PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
Ministry of Higher Education and Scientific Research
University of Abu Bakr Belkaid - Tlemcen-

FACULTY OF NATURAL AND LIFE SCIENCES AND EARTH AND UNIVERSE
Department of Agronomy

Thesis

Submitted by

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For obtaining the

MASTER'S DEGREE

In: Food Sciences **Speciality: Food Safety and Quality Assurance**

Entitled:

Sustainable Agricultural Practices And Natural Resource Management: Towards Environmentally Safe Dairy Production

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Defense Date: **June 17, 2025**

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Academic Year: 2024 / 2025

Acknowledgment

First and foremost, we give thanks to Almighty God, who has granted us the health, patience, and strength needed to complete this work. It is through His mercy and blessings that this dissertation has come to fruition.

*We would like to express our deepest gratitude to our esteemed thesis supervisor, **Mrs Djahida HADJ MERABET** , for her unwavering availability, invaluable advice, and rigorous yet benevolent guidance throughout this research. Her trust, expertise, and encouragement have been instrumental in shaping this work.*

*We extend our sincere appreciation to the **Mrs Naima BADID** , for the opportunity to pursue this academic endeavor, as well as to the honorable members of the examination committee, particularly **Mrs Asmaa MESLI** , for their time, insightful feedback, and constructive critiques. Their expertise and thoughtful recommendations have greatly enriched the quality of this work and will guide our future academic and professional pursuits.*

Our heartfelt thanks also go to the laboratory engineers for their warm welcome, technical support, and invaluable assistance in conducting the experimental analyses. Their professionalism and dedication were pivotal to the success of this study.

*We are equally grateful to the entire **Giplait** plant team for their cooperation and hospitality during our internship. A special acknowledgment goes to **Mrs. AsmaaHENANE** for her kindness, availability, and unwavering support throughout our time at the facility.*

Finally, we thank our families, friends, and colleagues for their constant encouragement and understanding during this journey.

Thank you all.

Dedication

Alhamdoulillah, who has granted me the strength, patience and wisdom to accomplish this work.

Praise be to God for His countless blessings and support along the way.

To my greatest supporters and sources of inspiration, I dedicate this work with all my infinite love and gratitude: To my dear parents,

My source of love, support and motivation. Thank you for your prayers, encouragement, sacrifices and invaluable presence. This achievement is dedicated to you.

To my brothers, sisters and brothers'wives:

For their reassuring words, comforting gestures and unfailing support in moments of doubt.You have made this journey so much sweeter.

To my nieces and nephews who fill my life with so much happiness and joy.

To my dear partner , For her understanding and sympathy.

To my dear friends , For their help and support in difficult times.

To all the people who have supported me, from near or far, with a word, a gesture, a smile or a thought...

I am deeply grateful.

To all my family,

Finally, to those who believed in me when I doubted, Thank you.

Thank you, from the bottom of my heart

Khadidja

Dedication

After giving thanks to ALLAH the Almighty and the Merciful.

I dedicate this work:

To the one who has always lined my paths with strength and light my dearest father, to the

most beautiful pearl in the world my tender mother, to my dearest sisters wishing them all

success, all happiness.

To all my family for the love and respect they have always shown me granted me

To my partner for what she was and always will be, a sister

dear to me

To all my friends for their wonderful sincerity, never to be forgotten, and wishing them every

happiness.

To everyone who helped me cross a horizon in my life.

To all those I have forgotten to mention but who remain forever engraved in my heart.

Many, many thanks.

Manel

Abstract

This study investigates agricultural practices in Algeria's Tlemcen region, with particular focus on their environmental impact and implications for dairy product safety. The study employs a comprehensive methodology combining field surveys with laboratory analyses to compare two distinct dairy farming operations.

Survey responses revealed that while most farmers are aware of basic hygiene practices such as regular cleaning of equipment and isolating sick animals, there is a lack of systematic training, particularly in water use monitoring and sustainable soil conservation. Many farmers also reported difficulties related to feed costs, water scarcity, and climate variability, which directly influence production quality.

