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Socio-economic study of milk production in Algeria

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To the eternal light of my life, ***my father, Papa****, may his memory be a constant blessing*

You were the unyielding mountain against which all my doubts would break, the single, unwavering star in my life's vast night sky. You were the first voice that whispered possibility into my young ears, the original architect of the dreams I now hold. And oh, how brightly you held the dream of this day, this moment when the title "Doctor" would finally embrace my name, a dream nurtured under the same sun that warmed your face.

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ABSTRACT

This dissertation analyzes Algeria's dairy sector, addressing its persistent challenges and outlining strategic revitalization pathways. Firstly, it assesses the national dairy landscape, critically examining livestock structures, species contributions, and disparities between potential and actual milk output. Secondly, the study quantifies Algeria's substantial reliance on imported powdered milk, detailing quantities, values, and key exporting countries, highlighting this dependency's economic burden. The research identifies a pervasive "systemic trap" within Algeria's dairy sector, characterized by singular mil sourcing, cattle-centric policies, policy inertia, and cheap imported powdered milk. These elements collectively impede the sector's potential and perpetuate import reliance. A comprehensive case study of Djelfa state, a key pastoral region, serves as a microcosm of these national challenges. Utilizing a rigorous mixed-methods approach with empirical survey data from 125 stakeholders across Djelfa (Ain Oussara, Djelfa, Messaad) and corroborating official statistics, a detailed ValueLinks 2.0 value chain analysis was conducted. This analysis mapped milk production, trade, and consumption patterns, revealing how its perception as a secondary product, coupled with an underdeveloped cold chain and informal markets, leads to wastage and depresses producer incentives. These findings resonate with broader literature on agricultural development in arid/semi-arid regions facing similar infrastructural and market inefficiencies. Crucially, the research transitions from diagnostic analysis to illuminate significant economic opportunities. It proposes strategic interventions: micro-level production enhancements (e.g., high-yield breeds, formalizing rural women's traditional processing skills), targeted market development (e.g., leveraging unique nutritional profiles for niche small ruminant milk markets), and essential infrastructure investments (e.g., decentralized cold chains, direct market linkages). Furthermore, the dissertation explores strategically reframing ghee production from a preservation mechanism into a high-value economic asset. In conclusion, this research dissects Algeria's dairy sector's multifaceted systemic trap through the Djelfa case study, articulating a tangible, economically viable pathway toward increased domestic milk production, reduced import dependence, and enhanced rural economic resilience. The proposed framework offers a blueprint for fostering a more self-sufficient and vibrant national dairy sector.

Keywords:

Algeria Dairy sector, dairy systemic trap, arid and semi-arid regions, milk value chain, ghee (clarified butter) production, agricultural revitalization, economic resilience.

الملخص

تُقدم هذه الأطروحة تحليلاً شاملاً لقطاع الألبان في الجزائر، متناولةً التحديات المستمرة وتحديد مسارات الإنعاش الاستراتيجية. أولاً، تُقيّم الأطروحة المشهد الوطني لقطاع الألبان، وتفحص بشكل نقدي هياكل الثروة الحيوانية، ومساهمات الأنواع المختلفة، والتفاوتات بين الإنتاج الفعلي والمحتمل للحليب. ثانياً، تُحدد الدراسة كمية الاعتماد الكبير للجزائر على مسحوق الحليب المستورد، مع تفصيل الكميات والقيم والدول المصدرة الرئيسية، مما يُسلط الضوء على العبء الاقتصادي الكبير ونقاط الضعف التي يفرضها هذا الاعتماد. تحدد الأطروحة "مصيدة منهجية" منتشرة داخل قطاع الألبان الجزائري، يتميز بالاعتماد على مصدر وحيد للحليب، سياسات وطنية تتركز حول الأبقار، جمود السياسات و كذا الأسعار المتدنية للحليب المستورد. هذه العناصر تُعيق بشكل جماعي إمكانات القطاع وتُديم الاعتماد على الاستيراد.

ويُخصص جزء كبير من هذه الأطروحة لدراسة حالة شاملة لولاية الجلفة، وهي منطقة رعوية رئيسية، تُعد نموذجاً مصغراً لهذه التحديات الوطنية. باستخدام منهجية بحثية مختلطة صارمة، شملت بيانات مسح ميداني تجريبي من 125 من أصحاب المصلحة المتنوعين عبر الجلفة وبيانات إحصائية رسمية داعمة، أُجري تحليل تفصيلي لسلسلة القيمة باستخدام منهجية ValueLinks 2.0. وقد قام هذا التحليل بتحديد أنماط إنتاج، تجارة، واستهلاك الحليب ، كاشفاً كيف أن تصورها كمنتج ثانوي، إلى جانب ضعف سلسلة التبريد والأسواق غير الرسمية السائدة، يؤدي إلى هدر كبير ويُثبط حوافز المنتجين. تتوافق هذه النتائج المحلية مع الأدبيات الأوسع نطاقاً حول التنمية الزراعية في المناطق القاحلة وشبه القاحلة التي تواجه تحديات مماثلة في البنية التحتية والأسواق. الأهم من ذلك، تنتقل الدراسة من التحليل التشخيصي لتسليط الضوء على فرص اقتصادية كبيرة للإنعاش. تقترح تدخلات استراتيجية: تحسينات على مستوى الإنتاج الجزئي (مثل السلالات عالية الغلة، إضفاء الطابع الرسمي على مهارات النساء الريفيات التقليدية في المعالجة)، وتطوير سوق مستهدف (مثل الاستفادة من الخصائص الغذائية الفريدة لحليب المجترات الصغيرة لأسواق متخصصة)، واستثمارات البنية التحتية الأساسية (مثل سلاسل التبريد اللامركزية، الروابط المباشرة بالسوق). علاوة على ذلك، تستكشف الأطروحة إعادة صياغة استراتيجية لإنتاج السمن"الدهان" من مجرد آلية حفظ إلى أصل اقتصادي عالي القيمة.

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RESUME

Cette thèse propose une analyse exhaustive du secteur laitier algérien, abordant ses défis persistants et identifiant des voies de relance stratégiques. Premièrement, elle évalue le panorama national du secteur laitier, examinant de manière critique les structures d'élevage, les contributions des différentes espèces et les disparités entre la production laitière réelle et potentielle. Deuxièmement, l'étude quantifie la dépendance considérable de l'Algérie vis-à-vis du lait en poudre importé, détaillant les quantités, les valeurs et les principaux pays exportateurs, ce qui souligne le fardeau économique important et les points de vulnérabilité imposés par cette dépendance. La thèse identifie un "piège systémique" omniprésent au sein du secteur laitier algérien, caractérisé par la singularité des ressources du lait, les politique concentrés sur les vache, l'inertie des politiques laitière et les prix réduits du lait importé. Ces éléments entravent collectivement le potentiel du secteur et perpétuent la dépendance aux importations.

Une partie significative de cette thèse est consacrée à une étude de cas complète de la wilaya de Djelfa, une région pastorale clé en Algérie, servant de microcosme à ces défis nationaux. En utilisant une approche rigoureuse de méthodes mixtes, qui a intégré des données d'enquête empiriques provenant de 125 parties prenantes diverses à travers la wilaya de Djelfa et des données statistiques officielles corroborâtes, une analyse détaillée de la chaîne de valeur a été menée en utilisant la méthodologie ValueLinks 2.0. Cette analyse a cartographié systématiquement les modèles de production, de commerce et de consommation du lait de petits ruminants, révélant comment sa perception en tant que produit secondaire, couplée à une chaîne du froid sous-développée et à des structures de marché informelles prévalentes, conduit à un gaspillage substantiel et déprime les incitations des producteurs. Ces résultats locaux sont en forte résonance avec la littérature plus large sur le développement agricole dans les régions arides et semi-arides, où des déficits infrastructurels et des inefficacités de marché similaires entravent la croissance. De manière cruciale, la recherche passe de l'analyse diagnostique à la mise en lumière d'opportunités économiques significatives pour la revitalisation. Elle propose des interventions stratégiques : des améliorations de la production à micro-niveau (par exemple, des races à haut rendement, la formalisation des compétences traditionnelles de transformation des femmes rurales), un développement de marché ciblé (par exemple, l'exploitation des profils nutritionnels uniques pour les marchés de niche du lait de petits ruminants), et des investissements essentiels dans les infrastructures (par exemple, des chaînes du froid décentralisées, des liens directs avec le marché). En outre, la thèse explore la refonte stratégique de la production de ghee, la transformant d'un simple mécanisme de conservation en un actif économique de grande valeur.

En conclusion, cette recherche non seulement dissèque le piège systémique multifacette du secteur laitier algérien à travers l'étude de cas de Djelfa, mais elle articule également une voie tangible et économiquement viable vers une augmentation de la production laitière nationale, une réduction de la dépendance aux importations et un renforcement de la résilience économique rurale. Le cadre proposé offre un plan directeur pour favoriser un secteur laitier national plus autonome et dynamique

Mots clés : Secteur laitier en Algérie, piège systémique laitier, régions arides et semi-arides, chaîne de valeur du lait, production de ghee (beure éclairée), revitalisation agricole, résilience économique.

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List of Abbreviations

ARDB: Agriculture and Rural Development Bank

CAGR: Compound Annual Growth Rate

CPM: Cow Powdered Milk

DAS: Directorate of Agricultural Services

DC: Directorate of Commerce

FAO: United Nations Food and Agriculture Organisation

GDC: General Directorate of Customs

GDLC: Grain and Dry Legumes Cooperative

GR: Growth Rate

IDC: Improved Dairy Cows

LDC: Local Dairy Cows

MARD: Ministry of Agriculture and Rural Development

MDC: Modern Dairy Cows

MF: ministry of finance

MTEP: Ministry of trade and Exportations Promotion

NCTR: National Center of Trade Register

NLFD: National Livestock Feed Board

RMP: Raw Milk Production

SCPM: skimmed Cow Powdered Milk

TIAH: Technical Institute of Animal Husbandry

WCPM: Whole Cow Powdered Milk

Summary

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INTRODUCTION

Introduction

Algeria's agricultural sector is a cornerstone of national sovereignty, stability, and food security, providing crucial employment while driving economic diversification away from hydrocarbon dependence (Bouziane et al., 2024; Khelifa, 2024). Within this structure, livestock production is essential, anchoring rural livelihoods and ensuring public access to animal protein (Kardjadj, 2017). Dairy farming, in particular, is vital for socioeconomic development, offering a stable source of income and employment, especially for rural communities, while directly contributing essential nutritional security (Pandey et al., 2024b; Rajkumar, 2023)Crucially, small ruminants (ovine and caprine) are uniquely adapted to Algeria's vast arid and semi-arid zones, positioning them as essential components of resilient, climate-adapted farming systems and vital local food security mechanisms (Kardjadj, 2017). Given its capacity for value creation and job generation, the livestock sector represents a critical avenue for achieving national economic resilience (Bengouga et al., 2019)

Despite significant national livestock potential—including over 36 million heads—the Algerian dairy sector suffers from a severe structural deficit. National self-sufficiency for dairy products lags critically at 49% (Boukhechem et al., 2019) resulting in an annual milk shortfall estimated at 1.5 to 2.5 billion liters (Lamraoui, 2024; Noui et al., 2024). This structural gap necessitates substantial annual imports of powdered milk, positioning Algeria as a major global importer (Kardjadj & Dachung Luka, 2016). The high domestic consumption rate (averaging 140 liters/citizen annually), which is culturally and nutritionally significant, is partly sustained by government subsidies for reconstituted milk.

This reliance on imported milk generates a profound fiscal and external dependency. This structural reliance imposes a significant economic drain on the state, notably through substantial government subsidies, estimated at 1.5 billion USD annually, which strains foreign exchange reserves and redirects capital from vital domestic investments (Bouziane et al., 2024; Kardjadj & Dachung Luka, 2016). Furthermore, this exposure renders the Algerian market acutely vulnerable to global price volatility and external shocks. Incidents such as the 2014 powdered milk shortage in New Zealand, which triggered a sharp 45% domestic price surge, underscore the inherent instability and risk to national food security (FAO, 2023).

The domestic implications are equally severe, fostering local stagnation within the dairy industry. The sustained availability of subsidized, cheaper imported alternatives creates an uneven competitive landscape that actively impedes the economic viability of local producers. This results in critically low raw milk collection rates (22.4% in 2011) and obstructs the necessary expansion of a self-sufficient dairy sector (Makhlouf & Montaigne, 2017; Sraïri et al., 2013a). Consequently, the current import regime undermines rural development, limits job creation, and perpetuates the economic vulnerability it was intended to mitigate.

Problem Statement and Research Gap

The central challenge to Algeria's food sovereignty is the perpetuation of a systemic trap within the dairy value chain—a profound paradoxical reliance on imports despite considerable indigenous potential. This systemic failure arises from a complex combination of interconnected factors: suboptimal domestic output, fragmented production and collection systems, and the economic oversight of high-potential traditional value-added products. This situation undermines rural development, heightens economic vulnerability, and limits job creation.

The current academic literature, while identifying individual constraints, exhibits critical deficiencies that hinder the development of integrated solutions:

- **Fragmented Problem Deconstruction:** Existing research often analyzes challenges in isolation, neglecting to examine the intricate synergistic effects of systemic interdependencies within the national dairy context.
- **Under-valorization of Diverse Milk Sources:** A prevailing focus on bovine milk has resulted in a significant oversight of the crucial contribution and development potential of small ruminant milk (ovine and caprine), especially in arid and semi-arid regions where these animals dominate the landscape.
- **Economic Blind Spot:** The economic implications and monetization potential of traditional value-added dairy products (such as ghee), which represent significant cultural and local capital, have not been subjected to a thorough, empirically validated investigation at the regional level.

- **Lack of Context-Specific Blueprints:** Integrated methodologies for revitalizing localized dairy systems remain theoretical, lacking concrete, economically viable implementation frameworks tailored to distinct agroecological and socioeconomic contexts, such as the transhumant practices and infrastructural deficiencies of the Djelfa region.

The strategic potential for import substitution lies fundamentally in optimizing these overlooked non-bovine value chains. The objective of this dissertation is, therefore, to develop a validated, context-specific framework for transforming the ruminant dairy value chain from a source of vulnerability to a driver of economic resilience. This dissertation directly addresses these gaps by offering an in-depth empirical analysis of the systemic constraints and undetected economic opportunities within the ruminant milk value chain in Djelfa. Utilizing the ValueLinks 2.0 approach and incorporating multi-stakeholder perspectives, this research provides a context-specific, integrated framework designed to revitalize the localized dairy sector. The findings offer essential, actionable insights to guide national strategies aimed at enhancing food self-sufficiency, reducing import dependency, and fostering resilient rural economic development in Algeria and comparable geopolitical environments.

Research Objectives

This research aims to comprehensively analyze and recommend strategic reforms for the Algerian dairy sector to achieve greater self-sufficiency and bolster food security. The particular objectives of this study are to reach this primary goal:

- To examine the macro-level mechanisms that sustain the systemic trap in Algeria's national dairy sector and their ramifications for the nation's strategic development and food security goals.
- To examine the manifestation of this systemic trap as significant operational and structural barriers within localised milk production value chains, evaluating their effects on efficiency, competitiveness, and the optimal utilization of various domestic milk sources.
- To assess the untapped economic potential of traditional value-added dairy products and to recommend strategies for improving their market access, quality standardization, and

incorporation into formal value chains, thus fostering enhanced local livelihoods and diminished national import reliance.

- To propose evidence-based strategies for significantly enhancing domestic milk production and fostering a sustainable, resilient, and self-sufficient national dairy sector, taking into account the unique socio-economic and agro-ecological contexts of Algeria's diverse production regions, with a specific focus on pastoral areas like Djelfa.

Research questions

This dissertation will investigate Algeria's dairy sector through the subsequent research topics, guided by the recognized structural challenges and overarching objectives.

1. What are the most significant macro-level elements perpetuating the systemic trap within Algeria's national dairy sector, and how do these factors simultaneously impede its strategic development and national food security objectives?
2. What are the key operational and structural barriers that emerge from this systemic trap in localised milk production value chains, and how do they affect efficiency, competition, and the full use of different milk sources?
3. What is the latent economic potential of traditional value-added dairy products (e.g., ghee), and how can their enhanced market access, quality standardization, and integration into formal value chains contribute to increasing local livelihoods and reducing national import dependency?
4. What evidence-based strategies, considering the unique socio-economic and Agro-ecological contexts of Algeria's diverse production regions, especially in pastoral areas like Djelfa, can effectively enhance domestic milk production and foster a more sustainable, resilient, and self-sufficient national dairy sector, thereby bolstering Algeria's food security?

Significance of the study

This research provides substantial relevance, influencing not only academic discourse but also informing policy, practice, and socio-economic growth within Algeria's key dairy sector. This study intends to rigorously address its objectives by:

- **Inform National Agricultural Policy:** This research offers evidence-based insights essential for reassessing cattle-centric policies, diversifying milk sourcing strategies, and alleviating the adverse impacts of import dependence and policy inertia on domestic production via an in-depth analysis of the macro-level dynamics of the "systemic trap." This immediately helps Algeria meet its goals for food security and strategic growth.
- **Optimize Localised Value Chain Efficiency:** The in-depth investigation into the operational and structural impediments within local milk production value chains will yield actionable intelligence. Focusing on regions like Djelfa, it will highlight pathways for comprehensive utilization of diverse domestic milk sources (e.g., ovine/caprine), thereby enhancing the efficiency and resilience of these local chains.
- **Unlock Latent Economic Potential:** A comprehensive examination of traditional value-added dairy products, especially ghee, is an important step forward. The study will provide clear ways to diversify revenue sources for local communities, especially by giving rural women more authority, promoting rural prosperity, and encouraging economic diversification. It will do this by suggesting ways to improve market access, standardize quality, and formally integrate.
- **Advance Sustainable Dairy Sector Growth:** This dissertation provides a framework for substantially increasing domestic milk output by suggesting evidence-based measures that are specific to Algeria's unique circumstances. It promotes a sustainable and resilient strategy for self-sufficiency, ensuring that recommendations are contextually pertinent and scalable, so as to enhance Algeria's overall food security against external disruptions and foster long-term agricultural sustainability.

In conclusion, this study produces essential insights, addressing a substantial academic deficiency in dairy value chains within dry regions, and offering a compelling catalyst for the transformation of Algeria's dairy sector into a resilient, self-sufficient, and economically dynamic contributor to national development.

Scope and limitations

This section clearly defines the scope of the study while acknowledging the potential limitations that may arise during the research process.

This study will focus on:

- **Geographical Scope:** The study will concentrate on Djelfa state in central Algeria, noted for its significant concentration of small ruminant breeding and production, in which it leads nationally, alongside its unique Agro-ecological conditions that have significantly promoted the advancement of the Agropastoral sector in the region.
- **Species Focus:** The study will primarily focus on the national dairy livestock potential all species included with a specific focus on small ruminant species in Djelfa state particularly caprine and ovine s specie for local milk production.
- **Value Chain Focus:** The study will investigate the key stages of the milk and ghee value chain, including production, processing, marketing, and distribution. With an strategic economic point of view for the specific purpose of promoting dairy sector.
- **Timeframe:** This study will examine a 25-year period (1997-2022) and assess the current state of the dairy sector while exploring potential future scenarios.

Limitations

- **Data Availability:** Data accessibility on specific elements of the dairy sector in Algeria may be significantly restricted and unattainable due to their heightened sensitivity within a strategic sector, potentially affecting the depth and comprehensiveness of the analysis.
- **Generalizability:** The findings may lack full generalizability to all regions and production systems in Algeria, given the specific focus on the selected region and livestock species. Moreover, Algeria's extensive territory serves as a significant source of geographical, agricultural, and economic diversity across its regions, which adversely impacts the generalizability of the findings.
- **Methodological Constraints:** Challenges may arise in data collection, such as potential biases in survey data or difficulty accessing reliable secondary data.
- **Dynamic Nature of the Dairy Sector:** The dairy sector is dynamic and constantly evolving: Changes in government policies, market conditions, and technological advancements may occur during the research period, potentially impacting the validity of certain findings.

Chapter I

METHODOLOGY

Methodology

This dissertation employs a Convergent Mixed-Methods Approach to provide a rigorous and multi-scalar analysis of the constraints within the Algerian dairy sector. This strategy involves the simultaneous, parallel collection and analysis of distinct quantitative and qualitative data sets, enabling triangulation to enhance the validity and dependability of the findings. This parallel design facilitates a holistic examination, moving from the identification of macro-level systemic traps to the detailed elucidation of their manifestation within specific local value chains.

1. Data Sources and Collection Strategy

The research utilized a dual-pronged data collection strategy to ensure comprehensive coverage, integrating national context with localized empirical detail.

1.1. Primary Data: Field Survey in Djelfa

Primary data were acquired through a structured field survey conducted in the Djelfa region. This state was selected purposefully because it functions as a microcosm of the national dairy sector's challenges and potential. Its critical characteristics include: its national leadership in ovine breeding; the representation of the arid climate dairy potential; and the presence of all four key ruminant species (ovine, bovine, caprine, and camelina), ensuring a comprehensive view of multi-source milk production. Furthermore, the region is characterized by a unique agropastoral vocation defined by transhumant and semi-sedentary lifestyles.

The survey was administered using a structured questionnaire delivered to 125 randomly selected respondents across three delegated states (Ain Oussara, Djelfa, and Messaad) to ensure geographical representation. Respondents included diverse stakeholders essential to the value chain, such as breeders, retailers, households (consumers), and older women possessing traditional knowledge of milk processing and preservation. This approach provided multi-perspective insights into constraints, opportunities, and local production/trade dynamics.

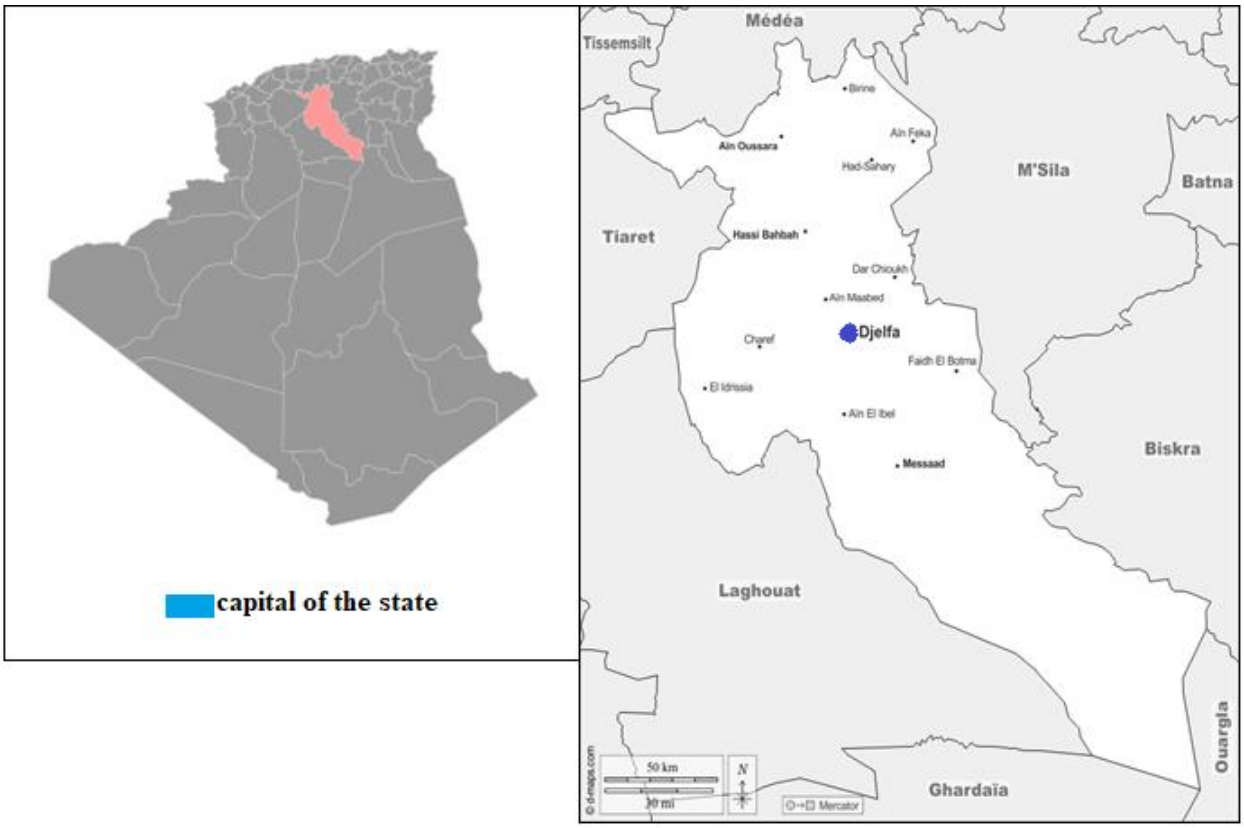


Figure 1 Geographical and administrative map of Djelfa state, Algeria

1.2. Secondary Data: National Contextualization

To establish the macro-level context and define the national systemic trap factors, official statistical data and policy documents were systematically gathered from pertinent national and international organizations, including:

- **International Bodies (Macro-Economics):** FAO, TradeMap, and GAIN provided critical data on national dairy production levels, import quantities, economic values, and key exporting countries, essential for modeling the Paradox of Import Dependency.
- **Algerian National Entities (Policy & Trends):** The Algerian Ministry of Agriculture and Rural Development supplied policy frameworks, national livestock censuses, and general production trends.
- **Regional Entities (Localized Statistics):** The Directorate of Agricultural Services and the Agropastoral Research Center in Djelfa State provided specific regional statistics and research insights into local agropastoral systems.

2. Analytical Frameworks and Statistical Methods

Both national and local datasets were subjected to rigorous analysis, tailored to their respective contributions to the overarching research objectives.

2.1. National-Level Data Analysis

Data from national and international sources were processed using Microsoft Excel and Statgraphics 19 and IBM SPSS to statistically model the national dairy sector's performance over the study period [1997–2022]. Key analyses included:

- **Economic Metrics:** Calculation of the Growth Rate (GR) and Compound Annual Growth Rate (CAGR) to evaluate trends in raw milk production and import costs.
- **Statistical Modeling:** Correlation Coefficient (r) and Regression Analysis were employed to estimate the relationship between dairy herd composition (proportion of dairy animals) and raw milk production. A Scatter Plot was utilized to visually assess the potential impact of domestic production on imported milk quantities.

