Tropentag 2025
September 10-12, 2025
Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Bonn, Bonn, Germany

From waste to dairy: Potential to enhance camel milk production with sustainable feed alternatives

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Introduction

The arid Draa-Tafilalet region of Morocco has long relied on traditional transhumant camel herding and oasis-based farming (Alary et al., 2021; Al haj and Al Kanhal, 2010). Recently, the growing demand for camel milk products across Morocco has presented a valuable opportunity to enhance local livelihoods. However, recurrent droughts are severely impacting pasture availability and quality, resulting in low milk yields, even in camels, which are otherwise well-adapted to heat and aridity (Julien et al., 2021; Taha, 2023). To address this challenge, the CAMilk Project seeks to improve camel nutrition by developing balanced feed supplements from underutilized agricultural co-products rich in nutritional value. In the project's initial phase, a scoping study was undertaken with the following objectives:

1. To identify and evaluate promising agricultural co-products for camel feed.
2. To examine opportunities and constraints in the camel value chain in Draa-Tafilalet.
3. To assess market demand and consumer preferences for camel dairy products in Morocco.

This paper presents preliminary findings linked to the first two objectives.

Material and methods

This qualitative study employed focus group discussions (FGDs) and semi-structured interviews to gather in-depth insights into two main areas:
(a) the availability, current use, and nutritional quality of agricultural co-products, and
(b) camel feeding practices, milk production and use, market dynamics, and herders' willingness to incorporate agricultural co-products into camel diets.
FGD and semi-structured interviews were conducted in six farms and cooperatives and four camel herder communities. between April 27 and May 4, 2024, in three regions: Taroudant, Agadir, and Draa-Tafilalet. Participants were selected through convenience sampling, with an aim to ensure diversity in production systems. Recruitment occurred through local networks and word-of-mouth in rural communities. Prior to fieldwork, semi-structured interview guides were developed to ensure consistency across sites and participants. Each focus group and interview was facilitated by a trained moderator, accompanied by an assistant note-taker and a translator. Interviews were conducted in French and the local dialect Darija, with simultaneous translation as needed. All discussions were audio-recorded with participant consent and lasted approximately 60 to 90 minutes.

All audio recordings were transcribed verbatim and translated into French for analysis. Transcripts were then organized into thematic tables corresponding to the key areas outlined in the discussion guides, separated by focus group. The data were analyzed using a qualitative content analysis approach, categorizing participant responses into pre-identified themes while remaining open to the emergence of new insights. All participants provided informed consent prior to the interviews and were assured of confidentiality and anonymity throughout the research process. Personal identifiers were removed from transcripts, and all data were stored in encrypted digital formats accessible only to the research team.

Results and Discussion

Availability, use and quality of agricultural co-products

The study identified a range of agricultural co-products with varying levels of utilization and potential for integration into camel feeding systems in southern Morocco. *Tomato* cultivation generates significant volumes of organic residues that are already partially used by transhumant herders, particularly for grazing sheep and goats. These arrangements offer mutual benefits: farmers reduce cleanup costs and collect manure, while herders gain access to supplementary forage, often for free or a modest fee. However, the intensive use of phytosanitary treatments in tomato production raises concerns about the safety of these residues for animal feed. *Banana* plantations produce fibrous biomass, including leaves and stems, which are largely left in the fields for soil regeneration. While their nutritional value is perceived to be low and handling labor-intensive, their limited pesticide use makes them a safer candidate for feed experimentation. *Watermelon* residues are directly consumed by grazing camels post-harvest and are reportedly more palatable than tomato waste, highlighting their relative feeding value. *Argan* press cake is already a well-established co-product in some local goat feeding practices, but it remains unknown in the Drâa-Tafilalet region for camels. Preliminary studies have shown that using argan by-products as a feed source for camels can improve their milk production by up to 52.7%, while also positively influencing the microbial quality of the milk (Mercha et al, 2020). Furthermore, the interest expressed by women in argan cooperatives in processing this residue into animal feed suggests opportunities for creating added value and empowering the local economy.

Camel feeding practices, milk use, and willingness to feed agricultural co-products

The interviewed herders represented both transhumant and peri-urban sedentary systems, with herd sizes ranging from 10 to 80 camels. Transhumant herders typically manage smaller herds of 10–20 camels, often alongside larger flocks of small ruminants. In contrast, peri-urban herders tend to keep larger camel herds (30–80 animals) without additional livestock species. In line with the findings of Julien et al. (2020), camel herds are predominantly female, with approximately one-third lactating at any given time. The remainder are either pregnant or non-productive. Young animals and males account for around a quarter of the herd.

For all the herders interviewed, natural rangeland forms the basis of feeding their camels. While peri-urban herds remain relatively sedentary, grazing year-round on the same plots surrounding Zagora, herders in more remote areas continue to practise transhumance. These movements are based on forage availability and governed by customary land use rights. Some transhumant herders traverse irrigated farmland, grazing their animals on grassy field edges or on crop residues left after harvesting, such as in watermelon fields. Several herders emphasised that pasture-based feeding produces higher-quality milk and preserves its perceived therapeutic properties. As one herder explained: *"You cannot talk about camel milk without mentioning*

pasture and transhumance, because the quality of camel milk lies in the grazing. But in times of forage scarcity, we are forced to bring them back and offer fodder."