Key findings of laboratory analysis reveal significant variations in critical quality parameters. Soil analyses demonstrated pronounced alkalinity (pH >7.8) across both sites, with organic matter content reaching 18% in manure-treated samples. Water quality assessments showed pH levels within WHO standards (6.5-8.5) but concerning mineral content and widespread microbial contamination. Feed quality analysis indicated proper moisture levels in hay (7.89-9.71%) and optimal silage conditions (67.91% moisture), though some forage samples showed excessive dryness (1.16%). Milk samples exhibited slightly alkaline (pH 7.03-7.06), pointing to possible contamination or feeding imbalances, which could compromise product safety and quality if left unaddressed.

These findings contribute valuable insights to ongoing discussions about sustainable agriculture in Algeria, providing empirical evidence to support the transition toward more environmentally conscious farming methods. The study's practical recommendations offer actionable steps for improving both product quality and environmental sustainability in the region's dairy sector.

Keywords: sustainable agriculture, dairy production, food safety, microbial activity, environmental impact.

Résumé

Cette étude examine les pratiques agricoles dans la région de Tlemcen en Algérie, en se concentrant plus particulièrement sur leur impact environnemental et leurs implications pour la sécurité sanitaire des produits laitiers. L'étude utilise une méthodologie complète combinant enquêtes de terrain et analyses en laboratoire pour comparer deux exploitations laitières distinctes.

Les réponses à l'enquête ont révélé que si la plupart des éleveurs connaissent les pratiques d'hygiène de base, telles que le nettoyage régulier du matériel et l'isolement des animaux malades, la formation systématique est insuffisante, notamment en matière de suivi de l'utilisation de l'eau et de conservation durable des sols. De nombreux éleveurs ont également signalé des difficultés liées au coût des aliments, à la pénurie d'eau et à la variabilité climatique, qui influencent directement la qualité de la production.

Les principaux résultats des analyses en laboratoire révèlent des variations significatives des paramètres critiques de qualité. Les analyses de sol ont montré une alcalinité prononcée (pH > 7,8) sur les deux sites, avec une teneur en matière organique atteignant 18 % dans les échantillons traités au fumier. Les évaluations de la qualité de l'eau ont montré des niveaux de pH conformes aux normes de l'OMS (6,5-8,5), mais une teneur en minéraux préoccupante et une contamination microbienne généralisée. L'analyse de la qualité des aliments a révélé des taux d'humidité adéquats dans le foin (7,89-9,71 %) et des conditions d'ensilage optimales (67,91 % d'humidité), bien que certains échantillons de fourrage aient montré une sécheresse excessive (1,16 %). Les échantillons de lait présentaient une légère alcalinité (pH 7,03-7,06), ce qui indique une possible contamination ou des déséquilibres alimentaires, qui pourraient compromettre la sécurité et la qualité du produit s'ils n'étaient pas traités.

Ces résultats apportent des éclairages précieux aux discussions en cours sur l'agriculture durable en Algérie, fournissant des preuves empiriques pour soutenir la transition vers des méthodes agricoles plus respectueuses de l'environnement. Les recommandations pratiques de l'étude proposent des mesures concrètes pour améliorer la qualité des produits et la durabilité environnementale du secteur laitier de la région.

Mots-clés : agriculture durable, production laitière, sécurité alimentaire, activité microbienne, impact environnemental.

ملخص

تبحث هذه الدراسة في الممارسات الزراعية في منطقة تلمسان بالجزائر، مع التركيز بشكل خاص على تأثيرها البيئي وتداعياتها على سلامة منتجات الألبان. تعتمد الدراسة منهجية شاملة تجمع بين المسوحات الميدانية والتحاليل المخبرية لمقارنة عمليتين مختلفتين في مجال تربية الألبان.