- **Index Analysis:** The Base 100 Index was computed to enable a simple, comparative analysis of trend shifts between raw milk production and powdered milk imports.

2.2. Localized Value Chain Analysis

The ValueLinks 2.0 approach (Springer-Heinze, 2018) was the central organizing framework for synthesizing primary and localized secondary data.

- **Value Chain Mapping:** This approach facilitated the construction of an extensive, multi-link value chain map for local milk and ghee production in Djelfa. This map systematically identifies micro-level operators (yellow rectangles) and the regulatory/supervisory Meso and Macro-level institutions.
- **Informality Assessment:** The map distinguishes between formal links (continuous black arrows) and prevailing informal connections (non-continuous arrows) to elucidate the structural vulnerabilities restricting sustainable growth.

- **Strategic Economic Viewpoint:** Constraints and opportunities were systematically identified at each level of the value chain, leading to the development of a preliminary strategic economic viewpoint for promoting the ruminant dairy sector in Djelfa.

The integration of these statistical and mapping methodologies ensured that the dissertation achieved a holistic understanding: identifying macro-level policy drivers, empirically testing their economic effects, and illustrating their concrete manifestation as micro-level value chain constraints.

RESULTS AND DISCUSSION

Chapter II

The current state of the dairy sector in Algeria

1. An overview of the national dairy market

For the past 25 years, Algerian milk production has partially met the needs of the national market for goods with high daily consumption. It also serves as a significant supply of raw materials for the food and dairy processing industries, which together account for most of the market's demand for dairy products (cheese, yoghurt, butter, ghee…etc). According to the data provided by the Algerian official institutions, milk production outputs cover about 40-60% of domestic market needs (MARD, 2022) leads us to conclude that Algeria has never achieved self-sufficiency before in terms of raw milk material.

Importing is frequently the most effective solution for nations to make up for production deficiencies, particularly in the medium and short term. Algeria makes no exception, it follows this approach in order to make up for the shortfall in production of raw milk material and its derivatives, which represent a vital and extensively consumed item for Algerian citizens. The General Directorate of Customs (GDC)of Algeria officially reports that the country imports a large variety of milk products and derivatives, including various varieties of raw milk, yogurt, cheese animal fats and oils such as butter and ghee, derived from different dairy animal specie's milk (goat, sheep, cow) and other items whose domestic production is able to achieve national self-sufficiency.

According to the data provided by the same institution (GDC), milk and dairy products import costs represent about 10% of the global import costs of the nation. Similarly, data from this organisation attests to the fact that, for both quantity and invoice, powdered milk is the most often imported item within the aforementioned classification.

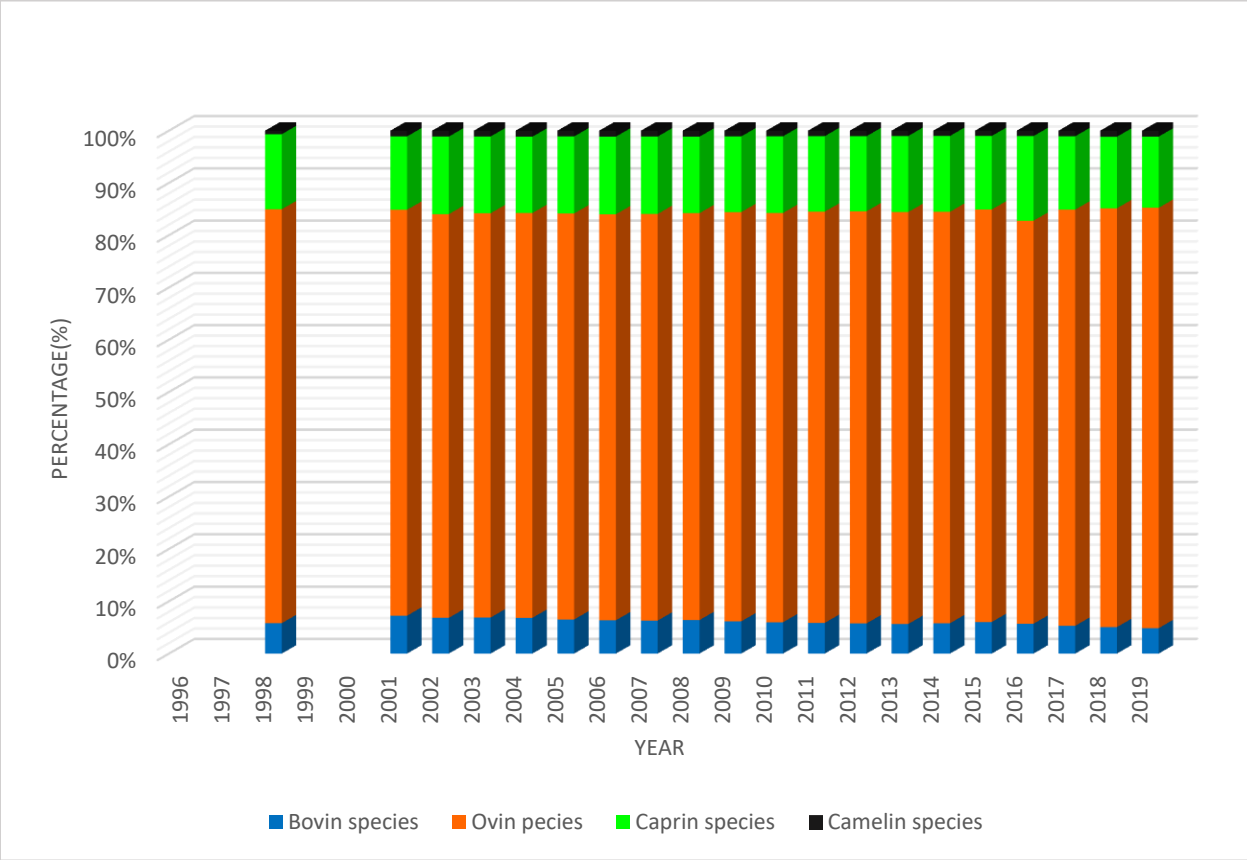
2. Milk production in Algeria

2.1.Ruminant livestock composition

Algeria possesses an enormous and diverse livestock. The livestock's size during the research frame time has increased consistently, from the lowest amount reported of over 22million head in 1998 to almost 37 million in 2019, with a compound annual growth rate (CAGR) of 2.55%.

The four main ruminant species that constitute Algeria's livestock are bovine, ovine, caprine, and cameline. which contributes partially to ensuring the market's demands for raw materials for the

dairy and red meat sectors. (MARD, 2022) have reported as showed in Figure 2 that small ruminant, which comprise over 90% of the Algerian herd on average is headed by ovine specie by around 75% and caprine specie by17%, followed by bovine species and camelina, the latter of which account for less than 1% of the livestock as a whole.



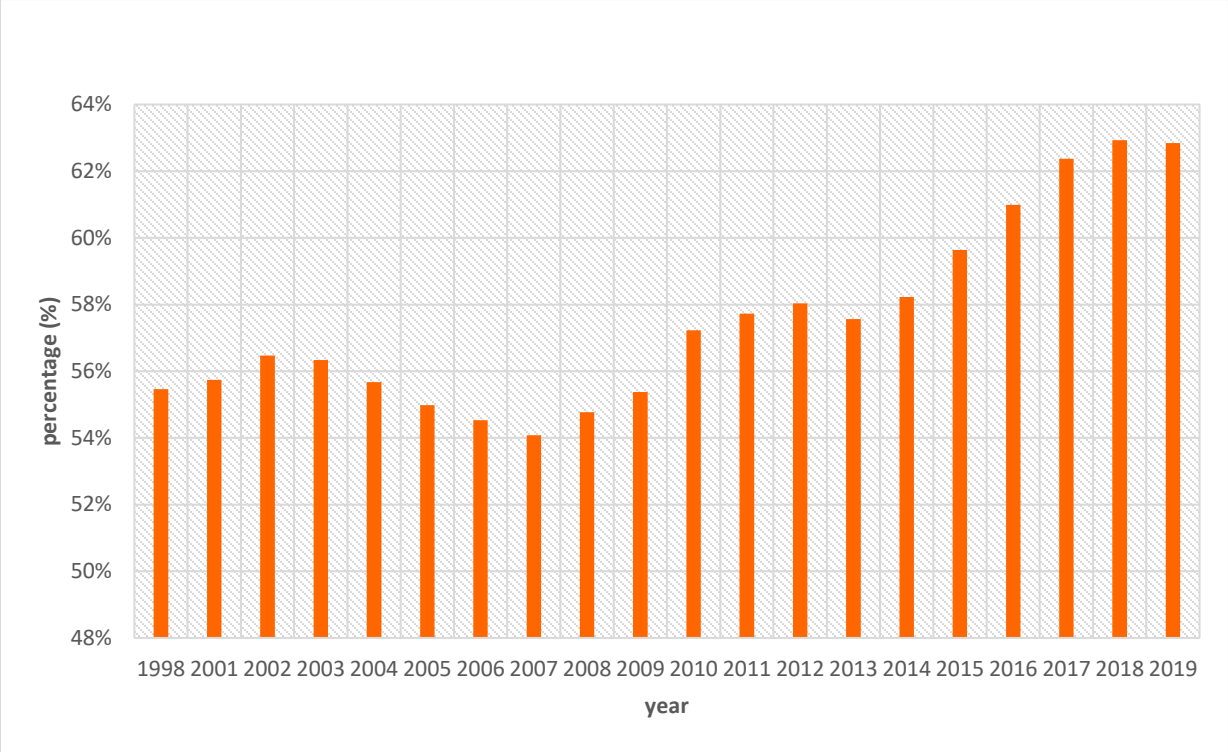
Source: MADR, 2022

Figure 2 **Evolution of the composition of national livestock based on ruminant species in Algeria.**

2.1.1. Ovine herd

About 75% of the national livestock is made up of the ovine herd, which is also the greatest herd in terms of size (with over than 20 million head) and variety. Its structure is predicated on the presence of adult sheep, including ewes and rams; hogget, which stand in for young male and female sheep that have not lambed and whose age is between 10-18 months; and lambs that are no older than 10 months.

The proportion of ewes (lactating ewes) to the entire herd reflects how strongly sheep husbandry is thought to contribute to milk production. Even though sheep farming is the predominant livestock farming practice in Algeria, with the primary goal of red sheep meat production, the most preferred for consumers, and what to guarantee by lambs, the percentage of lactating ewes that are typically preserved at lambing are surpassing the 50%, ranging between 54% recorded in 2007 and 63% recorded in 2022 as illustrated in figure 3 what contribute to a positive perception of sheep milk production in Algeria



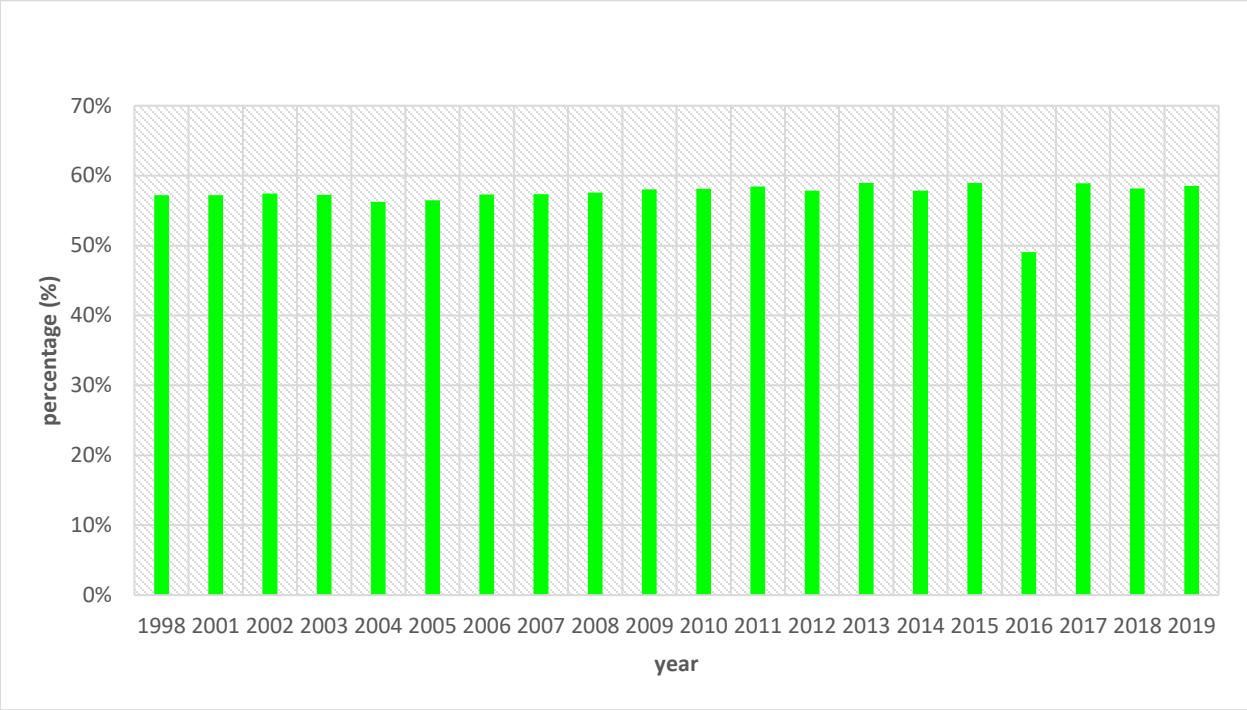
Sources: MADR, 2022

Figure 3 Evolution of the ratio of ewes to the entire ovine herd in Algeria

2.1.2. Caprine herd

The goat herd, which has been found to be the second largest contributor to the national herd composition with over 17% (an average of 2.5 million head), is structured on three main mixed categories (local breeds and imported breeds): young goats (under 2 years old) that are primarily intended to produce red goat meat known for its low fat content, and older goats that are mainly intended for breeding and milk production.

As seen in the chart in Figure 4, the proportion of goats (with lactating potential) to the entire herd ranges from 49% in 2016 to 59% in 2019, which demonstrates the significance of goat milk production.



Source: MADR, 2022

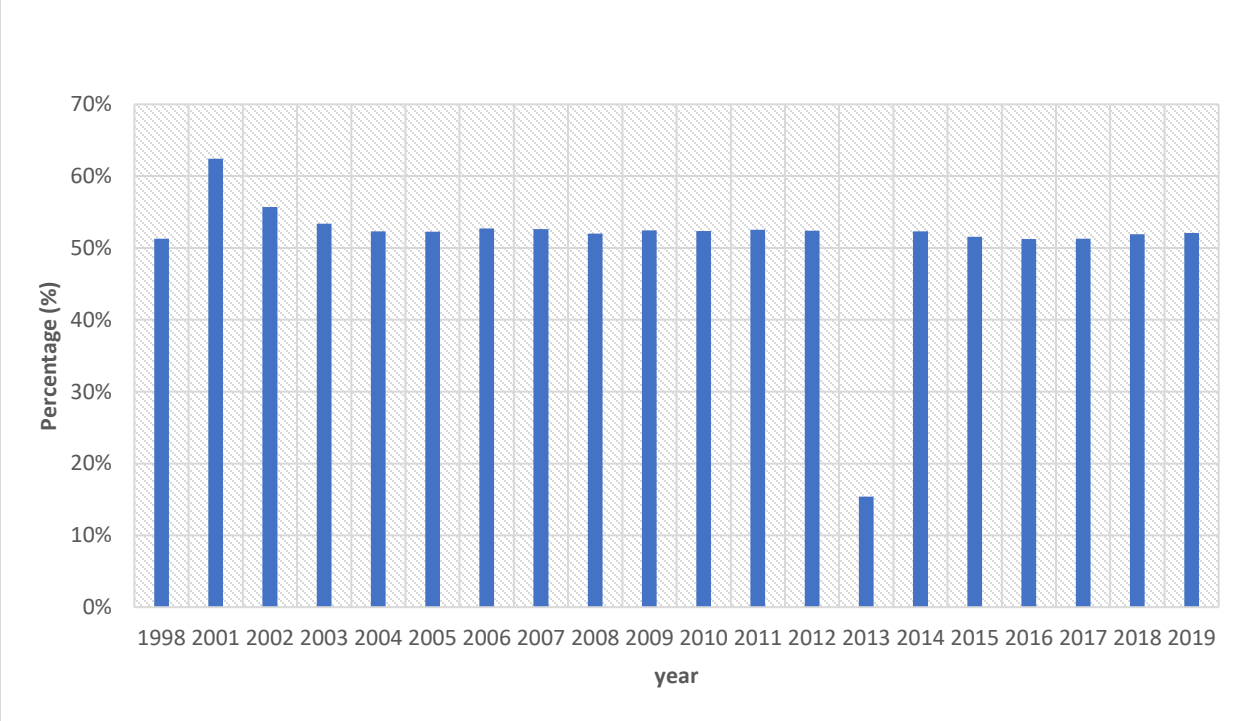
Figure 4; Evolution of the ratio of productive dairy goats to the entire caprine herd in Algeria

2.1.3. bovine specie

despite the fact that the bovine herd only makes up less than 8% of the country's livestock, placing it in third place, right behind the ovine and caprine herds, respectively, Algerian government organisations ' data show that cow milk production leads the dairy industry which can be stemmed from the important dairy potential of the dairy cows.

Actually, as per Figure 5, the proportion of productive dairy cows to the total bovine herd (PDC/TBH) greatest value of 63%, was recorded in 2001. This ratio dropped to about 52 percent in 2004, after which it remained steady until 2019. It is noteworthy that 2013 had the lowest ratio (15.33%).

The Algerian bovine herd has the most intricate structure. The three primary categories of productive dairy cows—improved dairy cows (IDC), modern dairy cows (MDC), and local dairy cows (LDC)—which account for over half of the total herd, contribute to the national milk production. The remaining herd is mostly split into two categories: bull calves and heifers, which are young bovine females older than 11 months who have not yet calved, and male and female calves less than 12 months

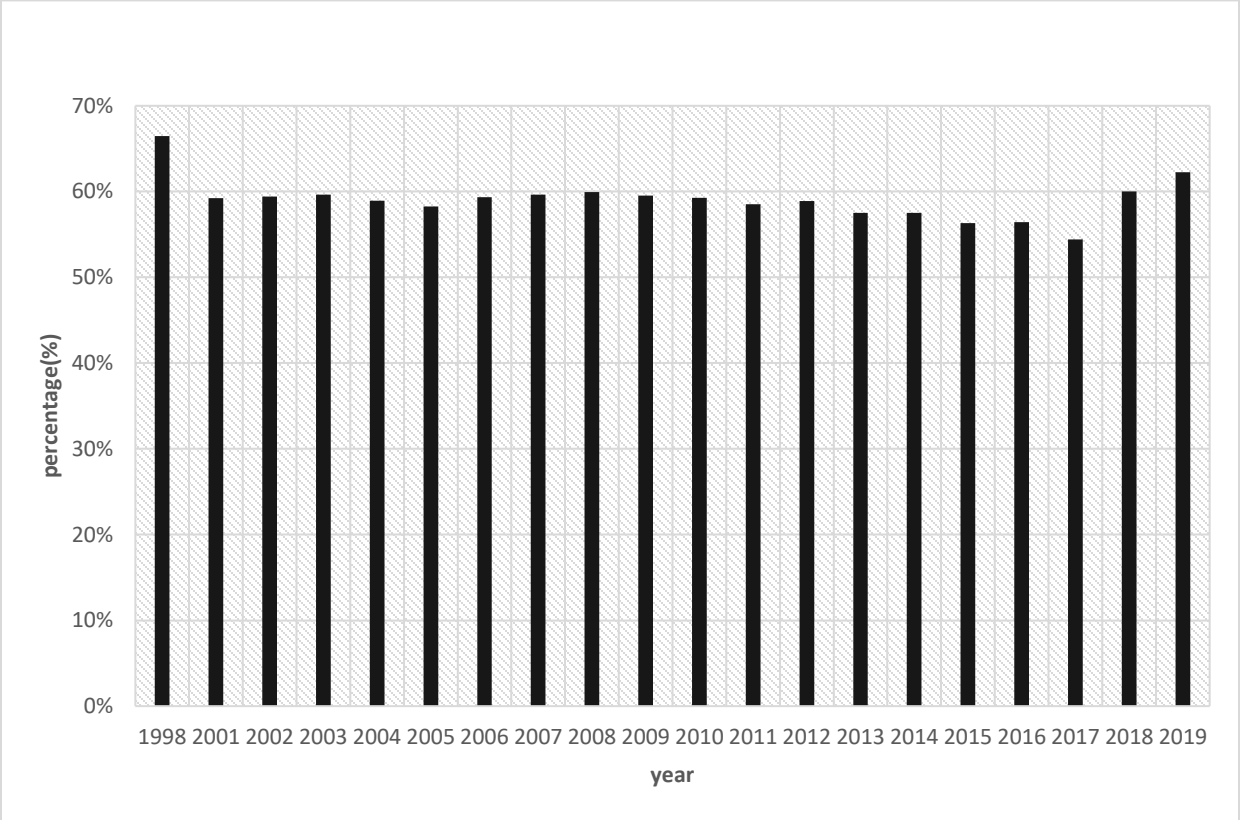


Source: MADR, 2022

Figure 5 Evolution of the ratio of the productive dairy cows to the entire bovine herd in Algeria

2.1.4. Camelina herd

Less than 1% of Algeria's livestock is made up of camelina species. In 1998, the percentage of female camels of the entire camelina herd reached its highest value, exceeding 66%. In 2017, this ratio decreased to around 54%, and in 2019, it rebounded to 62% as Figure 6 indicates.

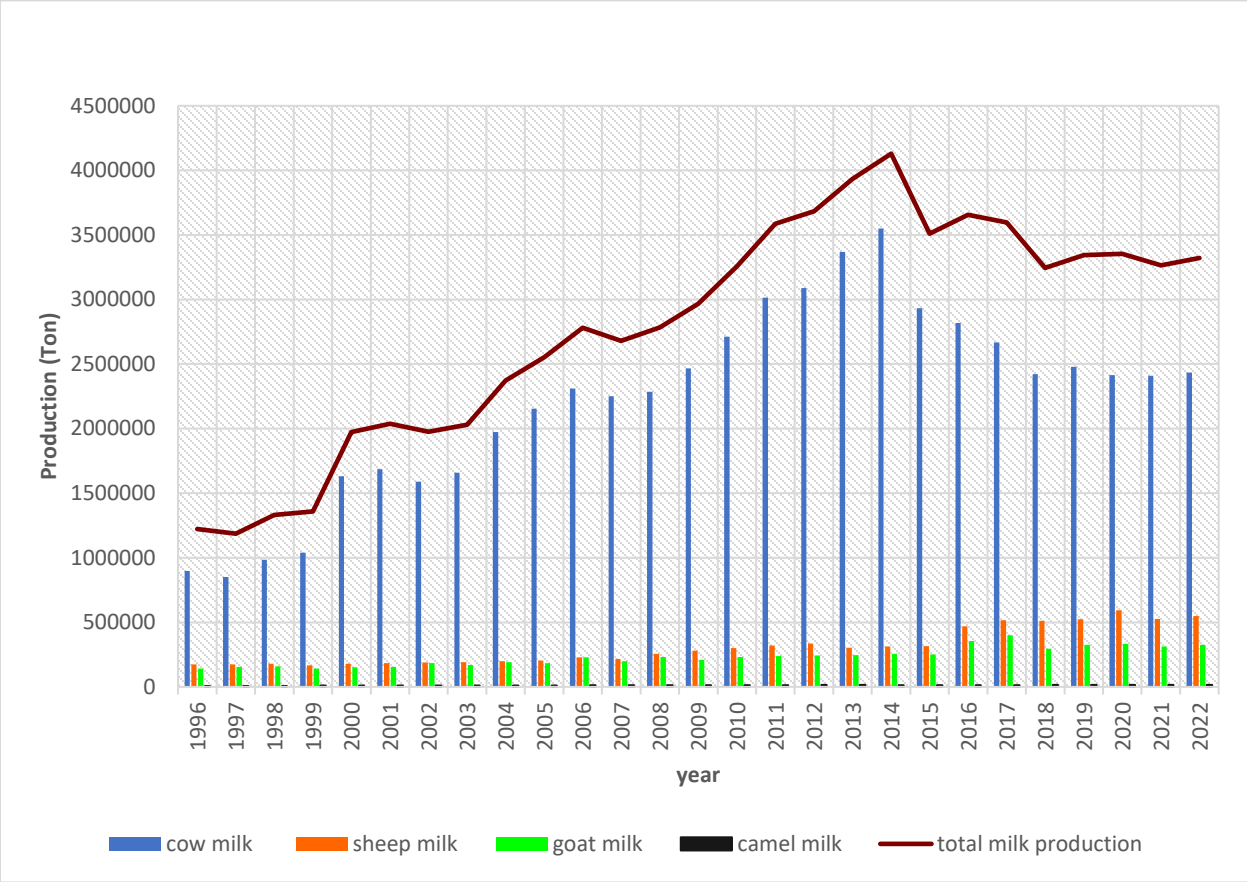


Source: MADR, 2022

Figure 6 Evolution of the ratio of dairy camels to the entire camelina herd in Algeria

2.2.Raw milk production

The four aforementioned species (bovine, ovine, caprine, and camelina) have ensured Algeria's national raw milk production (RMP) for the research frame time 1997 to 2022. With a growth rate of 348% and a compound annual growth rate (CAGR) of 7.61%, the RMP increased from around 1.22 million tons per year to over four million tons per year over the 1997–2014 period, which was marked by several changes in its quantity evolution. However, with a CAGR of -2.68%, the RMP fell by 80% over the next period, 2014–2022. It might be expressed quantitatively as a decrease of more than 0.6 million ton. Figure7



Source: FAO, 2022

Figure 7: Evolution in quantity of raw milk production based on ruminant species in Algeria

A contrast may be observed when comparing the growth of RMP amount with the evolution of total livestock size over the same time. From 1997 to 2014, both variables showed concurrent growing rates. However, the most interesting finding to emerge from the data comparison over the following period (2014–2022) is that, despite the herd's steady increase- which, based on the CAGR previously determined in section 2.1., the livestock size could reach in 2022-, the RMP curve has shifted downward;

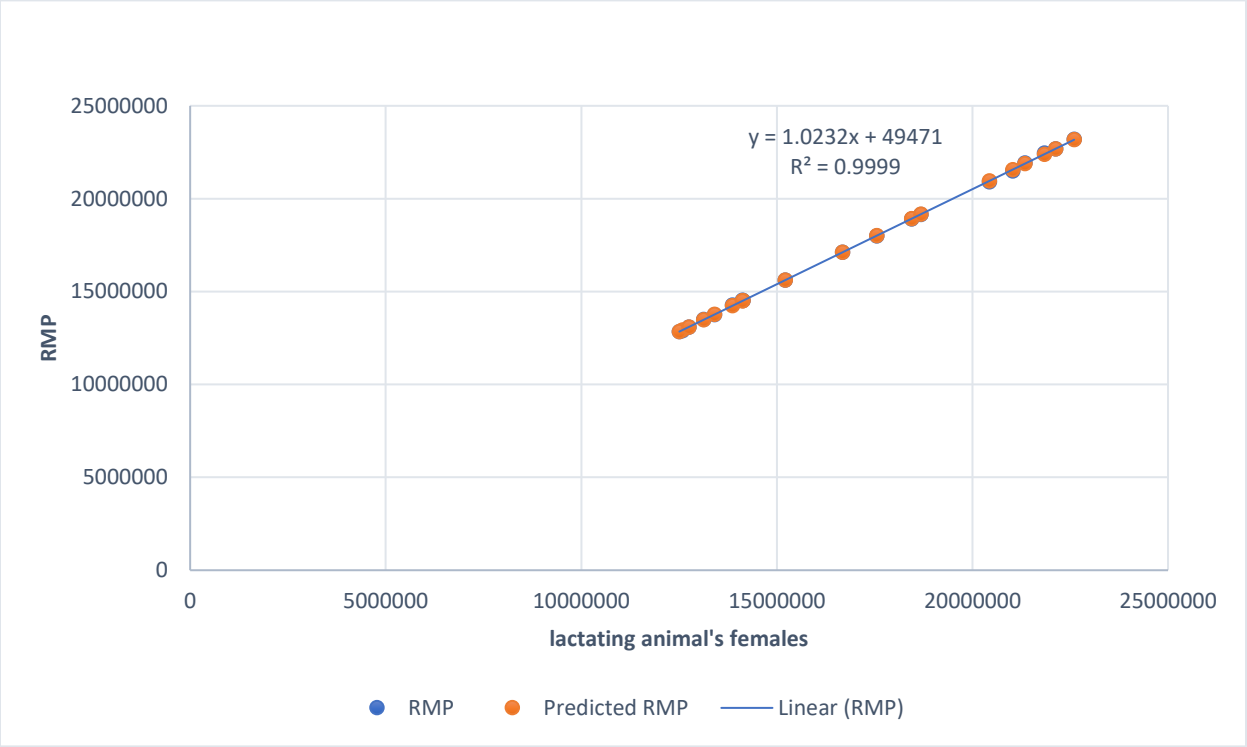


Figure 8 Regression analysis of the impact of the number of national lactating animal's females on the RMP in Algeria (dairy animals' line fit plot)

2.2.1. Cattle raw milk production

Even though the bovine herd makes up less than 8% of all livestock, the results, as shown in Figure 7, indicate that, of the four raw milk types originating from the four ruminant species previously mentioned, raw cow milk is the most predominant RMP. The RMP of the bovine species has increased nearly three times, reaching 2022 with a compound annual growth rate (CAGR) of 4.3% over the period of the study (1997–2022).

