analysis: A value chain adapted to local resources

The environmental analysis of the camel milk value chain in a local context, characterized by the absence of processing and pasteurization, as well as by direct marketing with packaging in recovered plastic bottles, highlights particular environmental impacts.

Camel farming is based on an extensive system that utilizes natural rangelands that are often unsuitable for other forms of livestock farming. Camels have a relatively moderate carbon footprint and are well adapted to harsh climatic conditions, which constitutes an environmental advantage. Their ability to exploit unproductive pastures allows for effective use of natural environments. However, excessive pressure on certain areas, particularly around water points, can lead to localized overgrazing, soil degradation, and contribute to desertification. In terms of water, although they are drought-resistant, the water requirements of camels represent a constraint in the event of prolonged water shortages.

Feeding is another important aspect of this analysis. In addition to natural rangeland resources, herders rely on supplementary feed, including subsidized barley, which comes from remote regions. Transporting this grain over long distances consumes fuel and generates greenhouse gas emissions, increasing the industry's carbon footprint. Added to this is an ingenious and economically beneficial local practice: recycling stale bread as a feed supplement for camels. This repurposing of food waste reduces waste and offers environmental benefits by reintroducing a product at the end of its lifecycle into a useful consumption loop.

The absence of milk processing (neither pasteurization nor prolonged refrigeration) offers certain environmental benefits. It reduces energy consumption, often associated with processing equipment, and limits the use of water that would otherwise be required for cleaning and industrial processing. On the other hand, it raises hygiene and food safety issues, although these aspects are more related to health issues than strictly environmental ones.

Packaging milk in recycled plastic bottles (usually old water bottles) is an interesting form of reuse, extending the lifespan of single-use plastic. This practice thus contributes to a form of informal recycling. However, the lack of a structured collection or recycling system in some regions poses a risk of pollution if the bottles are discarded into the environment after use. The non-biodegradable nature of plastic remains a source of environmental concern.

Milk distribution is done locally, which limits the distances traveled and significantly reduces the carbon footprint linked to transport. The absence of an industrial cold chain, although posing conservation challenges, also contributes to reducing energy consumption. In short, this short and minimally mechanized value chain offers ecological advantages linked to its simplicity, the recovery of food waste such as stale bread, and its proximity, but it is not without challenges, particularly in terms of plastic waste management, the preservation of natural resources, and external food supply.

4.6 Gender analysis: a marginal role of women

The camel milk value chain is exclusively male-dominated across all segments, from camel breeding to milk marketing. All activities, including milking, processing, and distribution, are carried out by men. Women play no active role, except for owning animals when they inherit them, without directly participating in milk production or processing operations.

4.7 Value chain development pathways: Optimization of the camel milk value chain through organization, infrastructure and awareness raising

The development of the camel milk value chain relies on several complementary levers. On the organizational level, structuring actors is essential: the creation of cooperatives would bring breeders together, improve coordination of supply, and strengthen their negotiating power. This observation applies to all agricultural production, particularly in southern regions, farmers to join collective interest associations or to create them where they do not exist (Merrouchi and Amrouni Sais 2025). Such a dynamic would promote mutual aid among producers, encourage integrated farm management, and contribute to the overall improvement of the territories.

At the same time, establishing a clear regulatory framework governing milk collection and distribution would help formalize the value chain and ensure product quality. Local initiatives could also be supported to strengthen existing dynamics.

In terms of infrastructure, it would be appropriate to rehabilitate the only existing processing unit, with financial and technical support, in order to revive its activity and gradually introduce higher value-added products. The establishment of modern distribution channels, including suitable points of sale, would strengthen the visibility and accessibility of the product.

One of the strategic avenues for promoting the camel milk industry lies in the establishment of a spray-drying unit for the production of powdered milk. This technology would overcome the logistical constraints associated with the storage and transport of liquid milk, while opening up opportunities for access to the international market, particularly in Europe and Asia. However, the implementation of this project remains limited by the very high investment costs required for the installation and operation of such industrial infrastructure, in the absence of sufficient economies of scale and appropriate financial support (Faye et al., 2025).

Furthermore, awareness-raising and training constitute a cross-cutting lever: training breeders in good hygiene and production practices, informing consumers about the benefits of camel milk and the importance of a safe product, while strengthening the skills of those involved in processing, are all actions necessary to develop the value chain.

In addition, institutional support remains crucial. A specific national strategy for the development of this chain should be defined, access to financing for livestock and development projects should be facilitated, and private investment and public-private partnerships should be encouraged to drive sustainable and inclusive growth in this sector.

In the digital age and digitalization, networking, a priori, the three national camel milk dairies, becomes a necessity and represents a major step forward, to encourage sharing, the exchange of experience and know-how and thus promote, boost and upgrade their production through online sales to national and international consumers. Indeed, the consumption of this milk is experiencing unprecedented enthusiasm in many countries. While until recently it had remained limited to self-consumption in farms (Sraïri et al., 2019; Konuspayeva et al., 2021).

In recent years, several sales sites have been offering camel milk and its derivatives through suppliers who are not necessarily the producers, most of them being only resellers. With the exception of India, China, the United Arab Emirates, Kazakhstan and Australia, most supplier-resellers are located in countries without camel farming (Europe and the United States) (Konuspayeva et al., 2021).

5. Conclusion

An analysis of the camel milk value chain in the province of Tindouf reveals a sector characterized by essentially artisanal production and informal marketing. Breeders practice extensive livestock farming, based on the exploitation of local natural resources, with limited use of modern inputs. This traditional organization, although sustainable in its context, results in a lack of formal channels for milk collection and processing, which constitutes a significant obstacle to the structuring of the sector.

Despite growing demand, several constraints remain. Among these, the low acceptability of pasteurized milk, attributed to its organoleptic

characteristics, the absence of a specific regulatory framework, and the lack of suitable infrastructure are limiting factors. The short operating period of the local dairy established in 2017 illustrates the challenges related to logistics, economic organization, and the ability to integrate production into a structured distribution channel.

Furthermore, the camel value chain offers significant environmental benefits, including a reduced carbon footprint compared to other dairy sectors, due to the camel's unique metabolism and its ability to enhance arid ecosystems. These aspects highlight the importance of integrating environmental considerations into the analysis of the sector's development.

The results of this study invite further exploration of local dynamics, interactions between actors, and constraints specific to the region, in order to assess the prospects for structuring and sustainable development of the camel industry in Tindouf.

Authors Contributions

HAS, ML, RF, MF participated in study design and planning, data analysis and interpretation, and drafting of the first version of the document. HAS, ML, RF WB participated in surveys and data collection. HAS and LM reviewed the manuscript.

Conflicts Of Interest

The study was carried out without any conflict of interest.

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