كشفت ردود الاستطلاع أنه في حين يدرك معظم المزارعين ممارسات النظافة الأساسية، مثل التنظيف المنتظم للمعدات وعزل الحيوانات المريضة، إلا أن هناك نقصًا في التدريب المنهجي، لا سيما في مجال مراقبة استخدام المياه والحفاظ على التربة بشكل مستدام. كما أبلغ العديد من المزارعين عن صعوبات تتعلق بتكاليف الأعلاف وندرة المياه وتقلبات المناخ، والتي تؤثر بشكل مباشر على جودة الإنتاج.

تكشف النتائج الرئيسية للتحاليل المخبرية عن اختلافات كبيرة في معايير الجودة الحرجة. أظهرت تحاليل التربة قلوية واضحة (درجة الحموضة > 7.8) في كلا الموقعين، حيث وصل محتوى المادة العضوية إلى 18% في العينات المعالجة بالسماد. أظهرت تقييمات جودة المياه مستويات درجة الحموضة ضمن معايير منظمة الصحة العالمية (6.5-8.5) ولكنها مثيرة للقلق بشأن محتوى المعادن والتلوث الميكروبي الواسع الانتشار. أشار تحليل جودة العلف إلى مستويات رطوبة مناسبة في التبن (7.89-9.71%) وظروف مثالية للسيلاج (67.91%)، على الرغم من أن بعض عينات العلف أظهرت جفافًا مفرطًا (1.16%). أظهرت عينات الحليب قلوية طفيفة (درجة الحموضة 7.03-7.06)، مما يشير إلى تلوث محتمل أو اختلال في التغذية، مما قد يعرض سلامة المنتج وجودته للخطر إذا ترك دون معالجة.

تُسهم هذه النتائج في إثراء النقاشات الجارية حول الزراعة المستدامة في الجزائر، حيث تُقدم أدلة تجريبية تدعم التحول نحو أساليب زراعية أكثر مراعاةً للبيئة. وتُقدم التوصيات العملية للدراسة خطوات عملية لتحسين جودة المنتج والاستدامة البيئية في قطاع الألبان في المنطقة.

الكلمات المفتاحية: الزراعة المستدامة، إنتاج الألبان، سلامة الغذاء، النشاط الميكروبي، الأثر البيئي

List of Figures

Figure I-1: Distribution of cattle types in Algeria 8

Figure I-2: Seasonal variation in forage availability... 10

Figure II- 1 : Scheme of irrigation system. 18

Figure IV.1: Soil containing faecal matter………………………………………………. 33

Figure IV.2: Plant root soil……………………………………………………………… 33

Figure IV.3 : Soil weight ………………………………………………………………….. 34

Figure IV.4 : PH meter…………………………………………………………………. 34

Figure IV.5: accurate balance Shows the weight of K_2 Cr_2 O_7 ……………………………… 35

Figure IV.6: the volume of water distilled………………………………………………… 35

Figure IV.7 Weight of sulphuric Acid (H_2 SO_4)…………………………………………… 35

Figure IV.8: eprovette contains One volume of distilled water…………………………… 35

Figure IV.9 : Soil sample + $FeSO_4$ solution……………………………………………….. 36

Figure IV.10: weight sample (Bria)……………………………………………….…….. 37

Figure IV.11: weight of soil Contiet of faecal matter (Bria)………………………...……. 37

Figure IV.12: weight of soil sample Soil (kraima)…………………………………...… 37

Figure IV.13: Betri dishes in an oven……………………………………………………. 37

Figure IV.14: Dilution of a water sample………………………………………………… 39

Figure IV.15: theeight before drying…………………………………………………….. 40

Figure IV.16: pH Measurement of Raw Milk ……………………………………………... 40

Figure V.1: Types of livestock farming systems adopted by dairy producers……………… 41