Nonetheless, as can be seen in figure 7 the bovine specie's RMP development may be separated into two main phases. With a significant GR amount of 418%, CRMP showed a developing speed between 1998 and 2014. It reached the peak in 2014 with over than 3.5 million tons as quantity and a CAGR of 8.77 percent. CRMP decreased by 69% during the next decade (2014–2022), dropping of more than 1.1 million tons over this period at a compound annual growth rate (CAGR) of -4.60.

Further analysis showed that the substantial positive influence that bovine RMP has on the evolution of the total RMP trend line further contributes to its significance. The CRMP and total RMP pace comparison from Figure 7 revealed an interesting parallel shifting rate, which may be explained by the extremely strong positive correlation between them (r=0.98) and a regression equation **y = 1.1697x + 179564,** which came out from the cow milk line fit plot displayed in Figure 9

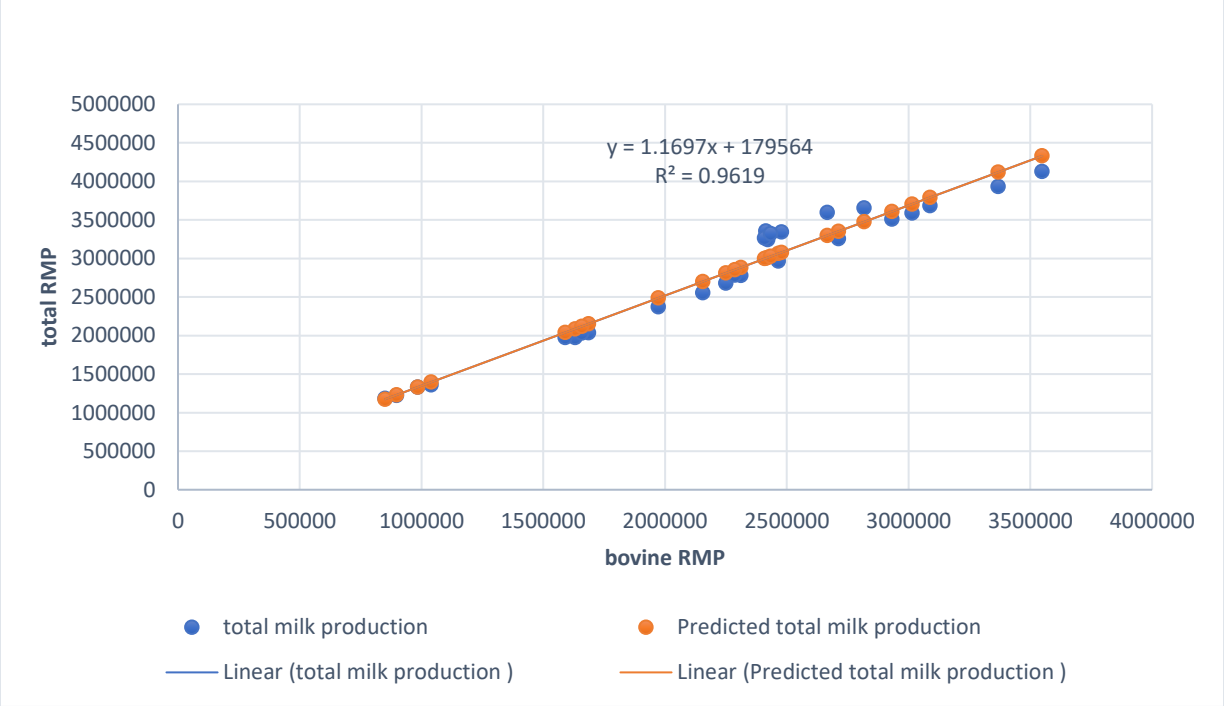


Figure 9 Regression analysis of the relationship between the total RMP and the bovine RMP in Algeria (bovine RMP line fit plot)

Meanwhile, according to the regression equation **y = -4E+08x + 2E+08x - 3E+07**, the bovine RMP is positively correlated (r=0.64) with the ratio of modern dairy cows to the total number of dairy cows, with an increasing trend line. The bovine RMP is highly influenced by the internal structure of the bovine herd, as evidenced by the correlation (r=0.44) between it and the ratio of the dairy cows in the overall herd.

Actually, Cattle are crucial in worldwide milk production, primarily because of their outstanding milk yield potential relative to other dairy species(Moula et al., 2015). (Horváth & Mikó, 2016) assert that a larger cattle herd generally increases milk production. Countries with substantial dairy

operations can generate increased milk output owing to a higher population of contributing animals.

The distribution of dairy breeds within a country's livestock population significantly influences milk production levels. Breeds such as Holstein Friesian, recognized for their high milk yields, play a crucial role in overall production(Alqaisi et al., 2020; Habimana et al., 2023). Nonetheless, this enhanced productivity often requires greater input demands, resulting in a complex interplay between efficiency, profitability, and sustainability (Moula et al., 2015). Nations depending on lower milk yield potential breeds, such as local or indigenous breeds, may encounter reduced overall output (Alqaisi et al., 2020)These breeds are generally more effectively adapted to local conditions, demonstrating resilience to heat stress and disease.

In Algeria, efforts to enhance the dairy sector since independence have not sufficed to meet the population's needs, resulting in substantial imports of powdered milk,which have been identified by Algerian researchers as a consequence of inadequate use of the dairy potential of cows, which is frequently due to outdated breeding practices and various structural, technical, and economic limitations on farms(Boukhechem et al., 2019)

2.2.2. Small Ruminant Milk Production

The RMP of the sheep herd, which accounts for over 75% of the nation's livestock, does not exceed, in the best scenario, 18%, ranking it in second position right after bovine RMP. Ovine RMP increased by 313% throughout the study frame time, from around 0.175 million tons per year to over 0.55 million tons annually in 2022, with a compound annual growth rate (CAGR) of 4.66%. Based on the regression equation **y = 4E+06x - 2E+06,** the figure illustrates a linearly increasing trend line with a good correlation (0.93) between the ovine RMP and the ratio of dairy sheep to the overall ovine herd.

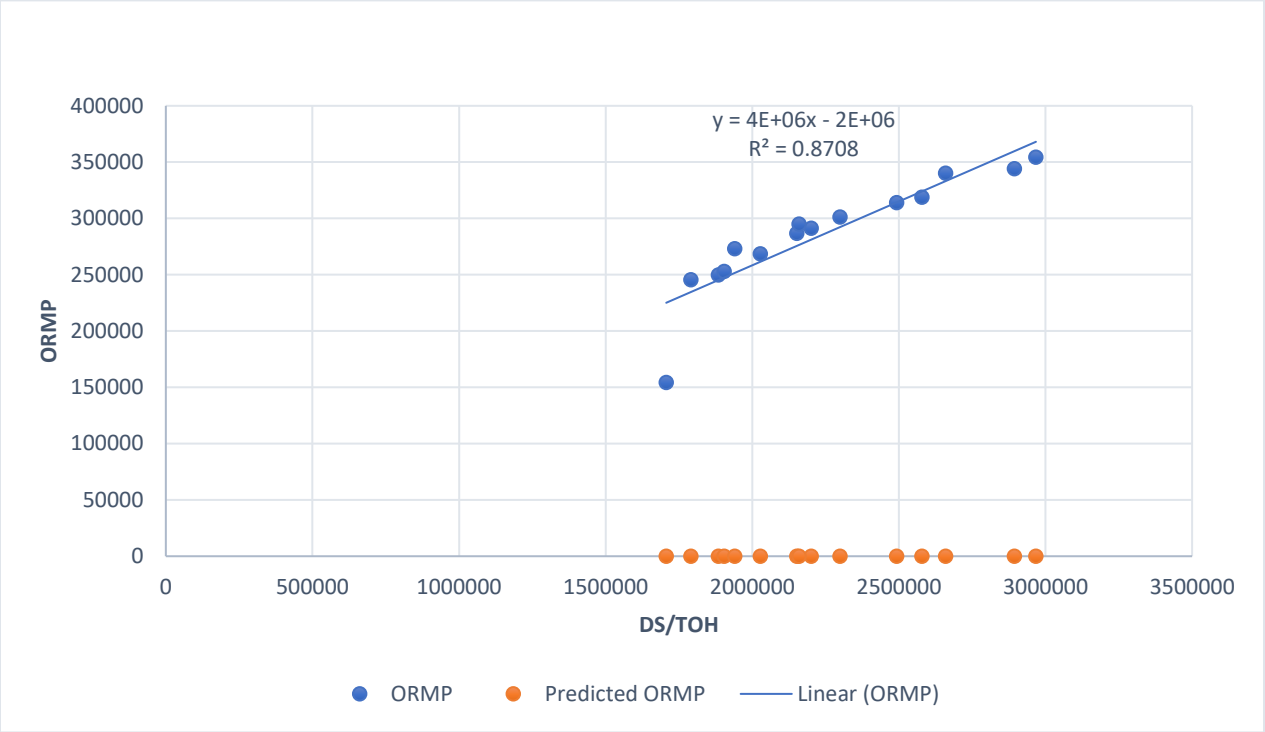


Figure 10 regression analysis of the impact of the ratio of dairy sheep to the total ovine herd on the ovine RMP in Algeria (DS/TOH line fit plot)

While Algeria predominantly relies on cow milk, additional milk and dairy production outcomes from sheep, goats, and camels remain minimal (Hales Nabila, 2023, 2024). The challenging conditions of North Africa, particularly in Algeria, render small ruminants such as sheep and goats indispensable for meat production. Furthermore, their adaptability to such conditions underscores their potential for milk production in the region (Sraïri et al., 2013a). Sheep milk production is a crucial component of the global dairy market, stemming this importance from the fact being an important food product in numerous countries, functioning as a primary component for different varieties of cheese and dairy products, especially in areas with varied Agro-ecological zones in which sheep exhibit notable adaptability. (Turynskiy et al., 2020)

Sheep are primarily raised for red meat production purposes including North African countries; however, their milk production is also significant, especially in low and medium-input production environments due to the challenging climate conditions that are prevalent in many areas of the region. The adaptability of sheep to diverse agroecological zones is a critical factor in their suitability for smallholder farmers.(Sraïri et al., 2013a; Tsigab et al., 2024)

Sheep farming in Algeria serves the dual purposes of red meat and milk production, with certain local breeds recognized for their dairy potential.

- The “Sardi” Sheep breed is the predominant breed in Algeria, recognized for its superior milk yield and high-fat content relative to other local breeds, making it particularly suitable for cheese and ghee production and meeting the increasing demand for dairy products in the region. (Boussekine et al., 2020)
- The “Rembi” Sheep breed is esteemed for its adaptability to native environmental conditions and its capacity to survive in arid regions. Rembi ewes exhibit moderate milk production, with an estimated total yield of approximately 60.4 kg during the lactation period (Benchohra et al., 2014; Turynskiy et al., 2020)

Additionally, various indigenous breeds contribute to milk production in Algeria, characterized by resilience and adaptability to local grazing conditions. Although these breeds may not achieve the high yields characteristic of specialized dairy breeds, they are crucial in subsistence farming (Tamendjari et al., 2024).

In summary, sheep breeds contribute significantly to milk production in Algeria through their enormous herd size and the highest ratio of lactating ewes to the total ovine herd in comparison with the other species, as mentioned previously, and the government's policies that aim to protect productive ewes, in addition to the adaptability, cultural importance, and economic value. While they may not match the high yields of specialized dairy cattle breeds, they play a crucial role in supporting local diets and economies.

In contrast, the caprine RMP ranks third in Algeria with a GR of 210% and a CAGR of 3% throughout the research period. It represents 11.1% of the country's overall RMP Caprine RMP reported a rise in quantity, totaling about 170,000 tons.

Additional statistical analysis showed that the caprine RMP is strongly correlated (0.82) to the number of dairy goats in the caprine herd. a growing linear fit line with the regression equation of $y = 0.1208x - 54109$is depicted by the regression analysis in figure 11.

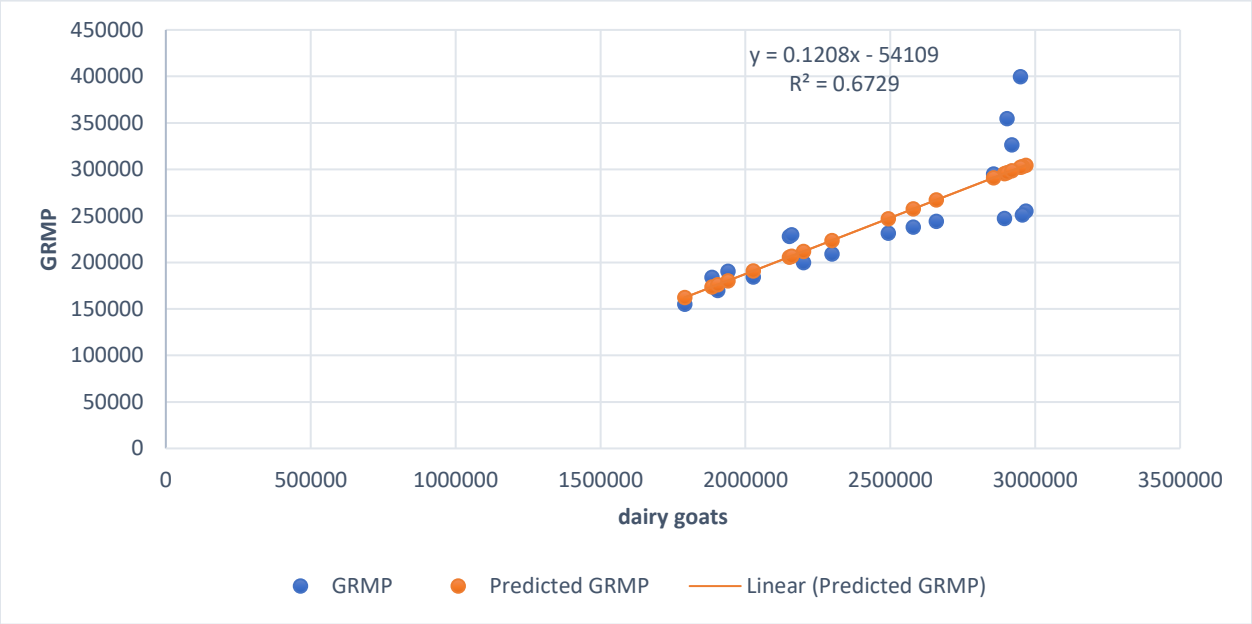


Figure 11 Regression analysis of the relationship between the dairy goats and caprine RMP in Algeria (dairy goats' line fit plot)

As representatives of Algeria's small ruminants, the ovine and caprine RMPs are actually evolving in the same path, and their percentage contributions to the national RMP are relatively comparable despite the substantial disparities in herd size—the ovine herd is approximately four times larger than the caprine herd. The introduction of new imported breeds with high dairy output and those who have made changes to the internal organization of the caprine herd may be partially responsible for this.

Goats play a crucial role in the agricultural economy of numerous countries, including Algeria, especially in challenging conditions. Their resilience, adaptability to adverse conditions compared to other livestock species, and ability to produce milk in marginal areas render them a significant resource, particularly for smallholder farmers.

In Algeria, goats play a crucial role in the livestock sector where goat milk is a significant component of national production. Levels as consequence, the Ministry of Agriculture in Algeria is promoting goat breeding in the Saharan regions, acknowledging the resilience and adaptability of goats in these challenging environments (Hales Nabila, 2022, 2024; Sraïri et al., 2013a).

The investigation of the capabilities of particular goat breeds for milk production in Algeria, alongside their geographical distribution, reveals the presence of both indigenous and imported goat breeds.

Saanen and Alpine are non- indigenous breeds to Algeria; they have been introduced and are esteemed for their exceptional milk production abilities. In Tizi Ouzou state, certain breeders have initiated production units for goat milk and cheese utilizing the Saanen breed, exemplifying its effective incorporation into the Algerian dairy industry (Ouchene-Khelifi et al., 2021). while (Benaissa et al., 2021) research declares the existence of the Alpine breed in Touggourt region, where the physicochemical properties of its milk have been examined and contrasted with those of other breeds such as Arbia and various crossbreeds.

On the other hand, a recent study provided by (Ouchene-Khelifi et al., 2021)characterizes local goat breeds as follows:

- Arabia goat is a local breed recognized as the predominant goat population in Algeria, distributed across multiple regions, with a notable presence in the steppe areas and highlands. The local breed, primarily raised for meat, also contributes to milk production. Its adaptability to the local environment renders it a suitable option for Algerian farmers.
- M'Zabite goat is predominantly located in Ghardaïa and Laghouat states, recognized for its milk production, which averages 2 to 3 liters per day. This breed demonstrates significant adaptation to Saharan regions, underscoring its potential for milk production in Algeria's arid zones.
- Makatia goat, found in the southern regions of Ouargla and El Oued, yields 1 to 2 liters of milk daily. This breed exemplifies the diversity of goat breeds in Algeria and their capacity for milk production across various ecological zones
- Naine of Kabylie goat, located primarily along the coast in Bejaia and Tizi Ouzou states, is predominantly raised for meat, as its milk production is limited to less than one liter per day. It illustrates the specialization of goat breeds for particular purposes in Algeria.

Goats provide a substantial contribution to milk production in Algeria owing to their resilience, a daptability, and nutritional value. Benefits that may be used by farmers aiming

to increase dairy production in marginal areas, creating economic opportunities while supporting sustainable farming practices

2.2.3. camelina milk production

Despite being the last and smallest contributor to the national livestock (less than 1%) and the national RMP (less than 0.6%), the camel RMP has interestingly increased over the study timeline, rising from about 6500 tons in 1997 to more than 15.5 thousand tons in 2022 with a GR of 239% and a CAGR of 3.54%.

Further statistical analysis has shown a substantial correlation (r=0.86) between the number of dairy camels and camel RMP. The regression equation **y = 0.039x + 5462.5,** and the dairy camel line fit plot in Figure 12 indicate that the camel RMP increases linearly with the number of dairy camels.

Camel milk production represents a potential growth area in Algeria, especially within arid and semi-arid regions. Currently, camel milk production in Algeria is marginal; however, the Ministry of Agriculture is promoting camel breeding in Saharan regions with the aim of enhancing milk production (Hales Nabila, 2023, 2022, 2024)

The adaptability of camels to challenging arid and semi-arid conditions might be responsible for their survival in environments characterized by water and food scarcity, especially during droughts. Camels may thrive on vegetation that is unsuitable for other livestock (Boudalia et al., 2023; Harek et al., 2024; Laouadi et al., 2018). These reasons render camels a valuable resource for populations in these regions, supplying food and economic security to local communities, particularly in the context of climate change (Harek et al., 2024)

Camel milk production exhibits significant potential, particularly in arid and semi-arid regions. The global need for camel milk and its derivatives is on the rise. This results from an increasing recognition of its nutritional and health advantages (Leksir et al., 2019)Camel milk serves as a significant source of nutrition. It contains a high concentration of vitamins, minerals, and protein. It has a lower fat content compared to cow's milk and is more easily digestible for individuals with lactose intolerance (Boudalia et al., 2023; Leksir et al., 2019). Research indicates that camel milk may possess medicinal properties, including enhancing immune function and combating cancer.

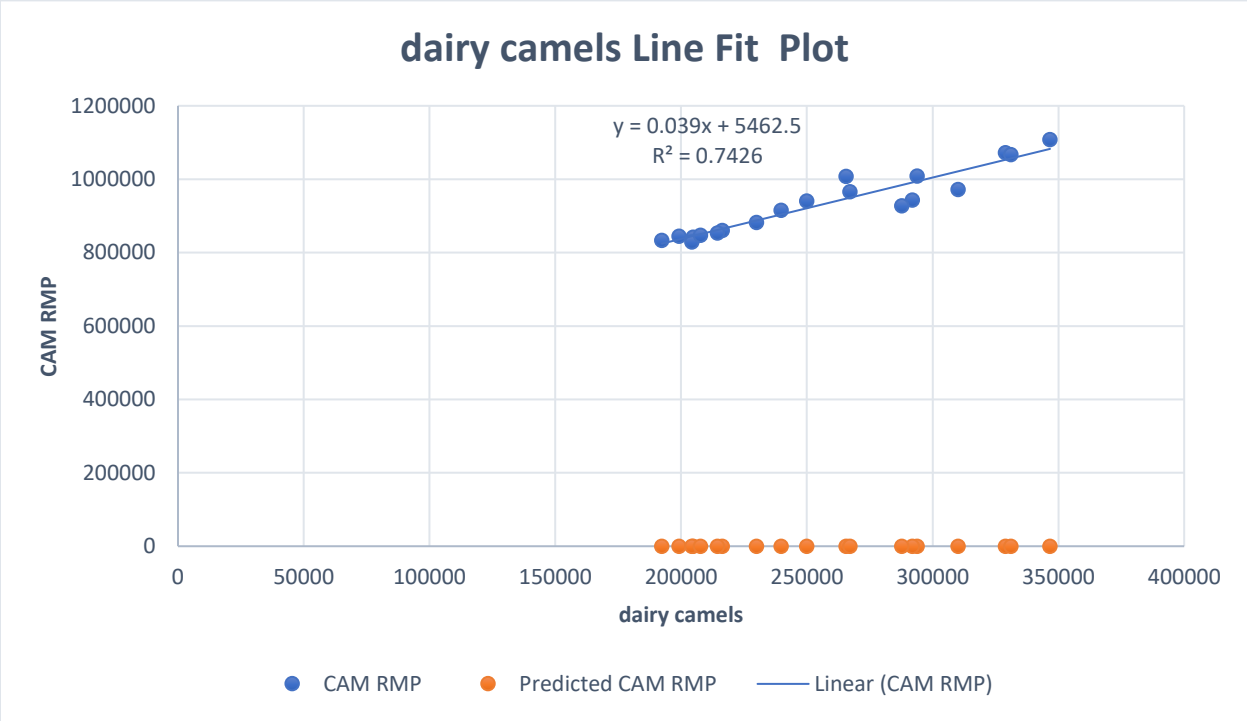


Figure 12 Regression analysis of the impact of the number of dairy camels on the camel RMP in Algeria (dairy camels' line fit plot).

According to (Leksir et al., 2019), Algeria displays an impressive dairy and cheese tradition, prominently featuring camel milk, particularly in the production of items such as ghee "Dhan" The increasing demand presents opportunities for farmers in arid and semi-arid regions to promote camel milk and enhance their livelihoods.