Herders increasingly rely on supplementary feeding, with commonly cited feedstuffs including barley, dates, alfalfa hay, dry bread, crushed maize, beet pulp, and watermelon residues. In accordance with Julien et al (2021), *barley* is widely considered an effective supplement for improving both milk yield and fattening, though not all herders have access to subsidized barley. *Alfalfa* is also viewed favorably, particularly when combined with barley, though its cost makes it unaffordable for many. It is typically purchased in sacks as dry hay. *Watermelon* residues are highly appreciated for their milk-boosting effects. Herders either graze camels directly in post-harvest fields (e.g. in Faideja), transport the waste back to camps, or purchase it in sacks. In contrast, *argan* press cake has not been used by the interviewed herders. Beyond its limited availability in the region, many herders perceive it as lacking nutritional value since the oil has already been extracted. Nevertheless, when informed of its potential crude protein content and benefits for milk production, some expressed openness to experimenting with it. *Tomato* residues are mainly used for goats but could potentially be offered to camels, according to several herders. Certain supplements, such as *beet pulp*, are viewed with suspicion by herders who believe they compromise milk quality. Although beet increases milk volume, it is thought to accelerate spoilage and reduce the milk's therapeutic benefits, which are qualities highly valued by herders who are recommended by local physicians for specific health conditions. Generally, peri-urban herders show more interest in improving both the quantity and quality of milk through feed interventions.

Camels are typically milked once or twice daily, morning and evening, primarily by men, while goat milking is usually handled by women. In the absence of market demand, some herders forgo milking, allowing calves to nurse freely. Milk yield ranges from 1 to 3 liters per day, with potential to reach 4–5 liters under favorable conditions. In 2024, transhumant herders had suspended milking for some years due to poor pasture availability, while peri-urban herders continued regular milking because they were able to supplement camel feeding.

2.4 Milk Use and Commercialization

Transhumant herders rarely sell camel milk, citing low production volumes and social norms that discourage commercialization (Julien et al, 2021). However, herders indicated that if production were higher, they would consider selling to cooperatives or local shops, though not directly to individuals. Milk is mainly consumed within the household. The herder and family members drink it cold, warm with sugar, or in tea. In the past, fermented camel milk (*leben*) was commonly made, but current production volumes are too low. Other traditional preparations such as *klila* (strained fermented milk) and *khaldara* (a mixture of milk, tea, and coffee) were also mentioned.

Peri-urban herders sell camel milk informally via personal networks. There are currently no functioning cooperatives in the region. Orders are usually placed via WhatsApp. The milk is sold in reused PET bottles, either fresh at local markets or frozen and shipped by road to northern cities such as Casablanca, Rabat and Agadir. Some herders have built up a loyal customer base through word of mouth, and their reputation and reliability are crucial for retaining clients. These findings are consistent with those of Labriji et al. (2021), who highlighted the logistical difficulties of sourcing camel milk from remote production zones, and Adari (2023), who pointed out that camel milk marketing relies on niche outlets, informal vendors, and cooperatives.

Clients include local residents and Moroccan and foreign tourists, especially those coming for therapeutic sand baths. Camel milk is primarily purchased for its perceived medicinal properties, particularly in the treatment of arthritis, respiratory illnesses, diabetes, hepatitis, gastric diseases (sometimes mixed with camel urine) and autism. Older clients are particularly frequent buyers. These findings are consistent with those of Ait El Alia et al. (2023), who identified health-related motivations for camel milk consumption. Recent research suggests that camel milk has many health-promoting properties (e.g. anti-diabetic or anti-cancer), which can partly explain the increase in demand both nationally and internationally (Muthukumaran et al., 2022).

While fresh milk dominates sales, processed forms such as *leben*, *smen* (fermented butter), and *khlila* are sold upon advance request. There is emerging demand for camel milk cheese (*jben*), though herders lack the equipment and know-how to produce it. Some noted that their mothers used to make it when they lived a nomadic lifestyle. Younger herders showed interest in developing innovative camel milk products such as cheese, powdered milk, and butter. In Morocco, processing cooperatives, such as those in Guelmim and Dakhla, have emerged as players, transforming camel milk into a range of products including pasteurized milk, yogurt, and cheese (Adary, 2023). However, processing camel milk presents challenges due to its distinct biochemical and structural propertie (Al haj, O.A. & Al Kanhal., 2010).

Conclusions and Outlook

Overall, the findings reveal significant potential for building a more resilient and sustainable camel milk economy by integrating nutritionally appropriate agricultural co-products into feeding systems. The most promising of these are watermelon and argan co-products. Realising this potential will require improved access to feed resources, enhanced knowledge of the nutritional value and safety of co-products, targeted support for innovation, and the development of sustainable market channels sensitive to cultural norms and environmental constraints. In light of these findings, the next phase of the project will pursue the following key objectives:

1. Nutritional and safety analysis of the most promising agricultural co-products, including assessments of their feed value and potential contaminants;
2. Co-development with herders of nutritionally balanced camel rations based on crop residues, to be tested through participatory on-farm trials;
3. Characterization of intra-household production and consumption patterns of dromedary milk, to evaluate how intensification of the value chain may affect access, distribution, and utilization within herder households; and
4. Consumer research to analyze the profiles, perceptions, and motivations of individuals using dromedary milk for therapeutic purposes, in order to better understand the sociocultural and health-related drivers of demand.

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