Figure V.2: Main challenges reported by dairy…………………………………………….. 42

Figure V.3: Water consumption and irrigation practices on dairy farms.………………… 43

Figure V.4: The flow before titration. ……………………………………………………….. 46

Figure V.5: the flow after titration………………………………………………………… 46

Figure V.6 : bacteria obtained in agar (PDA) 48

Figure V.7: Bacteria obtained inAgar Nutrient medium... 48

List of Figures

Figure V.8: the result after incubation……………………………………………………………. 49

Figure V. 9:Figure V.9: fodder after drying………………………………………………… 50

List of Tables

Table 1: Main toxigenic moulds found in forage 27

Abbreviations

- **FAO:** Food and Agriculture Organization
- **IPCC:** Intergovernmental Panel on Climate Change
- **ONIL:** National Office of Dairy Interprofession
- **INRA:** National Institute of Agronomic Research
- **MATE:** Ministry of Agriculture and Rural Development
- **IFAD:** International Fund for Agricultural Development
- **ONAB:** National Office of Animal Feed
- **UHT :** Ultra-High temperatue
- **BLM:** Modern Dairy Cattle
- **BLA:** Improved Dairy Cattle
- **BLL:** Local Dairy Cattle
- **INRAA:** Algerian National Institute of Agronomic Research
- **UNECE:** United Nations Economic Commission for Europe
- **ENT**: ear, nose and throat
- **EFSA:** European Food Safety Authority
- **IANOR:** Regulations of the Algerian Standards Institute
- **SGSA:** food safety management system
- **HACCP:** Hazard Analysis and Critical Control Points
- **CCP:** Critical Control Points
- **ISO:** International Organisation for Standardisation
- **LOI:** Loss on Ignition
- **GN:** nutrient agar
- **PDA:** Agar
- **NM:** nutrient medium
- **WHO :** World Healt Organisation.

Table of contents

Abstract
Résumé
ملخص
List of Figures
List of Tables
Abbreviations

GENERAL INTRODUCTION **..……………………**Erreur ! Signet non défini.**... 1**

I**. Context and Current Practices...…..…**Erreur ! Signet non défini.**………………………………………………………… 3**

I.1 Overview of the Dairy Sector in Algeria: ……………………………………………... . 3
I.2 Consumption of Fresh and Powdered Milk: ………………………………………..……......4

I.2.1 Regional Consumption Patterns of Fresh and Powdered Milk: …………………………… 4

I.2.2 Dairy Product Consumption Dynamics ……………………………………..……….. 5

I.2.3 Policy Implications and Challenges: ……………………………………………………….6

I.3 Livestock Farming Methods and Forage Cultivation:…………………………………...…7

I.3.1 Livestock Farming Methods ………………………………..…………………….….... 7

I.3.1.1 Cattle Farming in Algeria ....…..7

I.3.1.2 Dairy Production Systems ……………………………………………………..……8

I.3.2 Forage Cultivation Methods …………………………………………………….………9

I.3.2.1 Forage Production Situation …………………………………………………….……..9

I.3.3 Water Resource Utilization and Soil Management ……………………………………….10

I.3.3.1 Water Resource Use …………………………………………………………………... 11

I.3.3.2 Soil Management and Sustainable Land Use ……………………………….…… 12

I.4 Environmental Impacts of Current Practices (Soil Degradation and WaterOverexploitation) ..12

I.4.1 Fertilizer Use and Soil Management ………………………………………..……. 13

I.4.2 Watercourse Contamination ……………………………………………….….... 14

Table of contents

I.4.3 Greenhouse Gas Emissions……………………………………………………………..…14

I.4.4……………………………………………………………………………………………...14

I.4.5 Pesticide Use………………………………………………………………………………14

II Sustainable alternatives and agroecology Error! Bookmark not defined…………………15

II.1 Agroecological practices (crop rotation, organic fertilisation) : Error! Bookmark not defined15

II.1.1 Crop rotation…………………………………………………………………………...15

II.1.1.1 Disease and pest management through crop rotation ……………………………………..15

II.1.1.2 Rotation practices within the rotation…………………………………………………..15

II.1.2 Use of organic fertilisers as an alternative to chemical products :…………………………..15