Despite the challenges, the potential benefits of camel milk production, particularly in arid and semi-arid regions, are significant. With increased investment in research, infrastructure, and breeding programs, camel milk production can become a more viable and sustainable source of income and nutrition for communities in these regions.

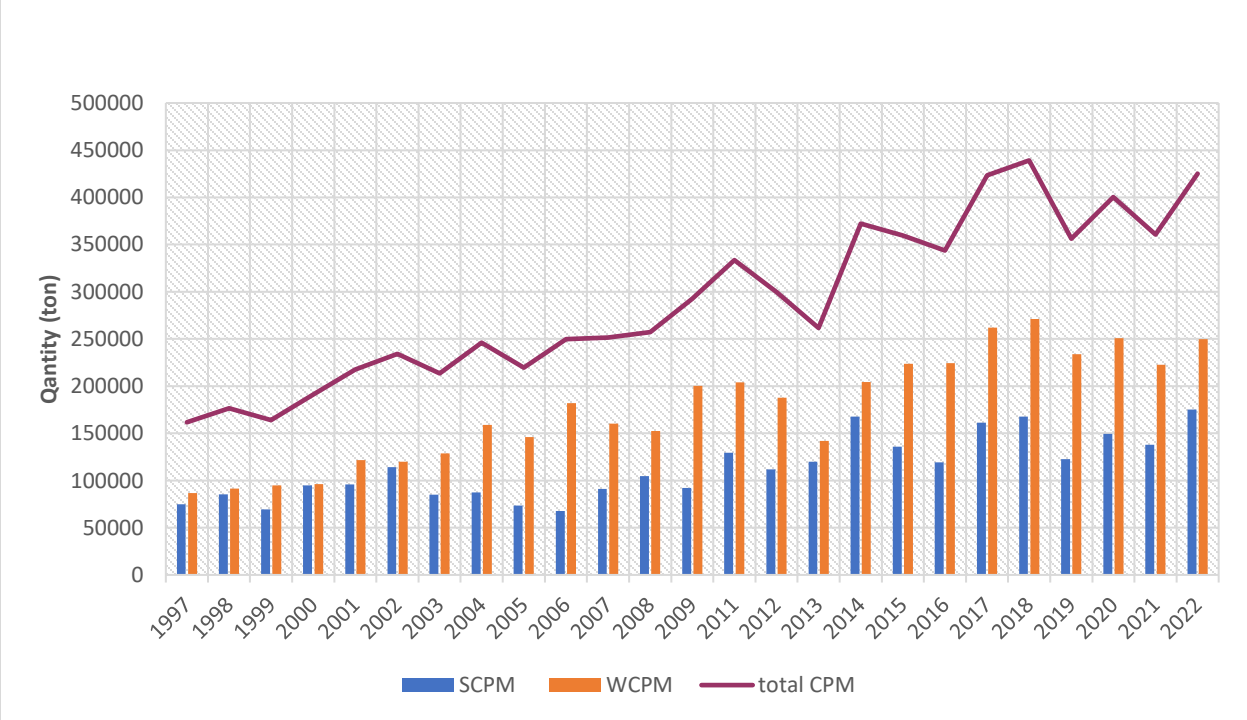
3. Milk imports in the Algerian market

3.1.Changes in milk imports in the Algerian milk market

The Algerian government funds milk production for the general public's daily consumption, which is dependent on the imports of whole and skimmed powder milk, being the largest imported item among dairy products in terms of both quantity and import costs. The most interesting aspect that

stands out in the collected data reveals that the massive amounts of imported powder milk come from a single category: cow's powder milk (CPM), which is transformed into Algerian dairy factories before being sold on the consumer market in the form of reconstituted milk.

As can be seen, referring to the chart in Figure 13, over the last 25 years, milk import quantity has been on an upward trajectory with a GR = 263% and a CAGR of 3.94%. the imported CPM has risen by about two and a half times, jumping from about 161 thousand tons in 1997 to more than 425 thousand tons in 2022. The highest amount of imported CPM was recorded in 2018 in an estimated amount of 450000 tons, while the lowest amount was reported in 1997. further analysis of the data reveals that while the amounts of the two types of imported CPM: whole cow powdered milk (WCPM) and skimmed cow powdered milk (SCPM) were roughly equal between 1997 and 2002, starting in 2003, the quantities of imported WCPM have increased annually by 30 to 50 percent with GR= 288% and CAGR of 4.32% when compared to the quantities of imported SCPM with GR of 234% and a CAGR= 3.46%.

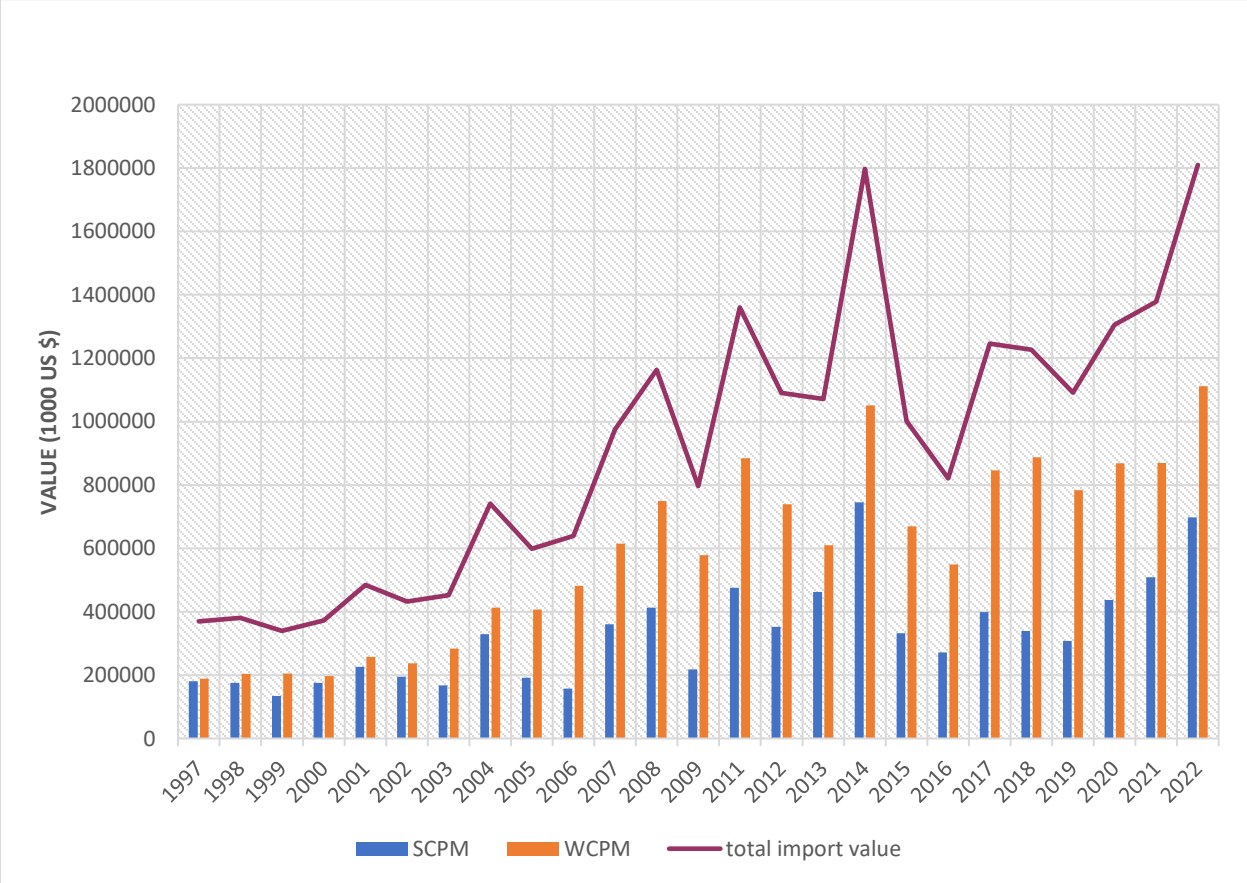


Sources: FAO, 2022

Figure 13Variation in the quantity of imported cow powdered milk in Algeria

The rising rate of the aforementioned imported CPM quantities logically leads to an increasing trend in CPM import costs parallelly. As shown in Figure 14 an increase in import costs of more than 1.5 billion US$ during the studied period has been recorded, jumping from 300 million US$ in 1997 to more than 1.8 billion US $ in 2022, which represents the biggest and heaviest costs Algeria has ever had to pay for the purchase of powdered milk. It is worth noting that CPM import costs have risen approximately 5 times during the research frame time, with GR = 489% and a CAGR of 6.55. This could be explained by the changes in the CPM global unit price, which depend on the international market fluctuations alongside the CPM exporting country.

This can be seen clearly by comparing the data recorded during 2014 and 2018, where, although the statistics indicate that the quantity of CPM imported in 2014 was less than that of CPM imported in 2018, the costs for 2014 were greater than those of 2018.



Source: FAO, 2022

Figure 14 Evolution in annual import costs of cow powdered milk in Algeria

3.2.Shares of exporting countries in the Algerian milk market

As mentioned in the previous section, the Algerian powdered milk imports are represented by only two items, SCPM and HCPM, with contrasted quantities coming from a wide range of exporting countries from different continents (America, Europe, Asia, and Australia).

With an average of 332 thousand tons per year and a yearly market size value estimated to be over one billion US dollars, the Algerian milk market has been dealing with around 49 exporting countries since 1997. Since then, changes in domestic market needs and exporting countries' ability to export this commodity (CPM) have caused the market shares of exporting nations in the Algerian milk market to fluctuate yearly.

Six nations are recognized as the major suppliers of CPM, as shown by the map presented above, which shows the geographic distribution of milk exporting nations according on their yearly market share in the Algerian milk market. This firm accounts for more than 73% of the Algerian milk market and has been a permanent supplier for more than 21 years, which has permitted them to acquire the lion's share of this market.

With over 5 billion US dollars in trades over the last 25 years, New Zealand leads the group with over 18% of the total annual average market size of the estimated one billion US dollars. France and Argentina follow with 4.3 billion US dollars and 3.3 billion US dollars in total transactions, respectively, and 16.10% and 14.16 % of the annual market share of the total annual average market size. Polan, Belgium, and Uruguay are the least valuable countries in this category, with total trades values of 2, 1.8, and 1.4 billion US dollars, respectively. Their average yearly market shares are estimated to be 8.11%, 8.45%, and 7.49%.

Moreover, the other 43 nations split the remaining estimated 27% of the average yearly volume of the Algerian milk market among themselves. Poland dominates this category with an estimated total trade value of 0.674 billion US dollars and yearly deals of over 27 million US dollars, while the Bahamas comes in bottom with only 55 thousand US dollars in trades for a single year.

3.2.1. Whole cow powdered milk shares

With a total of 45 nations, the analysis of the variation of Algerian milk market shares represented in Figure 15 displays the yearly market shares of WCPM suppliers in the Algerian milk market. Based on their existence frequency, 3 classes are used to categorize the Algerian market.

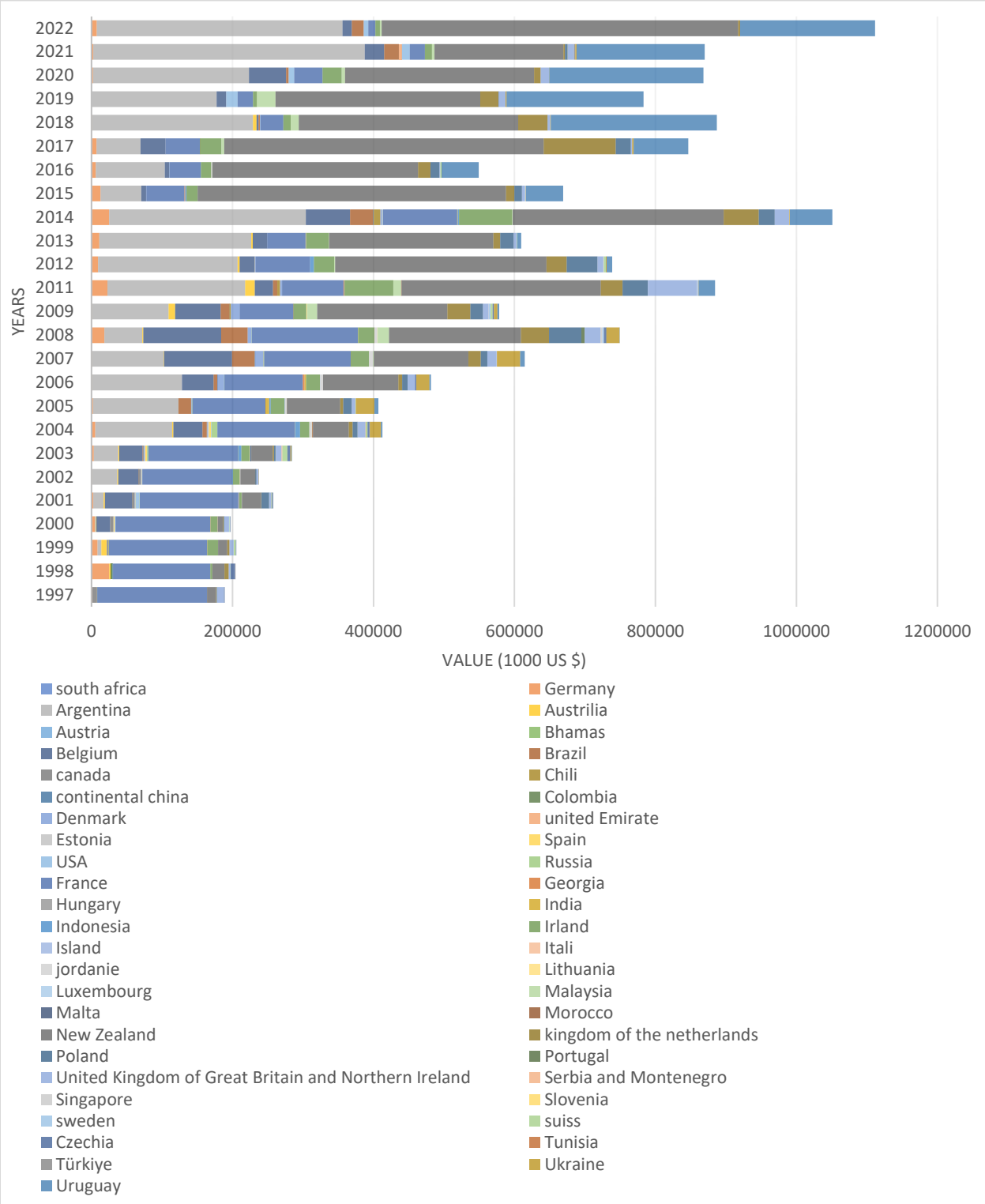
In 1997, France was ranked as the largest supplier of WCPM to the Algerian market, with the highest import costs exceeding 155 million US$ and a market share exceeding 83% of the total volume of CPM imports. The remaining market share was led by New Zealand with important costs of 12.8 million US$, followed by the United Kingdom of Great Britain and Northern Ireland, Germany, the Kingdom of the Netherlands, Denmark, and Poland with 11.92% total market share percentage.

It is noteworthy that Argentina, Belgium, Ukraine, Uruguay, and Malaysia were becoming constant WCPM suppliers for the Algerian milk market since 1999,2000,2002, 2003, and 2007, respectively.

The fluctuations of the Algerian milk market over the 25 years of the study have led France to fall into arrears, ranking last in 2022 with a market share of less than 1%, with only 10 million US$. While New Zealand ranks first, for its own, with more than half a billion US$ and a 45% estimated market share, followed by Argentina, Uruguay, Belgium, Germany, France, Ireland, Malaysia, and the Kingdom of the Netherlands.

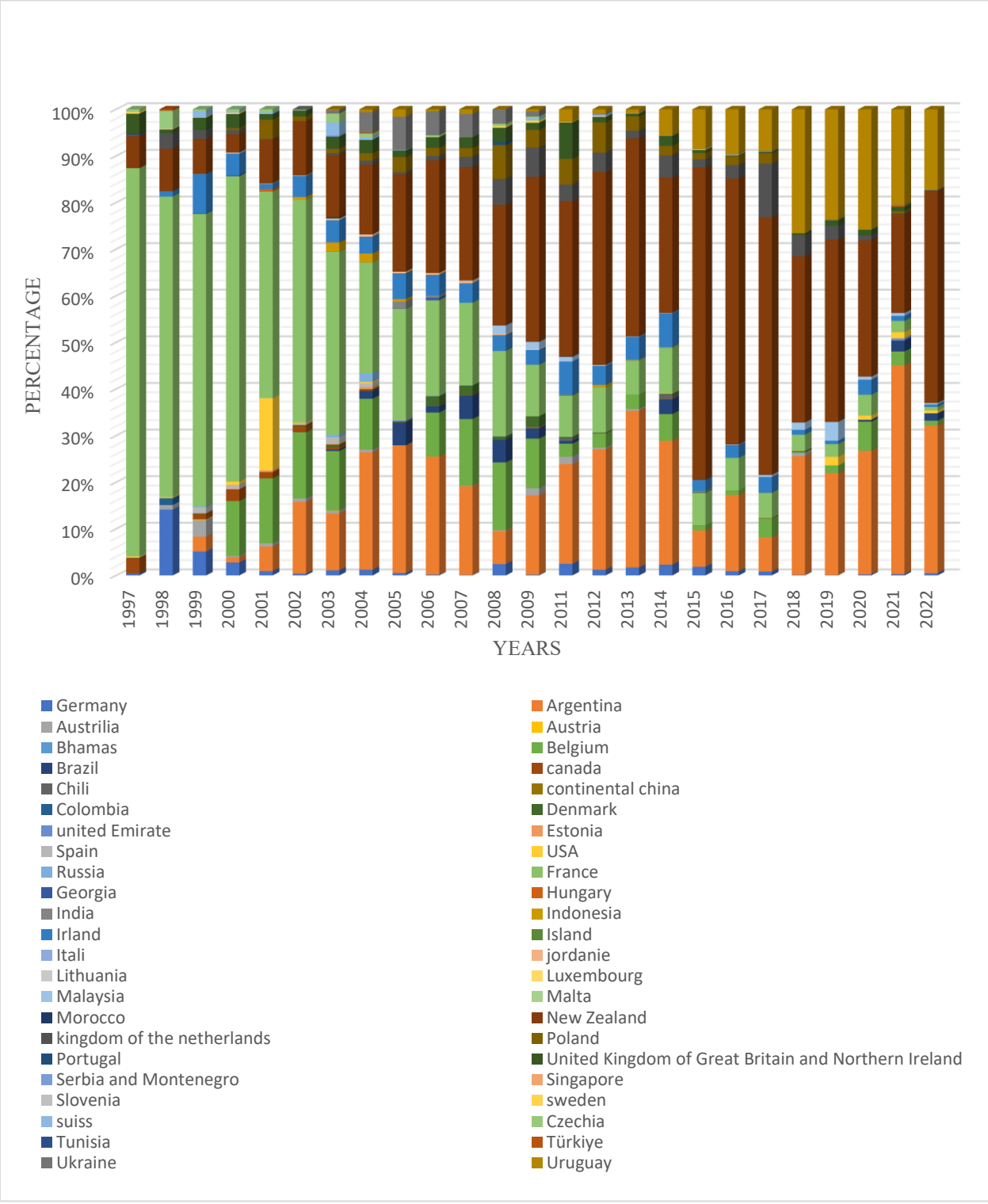
A significant number of nations exporting WCPM arose throughout the research period, joining the previously stated nations that supplied the Algerian market consistently. The market shares of this category of nations were diverse and affected by their presence frequency in the Algerian milk market, which was continuous or occasional for one year (Bahamas, Colombia, United Emirates, Luxembourg, Malta, and Slovenia) or multiple years.

The WCPM exporting nations are categorized in Table 01 depending on how long they have been in the Algerian market and how they rank within the same category based on their average yearly market shares.



Source: FAO, 2022

Figure 15 Variation in import values of WCPM in Algeria according to the exporting countries



Source: FAO, 2022

Figure 16 Percentage changes in the WCPM quantitative shares of exporting countries in the Algerian milk market

In the table below, three classes (A, B, and C) of WCPM exporting nations were adopted based on their presence frequency (number of years), which are (17-25, 9-16, 1-8 years), respectively.

Table 1 Sorting of WCPM exporting countries based on the presence frequency in the Algerian market

Class	Included Countries	country		Average /year		Total (25 years)	
				Quant (ton)	Val (1000 US$)	Quant (ton)	Val (1000 US$)
A	Germany, France, New Zealand, kingdom of the Netherlands, Ireland United Kingdom of Great Britain and Northern Ireland, Argentina, Belgium, Poland, Uruguay, Ukraine, Denmark, USA	max	New Zealand	55107.85	182375.8	1432804	4741772
		min	Denmark	886.6761	2776.889	15960.17	49984
B	Australia, Brazil, Malaysia, Canada, Jordany, Swiss, Czechia, Spain, Sweden, India, Indonesia	Max	Brazil	3613.766	13832.21	50592.73	193651
		min	Sweden	291.8	875.6	2918	8756

C	Russia, Georgia, Portugal, Singapore, Türkiye, Estonia, Lithuania, Chili, Continental China, Itali, Serbia and Montenegro, Austria, Hungary, Island, Bahamas, Colombia, United Emirate, Luxembourg, Malta, Slovenia	max	Colombia	1350	2746	1350	2746
		min	Bahamas	20	55	20	55

Class A: 17-25 years; class B: 9-16 years; class C: 1-8 years

As can be seen from the table below, of all the WCPM exporting nations, New Zealand has the largest market share. It is one of only four class A countries that has been continuously providing this essential substance to the Algerian market for 25 years, and it leads with an average annual import costs of roughly 183 million US dollars, which is equivalent to around 55 thousand tons in terms of average annual quantity imported. Denmark, on the other hand, is the smallest class A representative with the lowest market share, with average yearly import costs estimated at 248 thousand US dollars.

Identified as the smallest class with 11 countries, class B is led by Brazil with approximately 14 million US$ yearly market share average. However, Sweden ranked last with an estimated market share of more than 875 thousand US$ as a yearly market share average.

The market shares of the nations categorized in class C, the largest class with 22 nations, ranged from 55 thousand to 1.35 million US Dollars, with Colombia leading the way and the Bahamas placing last. It is noteworthy that these two nations' engagement with the WCPM market was limited to a single year.

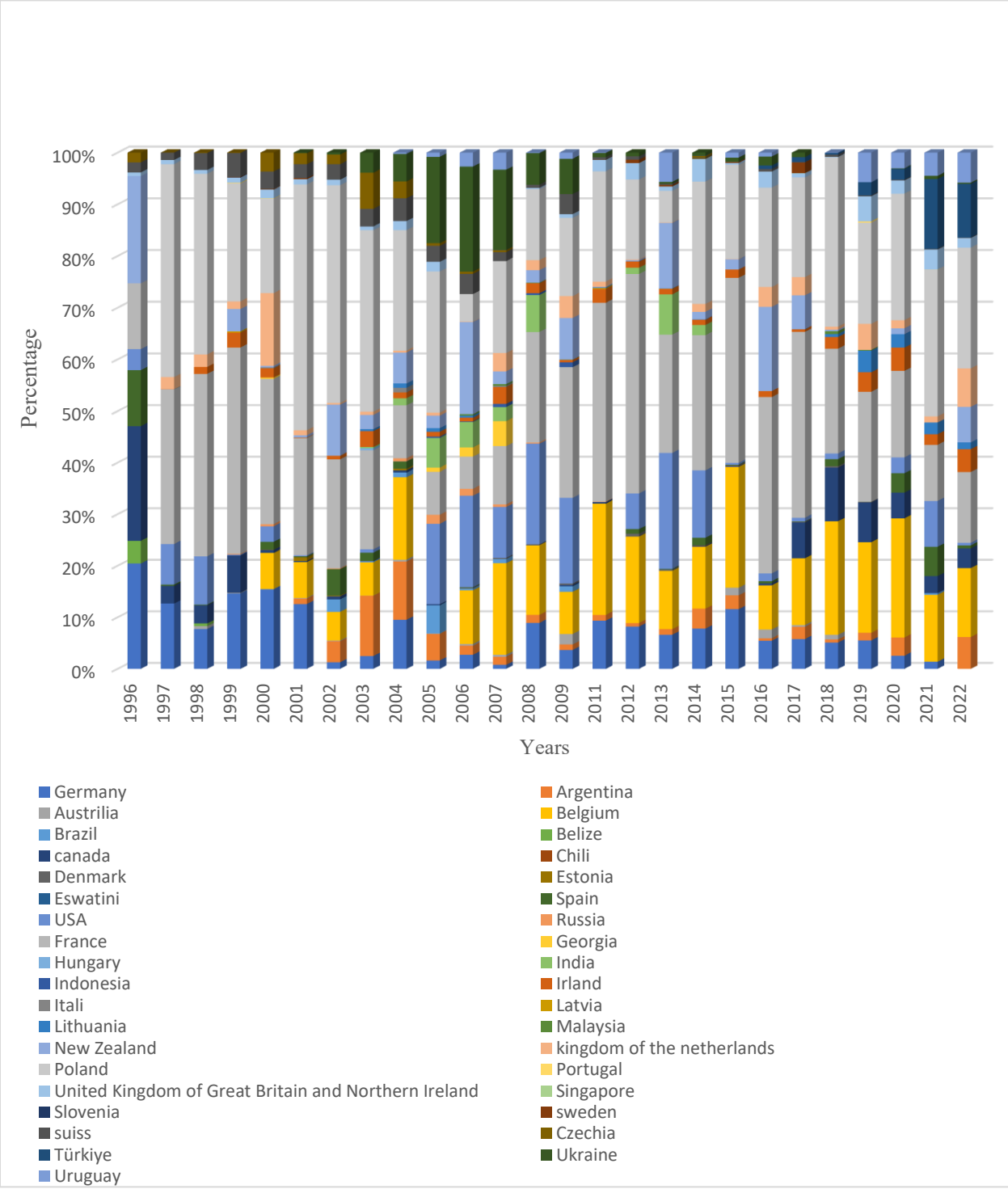
3.2.2. Skimmed cow powdered milk shares

The information in Table 2 demonstrates that 37 exporting nations of SCPM are involved in the Algerian milk market. 77% of the countries that export WCPM are also supplying the Algerian market with SCPM. Furthermore, we have noticed that three new exporting nations—Belize, Eswatini, and Latvia—have replaced the ten countries (Austria, Bahamas, Colombia, Continental China, Island, Jordan, Luxembourg, Malta, Serbia, and Montenegro, United Emirates)

Poland was ranked as the biggest SCPM provider to the Algerian market in 1997, accounting for 41.18% of all SCPM imports with the highest import costs of 65 million US$. France led the remaining market share with an important cost of fifty-seven million US dollars. Germany, the United States, Canada, the Netherlands, Switzerland, the United Kingdom of Great Britain and Northern Ireland, Spain, India, New Zealand, and the Czech Republic followed with 28.83% of the total market share percentage.

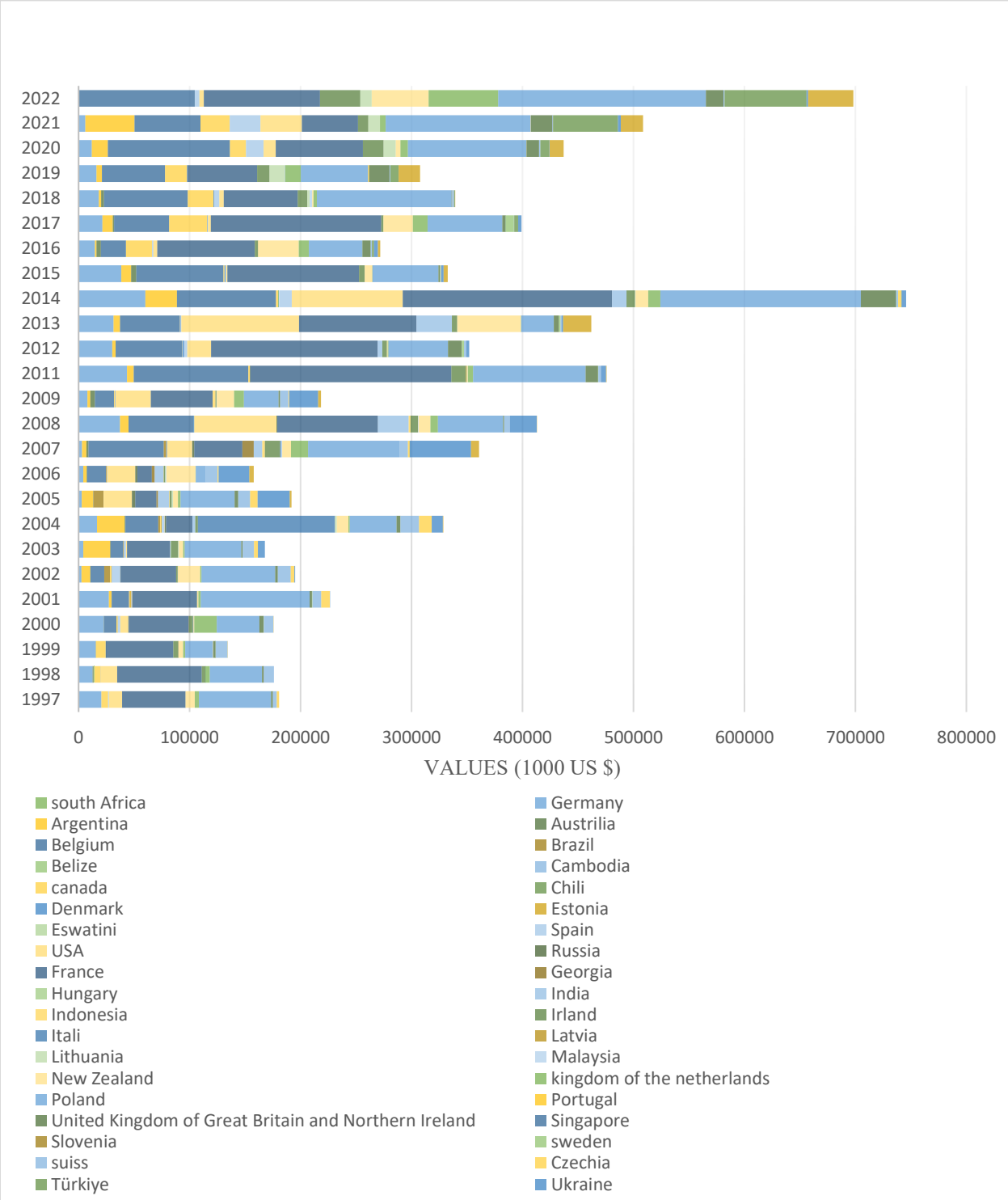
It is noteworthy that the fluctuations of the Algerian milk market over the 25 years of the study have led Poland and France to trade first and second place as the largest SCPM suppliers. Poland has come back to ranks at the top since 2020. In 2022, it headed the list with more than 187 million US $as import costs dominating the SCPM market with a share of 23.36%, followed respectively by France, Belgium, Türkiye, kingdom of the Netherlands, New Zealand, Argentina, Uruguay, Ireland, Canada, United Kingdom of Great Britain and Northern Ireland, Lithuania, Spain, USA, Ukraine and Swiss.

Throughout the research period, a significant number of countries began to export SCPM, joining the previously mentioned countries that regularly supplied the Algerian market. The various market shares of these countries were influenced by how frequently they were present in the Algerian milk market, whether it was for a single year (Belize, Chile, Eswatini, Hungary and Slovenia) or for several years.



Source: FAO, 2022

Figure 17 Percentage changes in the SCPM quantitative shares of exporting countries in the Algerian market



Source: FAO, 2022

Figure 18 Variation in import values of SCPM in Algeria according to exporting countries

On the subject of the exporting countries' classification, Class “C” is led by Brazil, which exports an average of 1272 tons of SCPM / year, while Singapore is ranked at the bottom of the class with 87.5 Tons/year and a total exported SCPM quantity of 175 tons.

Surprisingly, Denmark, which was at the bottom of class "A" with about 887 tons of WCPM annually, has fallen to the bottom of class "B" concerning SCPM, with about 204 tons/year. Turkey, on the other hand, moved up from class “C” in the previous part and now rates at 5123 tons per year at the top of class “B,” which is thought to be the smallest class with only 10 nations.

In terms of SCPM, Spain moved up from WCPM class “B” to the bottom of class “A” with more than 1.5 thousand tons annually, while France dominates the class “A” list with around 27.5 thousand tons annually.

Table 2: sorting of SCPM exporting countries based on presence frequency in Algerian market

Class	Included Countries	country		Average /year		Total (25 years)	
				Quant (ton)	Val (1000 US$)	Quant (ton)	Val (1000 US$)
A	France,kingdom of the Netherlands, Poland, Swiss, Germany, Ireland, USA, United Kingdom of Great Britain and Northern Ireland, Canada, New Zealand, Belgium Spain, Argentina, Ukraine	first	France	**27421.8**	**79585.8**	**685545.1**	**1989645**
		last	Spain	**1503.233**	**4058.143**	**31567.9**	**85221**

B	Australia, Uruguay, Denmark, Lithuania, Czechia, Itali, Sweden, Russia, India, Türkiye	first	Türkiye	**5123.024**	**17171.56**	**46107.22**	**154544**
		last	Denmark	**203.9507**	**550.7857**	**2855.31**	**7711**
C	Brazil, Malaysia, Indonesia, Portugal, Estonia, Georgia, Latvia, Singapore, Belize, Chili, Eswatini, Hungary, Slovenia	first	Brazil	**1271.75**	**3182**	**10174**	**19092**
		last	Singapore	**87.5**	**255**	**175**	**510**

Class A: 17-25 years; class B: 9-16 years; class C: 1-8 years

4. Impact of raw milk production on milk imports in the Algerian market

According to the reading of the anterior indices, Algeria's RMP index was about 34.47% in 1997 (base index 100 in 2009). This indicates that the country's raw milk output was approximately 65.53% lower than in 2009. Following the same pattern, Algeria's CPM importation index was almost 55.29% in 1997 (base index 100 in 2009), meaning that it was nearly 44.70 % less in 1997 than it was in 2009.

However, the posterior indices revealed that in 2014, Algeria's RMP index was almost 143.90%, meaning that during the years 2009–2014, the country's RMP multiplied by 1.43%. Following that, in 2018, has dropped by -1.78 percent as compared to the 2009 index base of 100. There was no change in the RMP index in Intel 2022. In contrast, many fluctuations in Algeria's CPM importation index were recorded. The index was 145.33% in 2022 (base index 100 in 2009), indicating a 1.45% increase in the CPM importation index from 2009 to 2022.

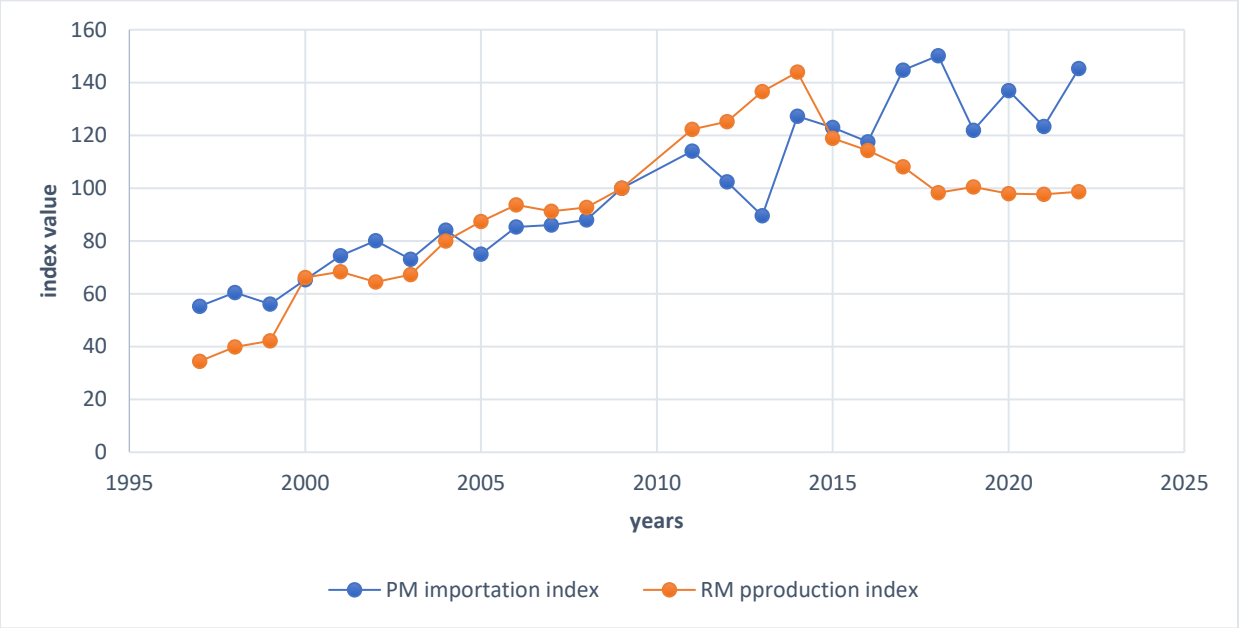


Figure 19 Variation in indices base 100 of domestic milk production and imported powdered milk in the Algerian milk market

The most interesting finding to emerge from the preceding sections is the positive correlation between the evolution of imported CPM and domestic RMP, which contradicts the expected inverse relationship between domestic production and imports.

The rates of their evolution were observed to be closely aligned during the study period. This is further substantiated by the significant convergence in their growth rates, where an increasing pace of domestic RMP has been observed with a GR= 280% and a CAGR= 4.2, parallel with the rise of the imported CPM with GR= 263% and CAGR= 6.5

According to the data presented in Figure 20, the regression analysis indicates a linear positive relationship, evidenced by a strong correlation coefficient of r= 0.84 between the domestic RMP in Algeria and the imported quantities of CPM, represented by the equation: = 0.086x + 45710.

The intricate relationship may stem from the interplay of multiple factors that influence a strategically significant sector, such as Algeria's dairy industry and its economic implications.

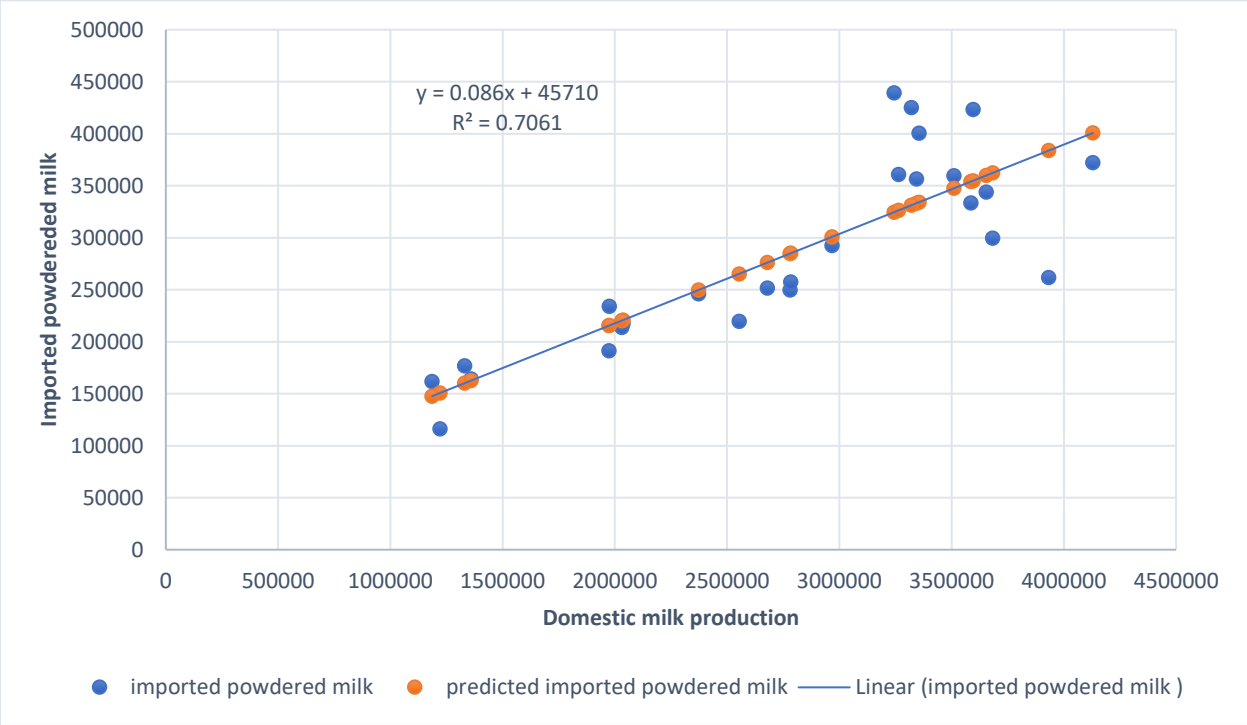


Figure 20 Regression analysis of the relationship between domestic milk production and the quantity of imported powdered milk in Algeria (domestic milk production fit plot)

5. Discussion

Dairy farming plays a significant role in Algeria's livestock sector and traditional food system, contributing to the country's nutritional security(Oulmane et al., 2022). The characteristics of livestock, including size, structure, and diversity (composed of multiple breeds within four ruminant species: cattle, sheep, goats, and camels) , are crucial factors that influence the national economy(Kherroubi et al., 2024; Meribai et al., 2016).The Ministry of Agriculture and Rural Development (MARD, 2022) reports that the national livestock population surpasses 38 million heads. Regression analysis reveals a significant positive linear correlation between national milk production and the ratio of dairy animals to total livestock, highlighting the importance of dairy farming.

According to (Mostefai, 2024) The Algerian dairy sector encounters a critical and ongoing national milk deficit despite significant livestock potential, especially in arid and semi-arid regions. Annual consumption is anticipated to surpass 5 billion liters, equating to 110 liters per capita, whereas local raw milk production satisfied only about 40% of demand (Benaissa et al., 2021; Benyagoub, 2019; Lamraoui, 2024). Bovine sources dominate the domestic supply, accounting for approximately 80% of total local milk production (Kardjadj & Dachung Luka, 2016) The exclusive dependence on cow milk production consistently does not meet the rising demand resulting from population growth and higher per capita consumption (Boukhechem et al., 2019) underscoring a critical gap between domestic capacity and national requirements.

5.1.The Systemic Trap in Algeria's Dairy Sector: A Macro-Level Analysis

The "systemic trap" within Algeria's dairy sector is a self-reinforcing cycle of intricate linkages that exacerbate dependence on imports while obstructing domestic output. This cycle exemplifies structural inefficiencies, path dependencies, and misaligned incentives that cumulatively undermine food sovereignty.

This section conducts a macro-level analysis of the Algerian dairy sector, identifying and examining the interrelated components that form its persistent systemic trap. An analysis of national demand-supply dynamics, historical policy orientations, and global market dependencies reveals how these elements negatively impact domestic sector development and national food sovereignty.

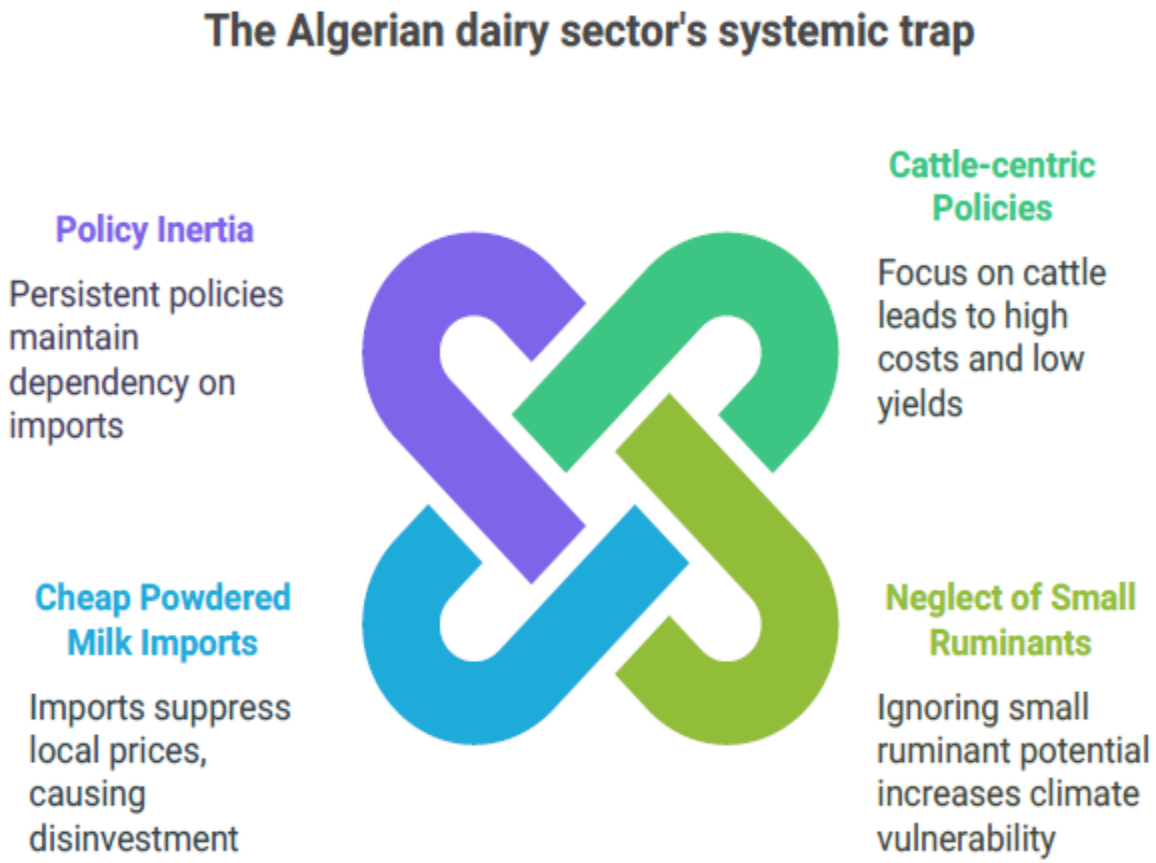


Figure 21 The Algerian dairy sector's systemic trap

5.1.1. Monoculture of Cattle Milk and Policy Path Dependency

Algeria's overreliance on cattle milk, mainly from low-yield indigenous breeds, combined with inadequate investment in genetic improvement or high-yield imported breeds, leads to low output. This point indicates an agricultural approach that is inconsistent with the nation's ecological and economic conditions. According to (Noui et al., 2024; Oulmane et al., 2022) High-yielding imported breeds, although productive, require substantial inputs (water, quality feed, cooling infrastructure) to reduce the heat stress prevalent in Algeria's climate, resulting in increased production costs and limited scalability particularly in arid and semi-arid regions of the country, where such conditions are more evident.

Previous policies supporting cow dairy farming - predominantly located in the northern plains- particularly via production and collection Bonuses, investment support, and fodder import and production support, have established a harmful path dependency, perpetuating an unsustainable model and hindering farmer diversification ((Makhlouf & Montaigne, n.d.; Mamine et al., 2016; Meribai et al., 2016) The exclusive emphasis on bovine sources, despite their intrinsic vulnerabilities, has markedly impeded the advancement of domestic milk production levels.

5.1.2. Underappreciation and Limited Commercialization of Alternative Milk Sources

The systemic trap is characterized by a systematic underestimation and restricted commercial use of small ruminants' milk output, including sheep and goats, as well as camels. Despite comprising over 90% of Algeria's livestock (MARD, 2022) and demonstrating resilience in arid environments their nutrient-rich milk, which is suitable for less fertile conditions, is largely neglected (Benaissa et al., 2021; Bouchetara et al., 2021; Kardjadj & Dachung Luka, 2016). The absence of legal recognition, policy support, and subsidies for dairy-focused small ruminant farming intensifies this oversight, resulting in significant cultural and institutional bias.

Market fragmentation, resulting from self-consuming in rural areas and disorganized value chains (collection, processing, marketing), hinders smallholders from effectively commercializing sheep and goat milk, even in pastoral regions where these species are prevalent (Bouchetara et al., 2021; Kherroubi et al., 2024; Labiod et al., 2023)

5.1.3. Entrenched Dependency on Powdered Milk Imports

Algeria's strategic diversification of suppliers from more than 50 countries aims to reduce supply risks and stabilize prices. This approach fundamentally represents a reactive response to an inherent shortfall in domestic production, rather than a proactive enhancement of dairy independence.

However, Algeria's significant dependence on imported powdered milk, which accounts for over 60% of its dairy requirements, has established a complex dependency characterized by adverse feedback mechanisms (Benmehaia & Bekkis, 2024)

The arrival of inexpensive, frequently subsidized powdered milk imports disrupts the domestic market, deterring investment in local dairy production and infrastructure as a result of inequitable

competition and diminished profitability for local producers (Faiza, 2024; Oulmane et al., 2022). Indeed, (Benyagoub, 2019) reports that the dependency on imports restricts local dairy processors' access to raw milk, hindering their development, while the increasing incorporation of powdered milk in processed products perpetuates reliance on foreign suppliers.

Reconstituted powdered milk, despite being cost-effective, lacks the nutritional and cultural value associated with fresh milk, leading to a shift in consumer behavior and a disconnect from local producers (Benmehaia & Bekkis, 2024; Oulmane et al., 2022)

5.1.4. Policy and subsidy frameworks and institutional fragmentation

Algeria's dairy sector is profoundly shaped by its policy and subsidy frameworks, as well as by significant institutional fragmentation

The milk subsidies implemented by the Algerian government, although intended to enhance local production and maintain affordability, have unintentionally led to a reliance on imports (Benyagoub, 2019; Oulmane et al., 2022). These subsidies favor the advancement of artificial fodder and equipment, predominantly benefiting capital-intensive cattle farms rather than smallholders or pastoralists.

According to (Makhlouf & Montaigne, 2017), Although the responsibility of the National Dairy Office (ONIL) to oversee the distribution of imported milk powder and subsidize price fluctuations, it reinforces a policy dependency that negatively impacts domestic production Moreover, institutional fragmentation due to insufficient coordination among agricultural, trade, and rural development ministries often leads to conflicting policies. The absence of coherence, combined with the emphasis on consumer price support instead of addressing fundamental issues such as low productivity and inefficient farming practices (e.g., outdated technology, insufficient training), has resulted in an imbalance that deters investment in the local dairy sector, thereby perpetuating a cycle of dependence.

5.2.National-Level Manifestations of the Systemic Trap

The systemic trap, driven by the aforementioned elements, manifests in severe consequences across Algeria's dairy sector.

5.2.1. Persistent Production Deficits and Inefficient Domestic Practices

Domestic milk production levels consistently fall short of meeting the increasing demand, despite significant efforts. The shortfall is directly associated with low productivity and inefficient agricultural practices. The average milk yield per cow in Algeria is 14.3 kg per day, equating to approximately 2.5-3 tons annually, which is significantly lower than international standards (Boukhechem et al., 2019; Sraïri et al., 2013b).

The limited yield results from outdated breeding practices, a lack of focus on modern husbandry, poor reproductive management, and the prevalence of small-scale family farms, which average two cows and inherently restrict production capacity and management efficiency(Boukhechem et al., 2019; Meskini et al., 2023; Pandey et al., 2024b, 2024a). Dairy farmers encounter considerable challenges in accessing resources, such as feed—affected by competition, dependence on rainfall for fodder, and reliance on expensive concentrates—as well as ongoing water scarcity, which further limits yields (Boukhechem et al., 2019; Mamine et al., 2016; Pandey et al., 2024b; Sraïri et al., 2013b)

5.2.2. Supply Chain Vulnerabilities and Price Instability

The insufficient diversification of milk sources significantly affects production levels and supply stability. The underutilization of alternative animal species makes the supply chain vulnerable to disruptions, such as the seasonality of cattle milk production, disease outbreaks, adverse weather conditions, and market fluctuations (Bouchetara et al., 2021; Noui et al., 2024; Sraïri et al., 2013b). This unique point of failure leads to significant shortages, reducing farmer profitability and hindering the establishment of collection mechanisms for undervalued species (Bouchetara et al., 2021)). Moreover, concentrated supply intensifies price volatility, negatively impacting both producers and consumers while discouraging essential sector investment.

5.2.3. Compromised Sectoral Resilience

The Algerian dairy sector exhibits reduced resilience, mainly due to a uniform milk supply that significantly restricts its ability to adapt to changing market conditions and climate-related challenges. The underutilization of viable alternative milk sources, such as ovine, caprine, and cameline, significantly exacerbates systemic vulnerability. The geographic concentration of bovine dairy farms, especially in northern Algeria, creates a regional dependency that renders the supply chain highly vulnerable to localized environmental stressors and natural disasters. The dependence on a single source significantly affects milk production by increasing vulnerability to environmental stress, economic fluctuations, limited adaptive capacity, and difficulties in resource distribution (Benyagoub, 2019)

5.2.4. Economic Burden and Macroeconomic Ramifications

The lack of diversification in milk sources has significant economic implications, maintaining dependence on imported powdered milk and hindering the dairy sector's overall development. The reliance on cow's milk fosters market dependency, making the local economy vulnerable to disruptions and price fluctuations that threaten the revenues of farmers and processors (Noui et al., 2024). The concentrated supply inhibits essential investment in the dairy sector owing to perceived risks (Labiod et al., 2023). Although goat and sheep milk demonstrate resilience and potential in arid environments, their underutilization, along with price controls and subsidies on cattle milk and imports, discourages investment and limits sector expansion and market diversification (Kardjadj & Dachung Luka, 2016; Mamine et al., 2016)This hinders the development of a strong domestic dairy industry that could enhance rural economic activity, generate employment, and improve livelihoods for a substantial number of rural households reliant on livestock (Mostefai, 2024; Rajkumar, 2023).

Chapter III

A Case study of Djelfa state's local Dairy Sector

Chapter III: Systemic Trap Manifestation and Revitalization Pathways: A Case study of Djelfa state's local Dairy Sector

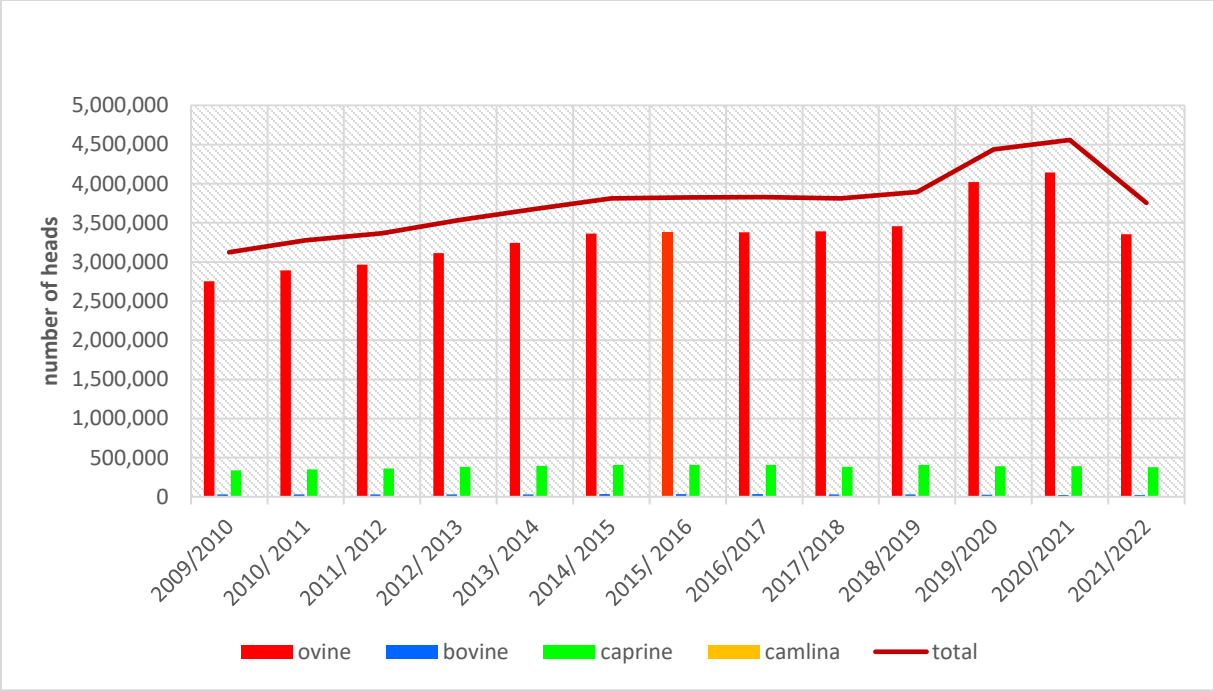
This case study consistently examines the particular dynamics of the dairy sector in Djelfa State. due to its unique agricultural characteristics, this region is particularly significant to our research, as outlined in Section 3.3. The primary aim of this research is to provide insight into the manifestations of systemic challenges, previously recognized in the national dairy sector, on the local value chains in Djelfa.
To attain this thorough comprehension, our investigation will methodically examine numerous essential dimensions:

- **Evolutionary trajectories of livestock and milk production:** This section will involve a thorough analysis of historical data to identify dominant trends and patterns in animal populations and milk production in Djelfa State.
- **Value Chain Analysis of Milk Production:** A comprehensive and detailed examination of the milk production value chain specific to Djelfa will be conducted. This will uncover crucial nodes, primary stakeholders, and intrinsic constraints that hinder efficiency and growth.
- **Identification of Economic Opportunities for Sectoral Revitalization**: This part will conclusively identify and meticulously examine feasible economic opportunities. These prospects are presented as tools for the strategic revitalization and improvement of the dairy sector in Djelfa State, providing practical insights for sustainable development and increased production.

1. Evolutionary trajectories of livestock and milk production:

1.1. Overview of Livestock Evolution

Figure 22 presents the divergent trends identified among different livestock species in Djelfa during the period [2009/ 2022], highlighting both congruence with national patterns and unique local dynamics.



Source: DAS, 2024

Figure 22 Evolution of the composition of Djelfa's state local livestock based on ruminant species in Algeria

1.1.1. Ovine herd:

Djelfa State ranks first nationally in ovine herd size, with more than 65% of the herd consisting of dairy sheep. The ovine population in Djelfa exhibited steady growth from 2.8 million heads in 2009 to more than 4.1 million heads in 2021. Although there was a slight decrease to 3.35 million in 2022, the overall trend continues to be strongly positive. The notable increase in Djelfa aligns with the national trend for ovine populations, which similarly saw substantial growth from 2009 to 2022. Djelfa's significant contribution to the national ovine population, ranking first, highlights its essential role as a major region for sheep farming.

1.1.2. Caprine Herd:

The caprine herd in Djelfa State is the fourth largest in the nation, with around 70% comprised of dairy goats. The caprine population in Djelfa exhibited an increasing trend, rising from 337,000 heads in 2009 to a peak of 0.4 million heads in 2016. After 2016, a gradual decline was noted, stabilizing at 0.38 million heads in 2022. Although national caprine herds demonstrated growth, Djelfa's decline post-2016 contrasts with national trends that typically show continued increase or

stabilization. This discrepancy may indicate particular regional factors affecting goat farming in Djelfa in recent years

1.1.3. Bovine herd

The bovine herd in Djelfa increased from more than 29,000 heads in 2009/2010 to a peak of more than 35,000 in 2014. A significant decline occurred, resulting in 22,1 thousand heads by 2022, the lowest value documented in the dataset. Djelfa's initial growth trajectory was comparable to national trends; however, its subsequent decline, especially after 2014, is more pronounced than the national average. This divergence indicates specific challenges affecting bovine farming in the region, compounded by the reality that dairy cows make up less than 50% of the overall bovine herd.

1.1.3. Camel herd

The camelina herd in Djelfa exhibited significant volatility and a predominantly declining trend. Beginning with 6,2 thousand heads in 2009, the population underwent slight variations before a marked decrease to 2,8 thousand heads in 2017, followed by a continued substantial decline to a record low of 774 in 2022. Compared to the national level, the camelina herd exhibited fluctuations while generally sustaining a higher and more stable population. Djelfa's significant decline in recent years contrasts sharply with national trends, indicating a marked reduction in camel farming within the state.

1.2. Analysis of Milk Production Levels

This section provides an analysis of the temporal changes in milk production levels in Djelfa State, categorized by ruminant species. This analysis assesses localized trends with national production data from 2009 to 2022.

1.2.1. Sheep milk production

Dominating the national production of sheep milk, Sheep milk output in Djelfa, as shown in Figure 23, demonstrated significant growth, increasing from 42 thousand tons in 2009 to a maximum of more than 56 thousand tons in 2020. A notable decrease to 17,014 tons was observed in 2021, followed by a modest recovery to 20,080 tons in 2022.

However, national sheep milk production demonstrated significant growth from 2009 to 2022. Djelfa's initial growth phase, extending to 2020, closely mirrored the national expansion, highlighting its significant role in the national sheep dairy production. The significant reduction in sheep milk production in Djelfa during 2021 and 2022 contrasts sharply with the consistent national growth, highlighting a recent and pronounced localized decline.

1.2.2. Goat milk production

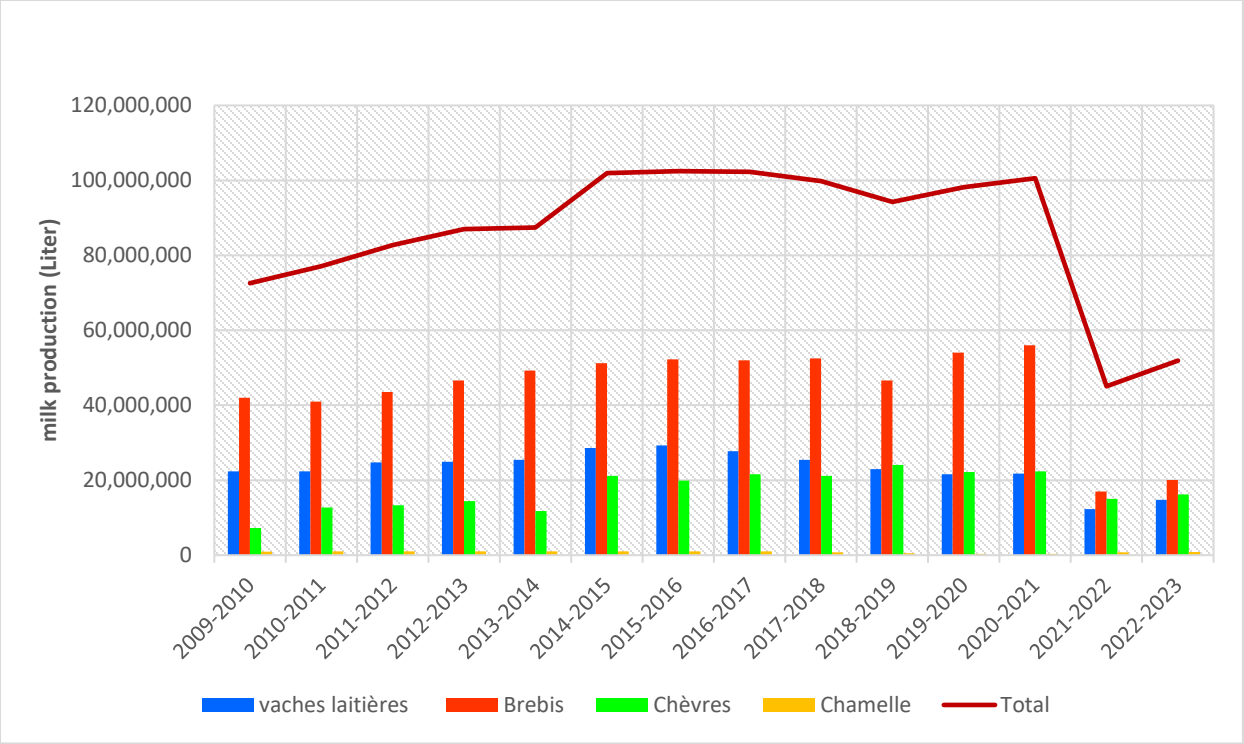
Goat milk production in Djelfa exhibited a significant rise from 7,229 tons in 2009, peaking at 24,066 tons in 2018. Following this peak, a decline occurred, reaching 15,035 tons in 2021, with a slight recovery to 16,208 tons in 2022.

*A*t the national level*, g*oat milk production demonstrated an overall increase from 2009 to 2022, despite experiencing some fluctuations. Djelfa's trend generally corresponds with the national growth pattern, yet it exhibits more pronounced peaks and troughs, especially the decline noted *after* 2018, which is more substantial than national variations**.**

1.2.3. Cattle Milk Production:

The production of cattle milk in Djelfa demonstrated fluctuations over the years. Beginning at 22,358 tons in 2009, and remained relatively stable until 2011, reaching 24,768 tons. This was followed by a growth phase that peaked at more than 29,3 thousand tons in 2015. Following this peak, there was a significant decline to 12,276 tons in 2021, followed by a slight recovery to 14,742 tons in 2022.

In contrast, Cattle milk production at the national level exhibited an upward trajectory beginning in 2009, reaching its zenith in 2014, followed by a gradual decline and eventual stabilization by 2022. The decline in Djelfa after 2015 is significantly more severe and prolonged compared to the national trend, indicating substantial localized challenges in the bovine dairy sector.



Source: DAS 2024

Figure 23Evolution in quantity of raw milk production based on ruminant species in Djelfa state, Algeria

1.2.4. Camel Milk Production:

The production of camel milk in Djelfa exhibited significant volatility and a predominantly regressive trend. After an initial rise from 961 tons in 2009 to a peak of 1,035 tons in 2012, there was a significant and sustained decline, reaching a low of 362 tons in 2020, followed by a partial recovery to 888 tons in 2022.

Camel milk production exhibited a consistent and steady increase nationally over the study period. The sustained national growth contrasts sharply with Djelfa's volatile and overall declining trend, highlighting a significant and ongoing challenge for camel dairy farming in the region.

A thorough analysis of milk production trends in Djelfa State, considering various ruminant species and their associated livestock population dynamics, uncovers notable patterns and significant contributions to the local dairy sector

- **The Prevalence of Sheep Milk:** During the examined timeframe, sheep milk consistently accounted for the highest volume of milk production in Djelfa. The remarkable production peak of 56,021 tons in 2020 significantly surpassed that of other species, underscoring its essential contribution to the dairy economy of Djelfa. The substantial milk production is closely linked to the notable and steady expansion of Djelfa's sheep population, which rose from 2.8 million in 2009 to more than 4 million in 2020, positioning it at the forefront of national sheep milk output. Nevertheless, the significant reduction in sheep milk production to 17,014 tons in 2021, despite only a minor decrease in herd size, indicates a possible decline in productivity per individual animal or other influencing factors affecting milk collection and reporting in the most recent years.
- **Remarkable Goat Milk:** The production of goat milk, although substantially less in quantity compared to sheep milk, exhibited a significant upward trend, increasing from 7,229 tons in 2009 to a zenith of 24,066 tons in 2018. This development typically corresponds with the increasing trajectory of Djelfa's caprine population, which reached its lowest point approximately in 2016. The notable decline in milk production post-2018 is significantly aligned with a gradual reduction in the caprine herd beginning in 2016, suggesting a direct correlation between variations in herd size and milk yield.

- **Diminishing Trend in Cattle Milk Production** Following an initial period of growth that peaked at 29,311 tons in 2015, cattle milk production has undergone a significant and prolonged decline, ultimately falling to 12,276 tons by 2021. This positions bovine milk as a comparatively minor and progressively contested element within the dairy sector of Djelfa. The observed decrease in milk production aligns with the contraction noted in Djelfa's bovine herd, which reached its highest level in 2014 before experiencing a marked decline by 2021. This trend indicates that a diminishing herd size serves as a fundamental factor influencing the reduction in bovine milk output.
- **Marginal camel milk production:** camel milk has consistently been the least among all species, reaching a peak of only 1,035 tons in 2012, followed by a significant and ongoing decline that culminated in a low of 362 tons in 2020. The contribution to Djelfa's overall milk output remains minimal, with its declining trend closely reflecting the significant reduction in Djelfa's camelina herd, which experienced a notable decrease starting in 2017.

This suggests a clear and serious relationship between the shrinking herd and the limited milk production.

The dairy production landscape of Djelfa State is overwhelmingly defined by the dominance and essential dependence on ovine and caprine milk. Critically, the decline in bovine production, contrasting sharply with national cattle-centric policies, signals that Djelfa's livestock dynamics diverge significantly from broader Algerian growth trends.

These observed divergences, particularly the alarming reduction in ovine yields and the contraction of bovine and camelina herds, indicate the presence of entrenched regional structural barriers rather than simple cyclical variations. Consequently, a detailed value chain analysis is imperative to elucidate how the national "systemic trap" elements specifically manifest at the local level, identifying precise bottlenecks, inefficiencies, and vulnerabilities essential for developing targeted revitalization strategies.

2. Analysis of the value chain Map of milk production in Djelfa state

The milk production and trade value chain map in Djelfa state, Algeria, is primarily composed of five links, each depicted by a white arrow at the top. Links are categorized into two primary groups: upstream business operations and downstream business operations, each link is represented by a yellow rectangle, which represents its micro-level operators, who carry out their operations under the supervision of regional, state, and local institutions, which stand in for the Meso-level and are represented by the yellow rectangle in the single corner snipped. The Algerian ministries, which are primarily represented by the yellow rectangle with four corners snipped at the bottom of the map, regulate at the macro level.

Continuous black arrows indicate formal links between operators, whereas non-continuous black arrows indicate informal connections. Black double arrows, on the other hand, stand for a contractual relationship

The value chain map of milk production and trade in Djelfa state, Algeria, is composed of five links organized into two primary business activity categories, as shown in the figure24

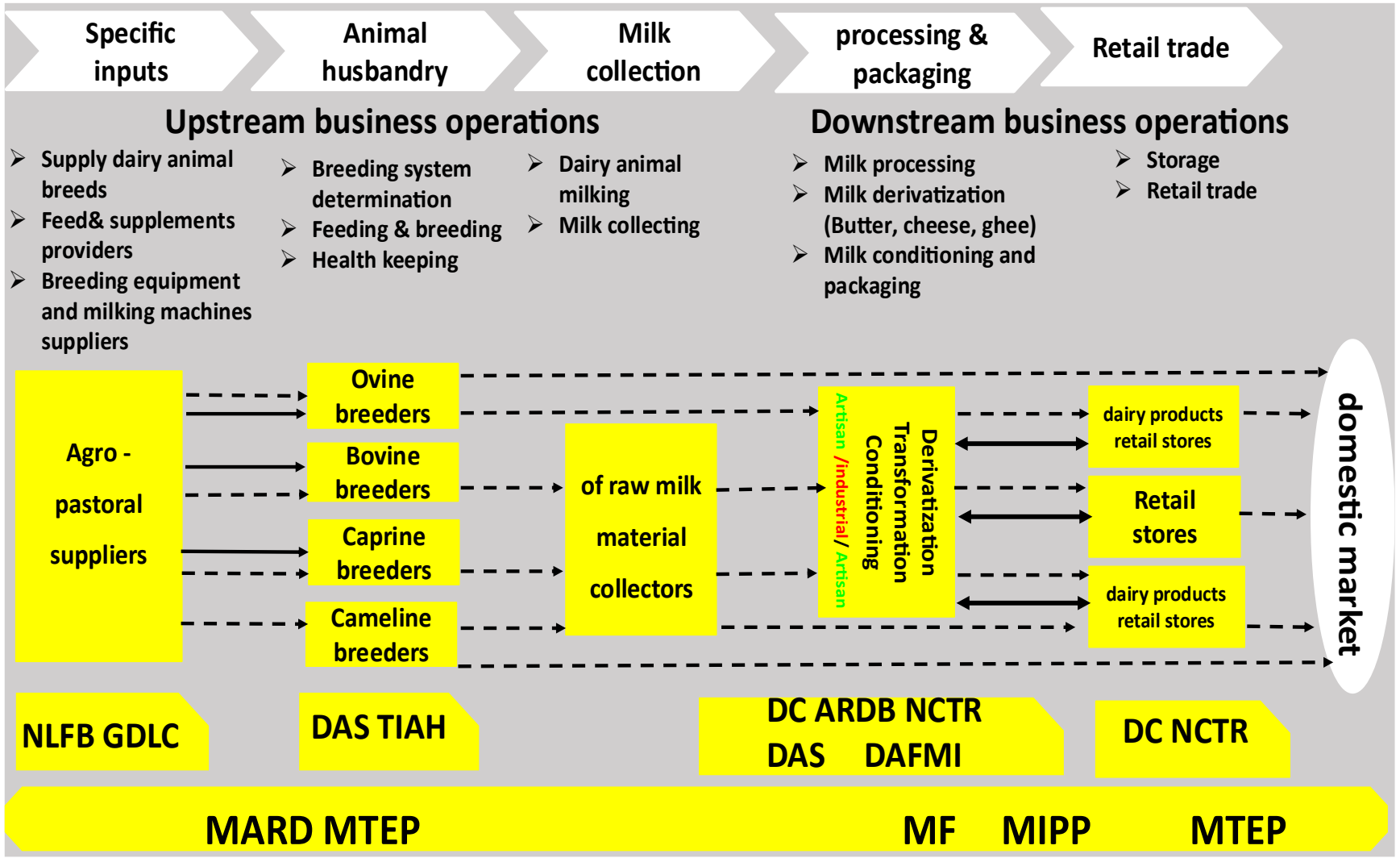


Figure 24 Overview of value chain map of raw milk production and trade in Djelfa state, Algeria, according ValueLinks 2.0 approach.

2.1. The upstream business operations:

Upstream business operations are covered by three linkages under the macro-level regulation of the Ministry of Agriculture and Rural Development.

Under the direction of the state's national livestock feed board (NLFB) and grain and dry legumes cooperative (GDLC), the agropastoral suppliers, who serve as the first link's micro-level operators for "specific inputs," provide, with either formal and informal links, multiple services such as dairy animal breeds, feed and feed supplements, different breeding equipment and milking machines to ruminant breeders, primary micro-level operators of the second link "animal husbandry", which is represented mainly by the breeders of four ruminant species: ovine, bovine, caprine and camel breeds as micro-level operators, manages the entire breeding process from the decision making of the breeding specie, breeding system, feeding, supplementing, and the health keeping of animals.

Under the supervision of the technical institute of animal husbandry (TIAH) and the state's directorate of agricultural services (DAS), the operators of the second link supply the third link's operators (milk collectors), who are typically the breeder's household feminine members (mothers, wives, sisters, and daughters), with the outputs of the husbandry process as raw milk material. These operators ensure that the animal is milked and that the raw milk material is collected by the operators of the fourth link in an informal manner.

Apart from this, camel milk which make an exception to this pattern. This type of raw material which is well-known and in highly demanded due to its medicinal properties, is directly supplied to the domestic market and the retail dairy stores, which represents the final link in the value chain, without going through any processing or derivatization steps.

2.2. The downstream business operations:

Under the regulation of the ministry of agriculture and rural development, and the ministry of trade and exportation promotion, the directorate of agricultural services and the directorate of commerce supervises the activities included in downstream business operations

The operators of the fourth link (processing and packaging) are primarily represented by women from breeders' households, who, by virtue of their extensive experience and precise know- how of

milk processing and derivatization, provide the operators of the last link: retail trade, with raw milk material and particular dairy products notably butter and ghee. Some of the dairy products retailers, through their experience, transform raw milk, traditionally into a variety of cheeses that can be displayed and sold in their stores, the reason of which, dairy retailers can also operate the fourth link.

nevertheless, according to the survey findings, over than 70% of consumers prefer purchasing milk and its derivatives—aside from yogurt and cheese—directly from producers considering their products are more reliable and less costly due to the lack of added value created at each link. As a result, a direct links has been created between the operators of the third and fourth links and the final consumer.

indeed, the figure illustrates that each link's operators are connected to one another through informal links, with the exception of the connection between agropastoral suppliers and breeders, where formal links are noticeable and have a complex relationship to state-funded agricultural investments and state-subsidized items such as animal feed trade, some medications and machines, and the importation of certain animal species.

While, contractual relationships, as showed in figure19 only appear between dairy retailers and the operators of the third or fourth links, who informally supply dairy retailers on regular basis with raw milk, and other particular dairy products that require specialized know- how such as "ghee"

Despite the fact that small ruminant account for more than 90 % of all livestock in Algeria and that one-third of the country's population derives their livelihood from herding them, the production of sheep and goat milk is not officially recognized as a milk provider. Despite having more over 21.5 million heads of sheep and 6 million heads of goats (MARD, 2022), it has been observed that the sheep milk is rarely present in either the local or national markets.

Small ruminant husbandry, which includes the generally related professions of caprine and ovine breeding, is a common practice in the Algerian steppe characterized by anarid or semi-arid climate and declining pasture conditions, which negatively impact the feeding of the large sizeof herds and force breeders to travel great distances to find suitable pastures(Sahraoui et al., 2020). These elements directly affect the small ruminant milk production, a quickly deteriorated product that

provides the farmer and his family with fresh milk. However, according to (Boussekine et al., 2020) the lack of cold chains, storage facilities, preservation tools, and dairy factories that use sheep milk as a raw material for their operations breeders' households, relying on their women's long-standing experience, derivatize fresh milk into "ghee," a dairy product with shelf life enhancement. The Algerian steppe's rural communities have been using this technique for centuries to preserve some of the milk's qualities even in extreme weather conditions.

In Algeria's desert, semiarid, and arid regions, camelbreeding is vital to the local population since they contribute to the circular economy by providing a steady and equitable income to camel breeders. Camel milk's significance to the dairy industry's economy is demonstrated by its significant quantitythat surpassed 15 tons produced in 2020(Boudalia et al., 2023). The nutritional value and medicinal properties of camel milk, together in addition to their capacity to produce milk for extended periods of time in severe conditions such as drought, high temperatures, and a shortage of grass, are the main reasons for which camel milk production and tradehave gained their importance

The purchase of value-added dairy products, including ghee, cheese, and yogurt, has the potential to substantially bolster local economies in multiple ways. The utilization of rural women's expertise in ghee "Dhan" production in Algeria's arid and semi-arid regions yields numerous advantages, including enhanced farmer income, job creation, fortified supply chains, diminished import reliance, improved nutritional and health outcomes, environmental sustainability, and cultural preservation. Investing in the production and marketing of these products enables local communities to stimulate economic growth while enhancing resilience and sustainability in the dairy sector.

3. Promotion of the value chain of milk production and trade

The territory of Djelfa state reveals a striking paradox: Despite its significant potential for dairy production, particularly in small ruminant husbandry (sheep and goats), it remains persistently dependent on reconstituted milk to satisfy domestic needs. This case study section aims to elucidate the complexities of this contradiction by analyzing the experiences of micro-level operators within the milk production and trade value chain derived from direct survey data. The operators—breeders, local collectors and processors, and retailers—are vital to the state's domestic dairy objectives; their contributions are crucial for attaining local and regional self-sufficiency.

Nonetheless, their daily experiences illustrate a complex array of limitations that hinder their capacity to fully engage in and contribute to the sector's advancement.

The survey findings reveal concrete impediments, a mosaic of constraints that transcend simple economic metrics in addition to a range of opportunities that can be explored to promote milk production and trade value chain.

3.1. Constraints of milk production and trade in Djelfa state

3.1.1. The Suboptimal Utilization of Natural Resources:

In arid and semi-arid regions, including certain areas of Algeria, the unsustainable use of land—exemplified by the cultivation of the steppe and excessive grazing—results in land degradation and desertification (Hassen et al., 2021). which, according to Boukhechem et al.,(2019) and Meskini et al.,(2023)has a direct impact on the availability and quality of natural pastures and forage. As an instance, in the Algerian steppe, almost 70% of potentially productive arid lands are impacted by natural degradation (Hassen et al., 2021)The limited availability and substandard quality of locally sourced forage, stemming from ineffective management of land and water resources, compel farmers to depend significantly on externally procured feed, especially concentrates (Boukhechem et al., 2019; Meskini et al., 2023; Mouhous et al., 2023).

This reliance connects them to the accessibility of feed resources and the fluctuations in the prices of raw materials, such as barley (Siad et al., 2022)The suboptimal utilization of natural resources, especially land and water, results in diminished local forage production, thereby necessitating an increased dependence on externally sourced feed.

3.1.2. High feed costs

Agro-pastoral suppliers and breeders, particularly smallholders, - as micro- level operators of the first and second links respectively)- are asserting their distress due to the increased costs of purchased feed, which adversely impacts their entire breeding operations.

Actually, the cost of feed constitutes the predominant expense in dairy production (Mouhous et al., 2023). The elevated costs associated with acquired concentrates and various feed resources markedly augment the total expenses involved in milk (Boukhechem et al., 2019; Eulmi et al., 2024). The escalating costs of feed in international markets, alongside the possibility of stagnant farm gate milk prices, pose a significant threat to the economic viability of dairy farming (Sraïri

et al., 2013a). Certainly, elevated feed expenses, particularly when combined with diminished milk production and possibly regulated milk pricing, can drive dairy farms beneath the threshold of profitability. The situation becomes increasingly problematic when the ratio of milk price to feed cost deteriorates (Boukhechem et al., 2019; Vouraki et al., 2020)

In response to elevated feed costs, farmers may find themselves in a position where they must sacrifice either the quantity or quality of feed, resulting in dietary rations for dairy animals that are not optimally balanced (Boukhechem et al., 2019; Sraïri et al., 2013a)This may lead to imbalances in energy and protein consumption, adversely impacting milk production, reproductive success, and the general well-being of the animals (Boukhechem et al., 2019)

The elevated expense associated with this feed markedly escalates the production costs for dairy farmers, adversely affecting their profitability and potentially resulting in nutritional imbalances that further diminish milk production and the overall health of the herd.

3.1.3. Lack of cold chain and collection infrastructure

In the current research, breeders, especially large-scale owners, identified the main challenges facing the milk sector in this region as the inadequacy of cold chains and the absence of collection infrastructure. Affects milk quality, reduces market access for farmers, hinders the development of the dairy sector, and significantly impacts the activities of operators at each link in the value chain. In areas without a cold chain, milk is prone to quick spoilage from elevated temperatures typical of arid and semi-arid climates (Eulmi et al., 2024; Pulina et al., 2017). In the absence of refrigeration during collection and transportation, the hygienic and chemical quality of milk declines, resulting in elevated acidity and bacterial counts (Nyokabi et al., 2018). This results in considerable milk losses and diminishes the appropriateness of milk for conversion into higher-value dairy products (Pulina et al., 2017; Sraïri et al., 2013a)

Djelfa state, characterized as a pastoral region, encompasses various lands utilized by breeders, especially large-scale owners who rely on the long-distance movement of their herds to seek grazing areas in other states. The remoteness and absence of a road network render those pastures difficult to access, leading to their total isolation from the power grid.(Mahirwe & Wei, 2018; Nyokabi et al., 2018) indicate that inadequate road conditions from production farms to collection points can negatively impact milk quality and restrict market access. The absence of formal collection and cooling infrastructure and efficient collection mechanisms, particularly in remote

pasture areas, results in a fragmented supply of raw milk and facing challenges in accessing formal processing units and markets. This frequently leads to milk being consumed on-farm or sold through informal local channels, where prices tend to be lower and demand may be inconsistent, resulting in significant reliance on the informal market (Nyokabi et al., 2018; Sraïri et al., 2013a). According to (Mahirwe & Wei, 2018)this situation adversely impacts breeders' income and results in the underutilization of potential milk output, contributing to inefficiencies within the dairy sector overall.

The infrastructural deficiencies in Djelfa state's dairy sector, notably the lack of a cold chain in remote grazing areas and the absence of designated collection and processing facilities for small ruminant milk production, constitute a considerable obstacle to the sector's development. This deficiency negatively impacts breeders, leading to significant losses due to rapid milk spoilage in high-temperature conditions typical of arid and semi-arid regions. The compromising position in milk preservation and transport capabilities undermines the economic viability of small ruminant farming and discourages investments in herd augmentation and genetic improvement efforts.

The lack of specialized processing infrastructure in ecologically challenging regions hinders the development of value-added dairy products, such as artisanal cheeses and cultured yoghurts, which could provide a substantial source of income diversification for breeders and enhance the domestic dairy market. This infrastructural neglect limits the potential of small ruminant milk production to enhance local and national dairy self-sufficiency, thereby maintaining reliance on expensive milk imports and obstructing the sustainable economic development of marginalized rural communities.

The intersection of significant challenges within the small ruminant milk production value chain in Djelfa state, such as the swift decline of pastures, exorbitant feed prices, the absence of an ope rational cold chain, inadequate milk collection systems, and the nonexistence of established whol esale markets and marketing channels, decisively drives small ruminant breeders in Algeria to pu rsue ghee production as their most feasible economic approach.

Confronted with the swift deterioration of raw milk under adverse environmental circumstances and the challenges of effectively transporting it to remote processing facilities, breeders find the mselves with constrained alternatives.

Ghee, a form of clarified butter characterised by its prolonged shelf life and significant value, pre sents a pragmatic approach to overcoming these logistical and market access challenges.

This transformation not only alleviates the threats linked to milk spoilage but also offers a metho d to cultivate a reliable source of income in the absence of well-defined milk markets.
Moreover, the cultural importance of ghee within Algerian culinary practices guarantees a steady , though regionally focused, demand, enabling producers to circumvent the constraints of the nas cent formal dairy market and depend on established distribution channels.

3.2. Analysis of Economic Promotion Opportunities within the Djelfa Milk production and trade Value Chain map

From an economic development standpoint, the current state of the milk value chain in Djelfa, marked by minimal milk output regarded as a secondary commodity and considerable wastage stemming from infrastructure and market limitations, reveals a tempting array of unexploited prospects. The current map illustrates informal connections and micro-level constraints, which underscore strategic intervention and economic development opportunities. By effectively utilizing the region's inherent potential, a reformed milk value chain may promote local economic development, generate employment, and improve livelihoods.

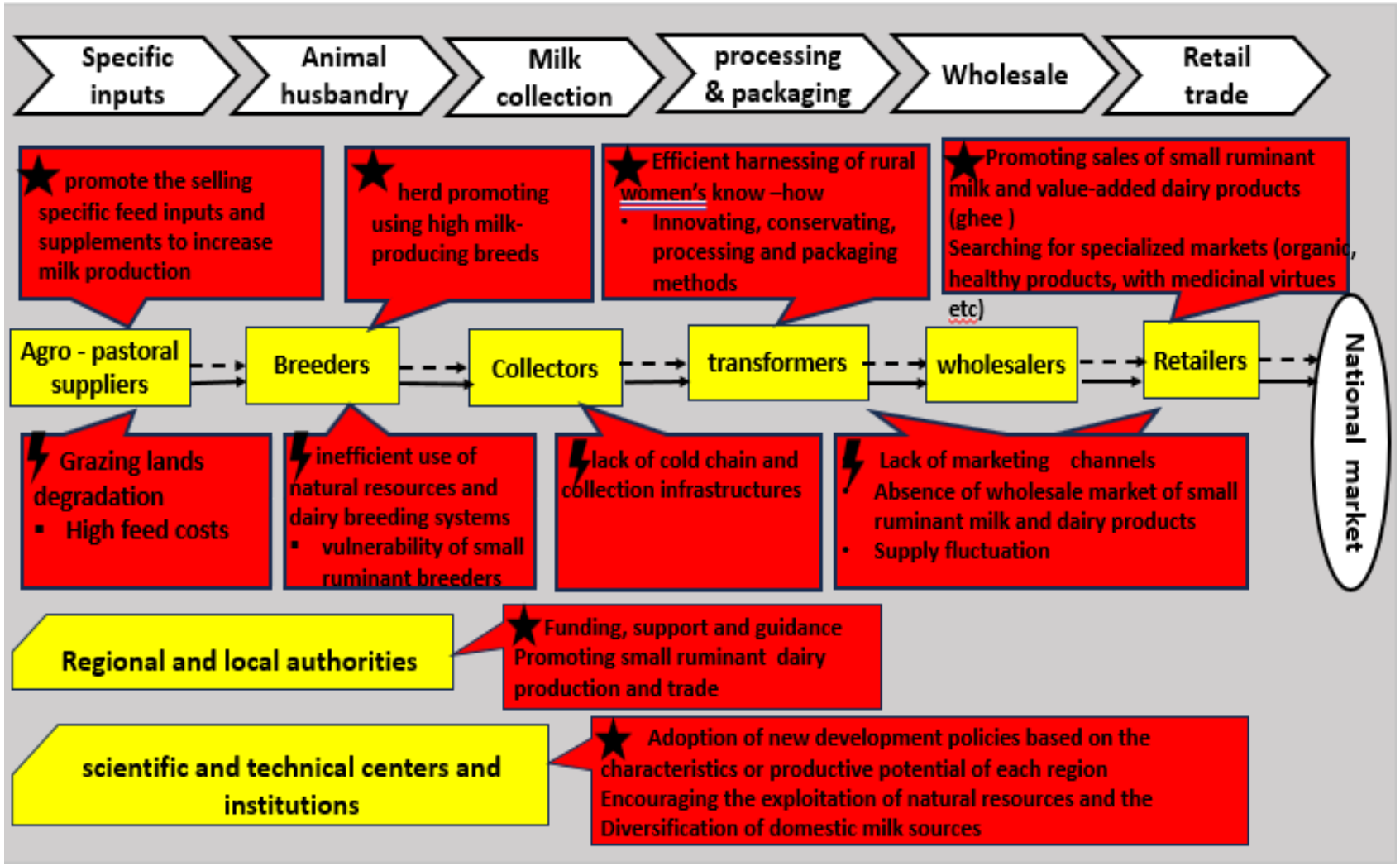


Figure 25Preliminary strategic economic point of view of promoting milk production and trade value chain map in Djelfa state, Algeria according to ValueLinks 2.0 approach.

3.2.1. Transforming Secondary Output into Economic Asset

The dominating perspective of small ruminant milk as a secondary product lacking intrinsic value indicates a great possibility for economic transformation. Rather than accepting current waste, projects meant to improve micro-level value could release great financial potential.

- **Herd Promotion and Breed Improvement:** Introducing high-yield milk breeds that fit the local environment can significantly increase milk production per animal, transforming a marginal commodity into a more valuable economic asset. This calls for funding in animal husbandry instruction, improved genetics access, and maybe breeder financial support.
- **Harnessing Rural Women's Know-how:** By appreciating and institutionalizing rural women's traditional knowledge and competence in milk processing (e.g., ghee manufacture, traditional cheese-making), local economic activity can be significantly boosted. Providing women with training in basic business management, quality control, and hygiene will help them create higher-value goods for the market.
- **Adopting Innovative Processing and Packaging:** Simple yet effective farming or cooperative-level processing technology can extend shelf life and create a range of product offerings other than raw milk. Beyond regional informal sales, creative and visually beautiful packaging can increase product appeal and open access to larger markets.

3.2.2. Strategic Market Development:

Economic valorization is restricted by the lack of strong marketing channels and wholesale marketplaces. Still, this lack also provides opportunities for intentional market development

- **Promoting Small Ruminant Milk and Value-Added Products:** Promoting small ruminant milk and products with added value by carefully stressing the unique nutritional value and possible health advantages of small ruminant milk, such as higher fat content and specialized protein and fatty acids profiles, can build niche markets and guarantee premium pricing. Promoting locally produced value-added items, including yogurt, artisan cheeses, and specialist ghee, will help significantly increase profitability.
- **Finding Specialized Markets:** Finding and entering specialized markets offers excellent chances for economic development. Included are the following:
  - Using conventional farming techniques and supporting organic certification will help to meet the growing demand for organic dairy products both domestically and maybe internationally.

- ❖ Encouragement of the possible health benefits of small ruminant milk and the development of products catered to specific dietary needs (like lactose-free substitutes and high-protein snacks) may help to attract health-conscious customer groups effectively.

- ❖ Appealing to consumers seeking unique and sophisticated options, artisanal and gourmet markets offer a chance to emphasize the unique flavor profiles and traditional manufacturing methods of locally produced dairy products.

3.2.3. Enabling Infrastructure and Institutional Support:

Although acknowledged as constraints, the lack of cold chain and collection infrastructure and wholesale markets marks important areas for investment and policy intervention that can expose significant economic opportunities.

- ➢ **Reduce Waste and Increase Marketable Surplus:** Through an optimal cold chain and collection system, the development of these fundamental elements will minimize waste and enhance marketable surplus, so directly increasing the volume of milk available for sale and processing. These fundamental elements currently afflicting the sector will significantly reduce the considerable post-harvest losses.

- ➢ **Improve Market Accessibility and Price Consistency:** Well-run wholesale markets will help breeders access larger markets outside of their local area, reducing information discrepancies and enabling price determination, enhancing stability and the possibility of higher returns.

- ➢ **Attract Investment and Foster Formalization:** Promote formalization and investment in processing, logistics, and marketing through an improved and methodical value chain supported by strong infrastructure and well-defined rules, driving economic growth and the formalization of the sector.

4. Potential economic benefits of ghee production and trade in Djelfa state, Algeria

Ghee, an assortment of anhydrous milk fat, serves as a culinary component and a product of traditional techniques and cultural heritage. It is produced via the thermal processing of butter, a process that involves simmering the butter until the milk solids separate and are removed, leaving behind the pure butterfat. In Middle Eastern and North African countries, ghee is known as

"maslee," "D'han," or "samin" (Abdullah & Alkhatib, 2021; Boussekine et al., 2020; Kumar et al., 2022). This conventional method of ghee production exemplifies its genuineness and the esteem it holds in Indian, South Asian, Tibetan, and Mongolian cuisines (Ulambayar et al., 2024)

In Algeria, ghee is one of several dairy products derived from naturally fermented milk sourced from various animal species within the national livestock, including cows, goats, sheep, and camels. It continues to exert a substantial influence on individuals' diets, especially among those residing in rural areas (Boussekine et al., 2020). As stated by(Iradukunda et al., 2018), the significance of this fermented product is in its role as a flavoring agent that enhances the taste and scent of several traditional foods, including couscous, Chekhchoukha, and R'fis. Ghee is a key ingredient in these dishes, adding a rich, nutty flavor and a creamy texture. Conventional medicine is utilized to alleviate pain associated with rheumatism, bone injuries, and certain respiratory ailments. This flavoring potential and health benefits are stemming from The fatty acid profile of ghee and its abundance of vitamins A, D, E, and K (Kataria & Singh, 2024; Tian et al., 2023; Ulambayar et al., 2024).

4.1. Traditional process of ghee production in Djelfa state, Algeria

Regardless of the diverse origins of the ruminant species, the final ghee product consistently arises from this same production process, as illustrated in Figure 25 and supported by Boussekine et al., (2020) and Maiza et al., (2020)

The responses from the survey have outlined a standardized procedure for ghee production, as illustrated in Figure 25. The process begins with the creation of curdled milk, known as "Rayeb" or "Raïb," which is achieved through the spontaneous fermentation and coagulation of raw milk at ambient temperature. Depending on the seasonal warmth, this process takes between twenty-four to seventy-two hours. Following this, "Lben" is produced through mechanical churning that lasts 20 to 60 minutes. The resulting "L'ben" can be directly marketed, while the extracted butter—after being immersed in a cold water bath—requires draining to eliminate excess water or must undergo a clarification process to yield the final ghee product. This product- for different purposes- is frequently used across various regions of Algeria, particularly in the steppes and Saharan areas. Numerous derivative dairy products such as "Raïb" and buttermilk "Lben," which are produced before the clarification process, are highly consumed and appreciated by local consumers, especially as accompaniments to traditional dishes (Leksir et al., 2019).

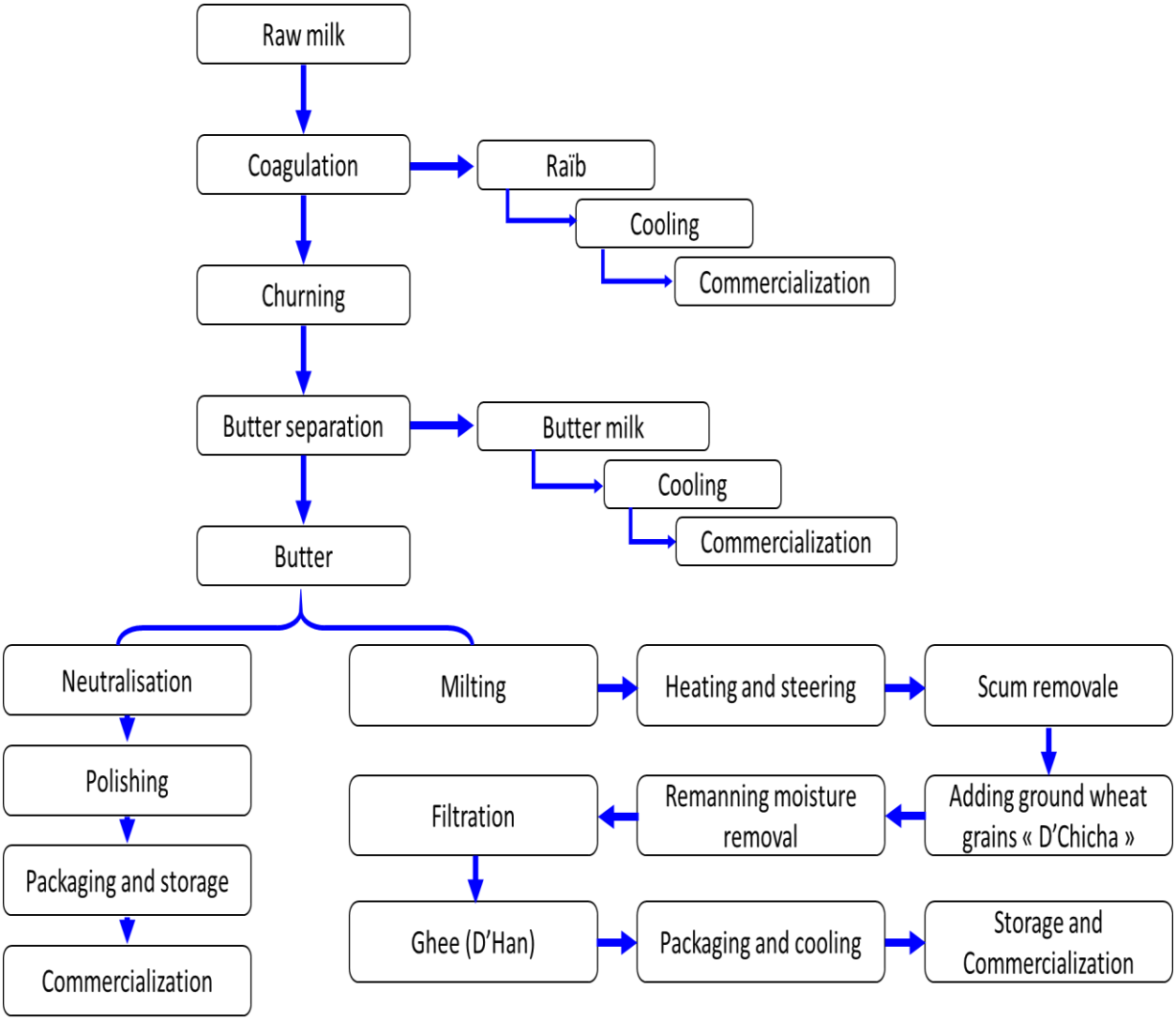


Figure 26: Illustrative diagram of the traditional process of ghee production in Djelfa state, Algeria

The ghee manufacturers assert that Ghee as an important shelf-life dairy product ensures its safety for human consumption by eradicating dangerous and spoilage microorganisms due to heat treatment as a vital manufacturing step, which has been provided by , (Rauh & Xiao, 2022), as an essential processing technology that prolongs the shelf life in dairy business and defined it as the duration for which food can be stored without deterioration or loss of nutritional value.

The processing of ghee for the Algerian pastoral community is an endorsed technique for preserving the qualities of raw milk, which, as noted by, (Feliciano et al., 2022) is a perishable

product susceptible to bacterial and microbial proliferation due to increasing ambient temperatures, resulting in milk deterioration.

4.2. Ghee varieties, uses, and consumption

4.2.1. Ghee uses

The significance of the natural animal ghee- locally referred to as "D'han"- in the dietary system of the Algerian steppe society from its rising demand due to the increasing frequency of its use. The survey results indicate ghee is favored by 75% of consumers, of which 39.6% utilize ghee monthly, 12.1% biweekly, and more than half of the respondents employ ghee often, ranging from weekly to daily usage.

Approximately 25% of the sample selected ghee to savor the distinctive flavor exclusive to pure "D'han" ghee, while nearly 50% of customers believe they can derive health benefits from ghee's constituents as a natural product devoid of chemicals.As illustrated in figure 26, thirteen percent of consumers are swayed by Steppe customs during their purchasing decisions, but less than ten percent of respondents regard the therapeutic virtues of natural ghee as a substantial consideration.

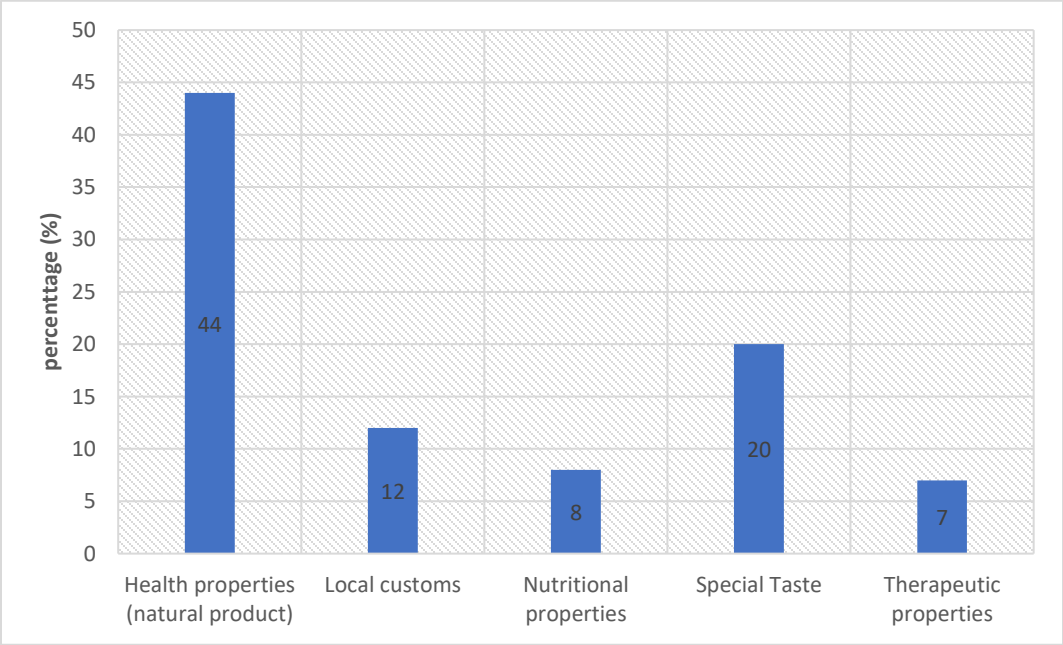


Figure 27: illustrative column chart of the different reasons for the use of animal ghee in Djelfa state, Algeria

4.2.2. Ghee varieties

The varieties of ghee manufactured in this study area are significantly influenced by the species of livestock maintained there, resulting in the identification of three distinct forms of ghee in Djelfa state

4.2.2.1. Small ruminant ghee (sheep and goat ghee)

Although the principal objective of sheep farming in Algeria, which boasts a livestock exceeding 19 million sheep, is the provision of red meat that accounts for over 50% of national production (Harkat et al., 2015), the nation's milk output—averaging over 420 thousand tons from 2012 to 2022 according to (FAO 2024)—remains remarkably substantial, surpassed only by raw cow milk production. According to the survey of milk producers and processors, all raw sheep's milk is converted into ghee due to the substantial quantities produced, which cannot be preserved because of the elevated temperatures in regions with intensive sheep farming and the absence collection infrastructure and cold chain logistics, as well as the economic benefits that producer-processor households can derive from this practice.

For comparable explanations, a broad range of goat milk output, which ranked third with about 3 00 thousand tons and is generally meant for domestic consumption of producer's houses as well as small-scale sales of raw milk to retail stores, is processed into ghee in the same period.

4.2.2.2. Cow ghee

In opposition to ovine and caprine dairy production, bovine milk production leads with nearly 3 million tons annually. Within the context of contract farming and subsidized production, as part of the Algerian government's strategy to achieve self-sufficiency in milk production for local daily consumption, the majority of cow's milk produced is processed and canned in dairy factories before being distributed to the local market. In addition, the remaining family farms primarily concentrated on self-consumption and exhibited low production levels. To enhance their financial income, some families convert a substantial portion of their raw milk into ghee for personal use and limited sales directly to consumers and select retail dairy stores.

4.2.3. Ghee consumption and preferences

In terms of consumption patterns of ghee and consumers' preferences, the survey findings, illustrated in Figure 27, indicate that sheep ghee is the most favored variety among the different types of ghee in Algerian steppe society. Despite its elevated cost, the significant co-potential arises from robust consumer preferences, high demand, and an abundance of this particular sort of

ghee.Seventy-four percent of consumers utilize it in traditional dishes such as Chekhchoukha, Couscous, and R'fis, while twenty-one percent use it for cooking purposes. In second place, cow ghee was selected by 26% of customers. Traditional cuisines represent 64% of consumption, with cooking at 20% and medicinal qualities at 12%. The third position is occupied by goat ghee, utilized for medicinal purposes by 36% of customers, while camel ghee is exclusively employed in the study region for its therapeutic properties.

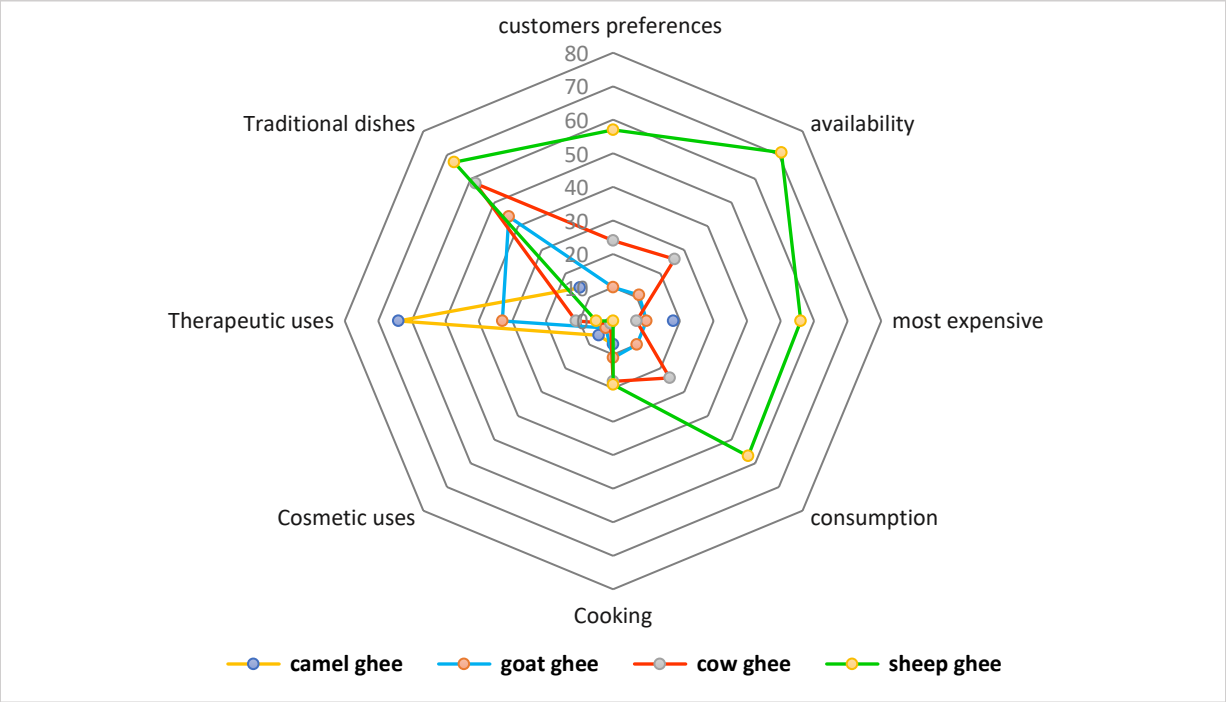


Figure 28: illustrative spider chart of competitiveness between four types of ghee produced in Djelfa state, Algeria

The intake of natural animal ghee is considered to be an important component of the cultural and civilizational heritage of the Algerian people (Boussekine et al., 2020)Demand for functional foods has risen due to enhanced public awareness of health issues (Kumbhare et al., 2023)Foods that provide health benefits beyond basic nutritional requirements, such as ghee, are classified as functional foods. Algerian consumers are increasingly recognizing the advantageous properties of natural, additive-free animal ghee, which include various culinary uses and nutritional, therapeutic, and cosmetic advantages, as supported by the findings of (Antony et al., 2018; Bharti et al., 2023; Maiza et al., 2020; Ulambayar et al., 2024)the variables contributed to a significant transformation in the consumer culture of users of this product.

The utilization of natural animal ghee among Algerian customers is a significant aspect of the standard diet across most Algerian states, attributed to its high level of nutrients (Johansen et al., 2019). This consumption is influenced by various factors, primarily the frequency of use and the quantity incorporated as a vital component in cooking and traditional dishes, which are often associated with notable socio-ethnic events unique to each region. The product's availability and accessibility in the local market also exert influence. Natural animal ghee is categorized as a hand-made product, produced traditionally and in limited quantities relative to population density and increasing demand. Consequently, its price, influenced by the principles of supply and demand and indicative of ghee quality, is considered the most significant factor. According to (Mamine et al., 2016), customers with controversial perceptions struggle to ascertain whether a product's pricing accurately reflects its quality. Price is no longer the sole metric of quality that influences.

Despite ghee being a product associated with subjective beliefs and limited verifiable information regarding its qualitative characteristics—primarily due to its elevated cost—trust and reputation may serve as coordination mechanisms. This is particularly relevant for consumers facing difficulties in quality assessment, especially given the absence of studies and research aimed at characterizing ghee and evaluating its quality (Bijman et al., 2010)

4.3. Analysis of the value chain map of ghee production and trade

Despite the comprehensive initiatives undertaken by the Algerian government to advance the dairy sector and the significance of fermented dairy products on both nutritional and socio-economic fronts, milk fats, particularly "ghee," remain an underexplored domain. In this context, the limited research conducted on this topic has predominantly been approached from a cultural and ethnic perspective. As far as we are aware, there has been no deep investigation into the socio-economic dimensions of ghee production. This section of the case study aims to explore various dimensions linked to ghee production and its commercialization, utilizing a comprehensive analysis of the value chain involved in these initiatives to enhance ghee production and trade

Given the potential of ghee production and commerce in Djelfa State, Algeria, the need for a comprehensive value chain map has become essential. This strategic planning tool will help us understand and optimize the entire process, from production to market, ensuring maximum economic benefits.

In a manner akin to the milk production value chain map, the ghee production and trade value chain map is developed based on the upstream business operations, which consist primarily of three Links. The downstream business operations encompass two Links, notably excluding the wholesale Link, which is not a significant part of the ghee production and trade value chain due to the inexistence of such Li

At the micro level, the operators within Link's framework are consistent across the milk production value chain map, executing their activities under the oversight of the same official entities at both the meso and macro levels. It is significant to highlight that the ghee production and trade value chain map constitutes an essential component of the milk production value chain map in Djelfa state, Algeria.

Figure 29 demonstrates that the operators at the micro-level of each Link are interconnected through informal channels with the operator of the subsequent Link throughout the value chain map. Although the operators of the first and second links are predominantly male, the roles associated with the third and fourth links—specifically milk collectors and transformers—are exclusively filled by females, typically rural women who are often mothers, wives, daughters, or sisters of the breeders. The most senior rural women from the breeders' households—predominantly mothers and eldest wives—possess a wealth of knowledge and skill in the artisan dairy sector. Their role is not just significant, but indispensable in the intricate process of converting raw milk into ghee, employing a specialized method followed by the conditioning and storage of the ghee.

The domestic market receives ghee in its diverse forms via informal channels associated with the two Links of downstream business operations, namely the processing and packaging Link and retail trade Link. Retail stores specializing in milk and dairy products, serving as the ultimate conduit in the retail chain, occasionally repackage and store ghee, thereby providing all consumers with ghee without exception.

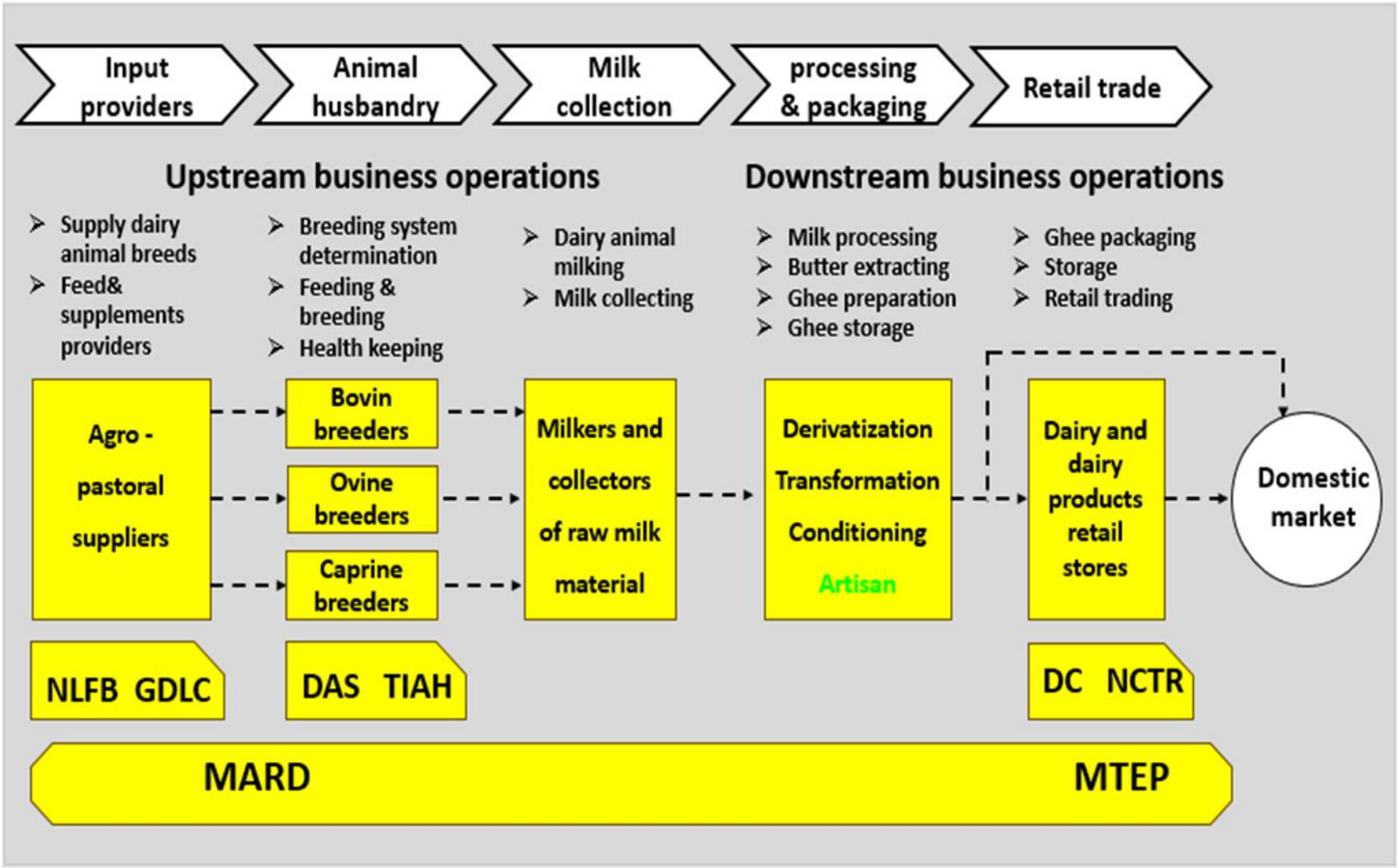


Figure 29 Overview of value chain map of ghee "Dhan" production and trading in Algeria, according ValueLinks 2.0 approach.

Nonetheless, the local market can be directly associated with the fourth link, given that a segment of ghee consumers favors acquiring it directly from the producer linked to the fourth connection. On one side, there is an expectation that the product will exhibit more excellent reliability, being naturally produced and free from additives. This emphasis on natural and additive-free ghee reassures consumers and instills confidence in the product. In contrast, on the other side, it is viewed as an initiative aimed at empowering rural women, who are often seen as vulnerable producers.

It appears to be extremely challenging to accurately estimate the size of ghee production and con sumption at the national and even local levels due to the lack of comprehensive data, the difficult y in obtaining data from official national and international specialized institutions (such as the M inistry of Agriculture and the FAO), and the lack of both a general perception and a national prod uction and trading regulatory plan for the ghee sector433.

4.4. Potential impacts of the promotion of the value chain of ghee production and trade

This section underscores the substantial potential of ghee production to significantly enhance the socio-economic landscape of Algerian states. By effectively transforming underutilized or potentially wasted raw milk into a high-value bioproduct, ghee production emerges as a pivotal strategy for:

- **Mitigating Import Dependence:** Ghee production offers a viable alternative to the reliance on imported dairy products, a significant expenditure for the Algerian economy. By fostering domestic ghee production and consumption, the nation can mitigate its dependence on imports, thereby improving its trade balance and minimizing its vulnerability to global market fluctuations in powdered milk prices.
- **Stimulating Rural Economic Growth:** Ghee production can serve as a potent catalyst for economic growth in rural areas. It has the potential to generate substantial income for dairy farmers, processors, and distributors, leading to job creation and poverty reduction within these communities. Furthermore, the establishment of local ghee processing units can stimulate economic activity in rural areas, creating demand for local raw materials, packaging materials, and other essential inputs.

- **Diversifying Rural Incomes:** Ghee production presents a valuable opportunity for income diversification for dairy farmers. By adding value to their raw milk through ghee production, farmers can enhance their income streams and improve their overall economic resilience.
- **Preserving and Revitalizing Cultural Heritage:** Ghee occupies a significant place within Algerian culinary traditions. By promoting the production and consumption of high-quality local ghee, this study contributes to the preservation and revitalization of this vital aspect of Algerian cultural heritage.
- **Developing Export Markets:** High-quality Algerian ghee possesses considerable potential to penetrate both domestic and international markets. The successful export of ghee can generate substantial foreign exchange earnings, enhancing the visibility of Algerian agricultural products on the global stage.

However, realizing the full potential of ghee production requires addressing several critical challenges. These include:

- **Ensuring Consistent Quality and Safety:** Establishing and maintaining rigorous quality control and safety standards for ghee production is paramount to building consumer trust and accessing high-value markets.
- **Developing Effective Market Channels:** The development and implementation of effective marketing strategies are crucial for promoting the consumption of local ghee and expanding market access both domestically and internationally.
- **Investing in Capacity Building:** Investing in comprehensive training programs for farmers, processors, and entrepreneurs is essential to enhance their skills and knowledge in ghee production, quality control, and marketing.
- **Improving Infrastructure Development:** Enhancing access to crucial infrastructure, including robust road networks, reliable electricity supply, and efficient cold storage facilities, is vital for the efficient collection, processing, and distribution of milk and ghee.

By effectively addressing these challenges and capitalizing on the inherent opportunities presented by ghee production, Algeria can significantly enhance its dairy sector, improve food security, and contribute to the socio-economic development of rural communities.

4.5. Enhancing Milk and Ghee Value Chains to Address Local Milk Supply Crisis in Djelfa state, Algeria

The Djelfa state instance demonstrates how carefully enhancing small ruminant milk and ghee value chains might help to solve local milk supply issues. Underdevelopment of value chains compromises the region's enormous small ruminant population by resulting in significant milk waste and reliance on outside milk supplies, mostly imported powdered milk. Djelfa can move toward a more locally sourced milk supply by addressing the found limitations and using available strengths.

A "systemic trap" in which low milk output, poor infrastructure, and limited market access mutually reinforce one another defines the current situation. Small ruminant milk is often considered a secondary product, which causes significant waste since inadequate cold chain and efficient collecting systems prevent this. This leads to a reliance on ghee manufacture as the primary preservation technique, therefore limiting chances for diversifying dairy products and reaching larger markets.

This case study highlights several important intervention possibilities. Small ruminant milk's value and marketability can be significantly improved by micro-level projects involving encouraging high-yield breeds, formalizing and upgrading rural women's traditional processing skills, and facilitating creative packaging methods. This strategy would save waste, empower small businesses—especially women—and provide fresh revenue sources.

Establishing specialized markets for value-added products, including organic or health-conscious choices and tiny ruminant milk, can help increase profitability and inspire more production levels. This calls for a different viewpoint, appreciating small ruminant milk's unique nutritional and possible health benefits and advocating its usage actively. Macro-level addressing of the shortfall in infrastructure is vital. By investing in cold chain infrastructure, milk collecting centers, and processing facilities, post-harvest losses will be significantly lowered, and the milk market supply will be improved.

Establishing functional wholesale marketplaces improves market access for manufacturers, reduces price volatility, and helps local production to be more fully integrated into the larger supply chain.

Currently, a coping technique, encouraging ghee production, could potentially be included in a more all-encompassing approach. Improving the efficiency and hygiene of ghee manufacturing, together with developing packaging and marketing plans appealing to a more extensive customer base, can help ghee become a significant product, therefore boosting the economic viability of small ruminant farming.

Through the promotion of small ruminant milk and ghee value chains, the Djelfa case shows that a comprehensive approach, including micro-level interventions combined with strategic infrastructure and market development, can significantly help alleviate the local milk supply situation. This strategy meets the urgent demand for more milk availability while encouraging sustained economic development, empowering residents, and lowering dependency on outside inputs, thus strengthening the dairy industry in the area.

CONCLUSION

&

RECOMMENDATIONS

Conclusion

This dissertation confirms that Algeria's persistent reliance on imported powdered milk is not a mere market shortfall, but the consequence of a self-reinforcing systemic trap. This trap is fundamentally rooted in a path-dependent policy bias that disproportionately favors large-scale bovine operations, thereby systematically subordinating the vast potential of small ruminants (ovine and caprine). This policy direction, coupled with current subsidy frameworks, has inadvertently solidified import dependency, subjected the domestic sector to global price volatility, and fundamentally constrained the sector's trajectory toward self-sufficiency. The insufficient exploitation of the inherent, climate-adapted advantages of small ruminant production represents the sector's most significant missed opportunity for milk source diversification and self-reliance.

The in-depth case study of the Djelfa value chain provides critical empirical evidence of this systemic failure. The regional dairy structure is defined by pervasive market informality, severe infrastructural deficits (notably the absence of an effective cold chain and adequate collection centers), and acute resource constraints (diminished forage accessibility and rising feed costs). Within this constrained environment, ghee production has emerged as the most viable economic strategy for small ruminant breeders. While this demonstrates the adaptability and resilience of local operators, the reliance on ghee production simultaneously underscores a profound economic loss, as it diverts raw milk from higher-value, perishable fresh dairy markets. This necessity highlights the urgent requirement to transform this survival strategy into a value-added opportunity by resolving the fundamental limitations of the raw milk supply chain.

This research makes three primary contributions:

- **A Novel analytical framework:** It introduces and empirically validates the "systemic trap" framework for analyzing development constraints in the dairy sectors of emerging economies. This framework emphasizes the synergistic effects of policy biases, infrastructural gaps, and market failures, offering a more nuanced model than fragmented problem deconstruction.
- **Valorization of neglected resources:** By focusing rigorously on small ruminant value chains, this study addresses a significant gap in the literature, traditionally dominated by cattle-centric models. It quantifies the role and resilience of ovine and caprine milk in arid

zones, positioning it as an essential component for achieving climate-resilient food security.

- **Context-specific intervention blueprint:** Through a mixed-methods approach and the ValueLinks 2.0 mapping of informal ties in Djelfa, the dissertation provides a concrete, localized blueprint for intervention, demonstrating the necessity of culturally relevant, decentralized solutions.

Based on the findings, a set of targeted recommendations is proposed to guide policy revision and subsequent research efforts, ensuring a transition from import reliance to sustainable domestic growth.

Policy must shift from centralized, blanket subsidies to regionally customized and targeted interventions that empower local producers and formalize the supply chain.

- **Infrastructure Investment:** Priority must be given to establishing cold chain infrastructure and reliable milk collection centers, particularly in arid and semi-arid regions, to mitigate post-harvest losses and unlock fresh milk markets.
- **Targeted Subsidy Reform:** Subsidies must be critically reassessed and reformed to directly promote local raw milk production and processing, rather than inadvertently reinforcing the economic advantage of imported powdered milk.
- **Market Access and Formalization:** Policies must facilitate the creation of structured wholesale markets and formal marketing channels for small ruminant milk and traditional value-added products, thereby ensuring equitable pricing and broader market penetration for local breeders.
- **Small Ruminant Support:** Dedicated support programs are required, focusing on sustainable feed management, breed improvement, and cost-effective veterinary services to enhance the productivity and profitability of small ruminant herds.

To advance the scholarly discourse and maximize the impact of policy, subsequent research must focus on methodological rigor, comparative analysis, and longitudinal assessment.

This includes prioritizing the establishment of robust, standardized data collection methodologies—potentially utilizing geospatial technologies and national databases—to overcome current data limitations. Furthermore, comparative studies across diverse Algerian agro-ecological zones and production systems are essential to validate the generalizability of the "systemic trap" framework and refine context-specific interventions. Crucially, researchers must undertake longitudinal studies to evaluate the long-term economic, social, and environmental ramifications of policy interventions over time, ensuring development strategies align with the overarching objectives of sustainable rural development and national self-sufficiency.

Ultimately, addressing Algeria's dairy deficit requires a strategic pivot: empowering local actors, valorizing indigenous small ruminant potential, and implementing a distributed, regionally customized approach that respects the unique agricultural and socio-economic characteristics of the nation’s diverse regions.

References

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APPENDEX

Survey on ghee consumption of animal fat(ghee)

Within the framework of developing local and national production and enhancing the role of women as a primary producer and consumer, this study aims to develop and promote animal ghee, known locally as “Dahan”.

1. Sex

- ❖ woman
- ❖ man

2. Age

- ❖ 20-30
- ❖ 30-40
- ❖ 40-50
- ❖ 50-60
- ❖ 60-70
- ❖ 70-80

3. Social status

- ❖ Single
- ❖ married

4.Educational level

- ❖ *Une seule réponse possible.*
- ❖ initial
- ❖ average
- ❖ secondary
- ❖ University
- ❖ No educational level

5. Professional status

- ❖ Without professional activity
- ❖ Government employee
- ❖ Private sector employee
- ❖ Private project owner

6. Place of residence

- ❖ Djelfa and its suburbs
- ❖ Delegated State of Ain Oussara
- ❖ Delegated State of Mesad

7. In the middle of the residence

- ❖ urban center
- ❖ Sub-urban (city outskirts)
- ❖ rural area

8. How often should I use ghee?

- ❖ Once a month
- ❖ Once every two weeks
- ❖ Once a week
- ❖ twice a week
- ❖ Three times a week
- ❖ Daily use

9.What is your favorite type of ghee?

- ❖ Vegetable ghee (factory)
- ❖ Natural animal manure "mouth"

10. The reason for preferring to use animal fat (ghee)

- ❖ Special taste
- ❖ Nutritional properties
- ❖ Therapeutic properties
- ❖ Health properties (natural product)
- ❖ Local customs

11. What is the most commonly used ghee

- ❖ Cow ghee
- ❖ Sheep ghee
- ❖ goat ghee
- ❖ Camel ghee

12.Uses of cow ghee

- ❖ *Une seule réponse possible.*
- ❖ Cooking
- ❖ Traditional dishes
- ❖ Sweets
- ❖ Medical uses
- ❖ Cosmetic uses

13. Uses of sheep ghee

- ❖ *Une seule réponse possible.*
- ❖ Cooking
- ❖ Traditional dishes
- ❖ Sweets
- ❖ Medical uses
- ❖ Cosmetic uses

14. Goat ghee uses

- ❖ *Une seule réponse possible.*
- ❖ Cooking
- ❖ Traditional dishes
- ❖ Sweets
- ❖ Medical uses
- ❖ Cosmetic uses

15. Uses of camel ghee

- ❖ Cooking

- ❖ Traditional dishes
- ❖ Sweets
- ❖ Medical uses
- ❖ Cosmetic uses

16.In your area of residence, what type of paint is most available?

- ❖ Cow ghee
- ❖ Sheep ghee
- ❖ goat ghee
- ❖ Camel ghee

17. Why is this particular type available?

- ❖ This type of animal is widely raised in the region.
- ❖ Large production of this species in the region
- ❖ This particular type is in high demand.

18. Where to buy ghee?

- ❖ Directly from the producer (rural woman)
- ❖ From the producer through an intermediary
- ❖ From shops selling dairy products

19. Why do you prefer to buy directly from the producer?

- ❖ close distance
- ❖ Reasonable prices (low)
- ❖ High quality
- ❖ Guaranteed product (natural without additives)

20. How are the ghee prices for you?

- ❖ Low prices
- ❖ Normal prices within everyone's reach
- ❖ Prices are a little high.
- ❖ expensive

21. What is the most expensive type of ghee in your area?

- ❖ Cow ghee
- ❖ Sheep ghee
- ❖ goat ghee
- ❖ Camel ghee

22. What are the obstacles that prevent you from constantly consuming ghee?

- ❖ Product not always available
- ❖ Difficulty accessing the product
- ❖ High prices
- ❖ Personal preferences
- ❖ Lack of complete details about product components
- ❖ The method of preservation and packaging is not suitable.

23. What are the factors that positively affect the purchase and use of ghee?

- ❖ Product availability without interruption
- ❖ Sell the product at low prices
- ❖ Attractive packaging method
- ❖ Product description (mentioning its components and nutritional and therapeutic properties)
- ❖ Marketing method