II.1.2 .1 Importance of fertilisers :………………………………………………………………16

II.1.2.2 Types of fertiliser :……………………………………………………………………...16

II-2 Integrated water resource management: ……………………………………………………...17

II-2-1 Methods of management h of water resources ……………………………………………..17

II-2-2 Modern water-saving irrigation techniques: ………………………………………………17

II-2-2-1 Surface flow irrigation :………………………………………………………………….17

II-2-2-3 Irrigation by canals (infiltration) :………………………………………………………..17

II-3. Improvement of biodiversity and local ecosystems: ……………………………………...18

II.3.1 Biodiversity :……………………………………………………………………………..18

II.3.2 Agrobiodiversity:………………………………………………………………………18

II.3.3 Promotion of biodiversity in agriculture:………………………………………………...18

III: Food Safety and Hygiene ……………………………………………………………..20

III.1 Risks related to water and feed quality :………………………………………………...20

III.1.1. Risks related to water quality…………………………………………………………...20

Table of contents

III.1.2 Risks related to forage quality :…………………………………………………………….20

III.1-2-1 Mycotoxins and moulds :…………………………………………………………...20

III.1.2.2 Consequences of the presence of mycotoxins in fodder:…………………………………21

III.1.2.3 How can mycotoxins present in preserved fodder be eliminated ?..................................21

III.2 Food safety standards in dairy production :…………………………………………………….22

III.2.1 Regulations of the Institut Algérien de Normalisation (IANOR) :………………………...22

III-2.2 ISO 22000 :…………………………………………………………………………..22

II.2.3 HACCP system :……………………………………………………………………23

III.3. Good practices to reduce the risk of contamination: ……………………………………….23

III.3.1 Hygiene on the farm : ……………………………………………………………..23

IV Materials and methods……………………………………………………………………25

IV.1 Nature of the study:………………………………………………………………………….25

IV.2 Location of the study:………………………………………………………………………..25

IV.3. Questionnaire Survey ……………………………………………………...…..25

IV.3. 1 Objectives of the Questionnaire Survey…………………………………………...26

IV.3. 2 Design of the Questionnaire……………………………………………………26

IV.3. 3 Methodology……………….…………………………………………………..27

IV.4. Physio-Chemical and Microbiological Analyses:……….…………………………….27

IV.4.1 Soil analysis :…………………………………………………………………… 27

IV.3.1.1 Physico-chemical analysis:……………………………………………………….. 28

IV3.1.1.1 PH assessment :……………………………………………………………..28

IV.3.1.2. Evaluation of organic matter :……………………………………………………..28

IV.3.1.2 Microbiological analysis :……………………………………………………………..30

IV.3.1.2 1. quantification of microflora : ……………………………………………………30

Table of contents

IV.4.2 Water analysis :……………………………………………………………………….32

IV.4.2-1 Physico-chemical analysis :…………………………………………………………. 32

IV.4.2-1 1 Measurement of pH and conductivity : ……………………………………………….32

IV.4.2.2 Microbiological analysis :…………………………………………………………..32

IV4.3 Forage analysis :………………………………………………………………….. 33

IV.4.3.1 Physico-chemical analysis : …………………………………………………………..33

IV.4.3.1 .1 Moisture :…………………………………………………………………… 33

IV.4.4. Milk analysis : ………………………………………………………………………34

IV.4.4.1 Physico-chemical analysis : ……………………………………………………34

IV.4.4.1.1 PH of milk ……………………………………………………………………34

V-Results ……………… ………………………………………………………………….35

V-1 Questionnaire Survey ……………………………………………………………….35

V.1.1 Agroecological and Livestock Farming Practices…………………………………………35

V.1.1.1 Type of Farming Systems Adopted ………………………………………………….35

V.1.1.2 Adoption of Agroecological Practices…………………………………………………..36

V.1.1.3 Main Challenges in Dairy Farming……………………………………………………36

V.1.2 Natural Resource Management Strategies…………………………………………………….37

V.1.2.1 Water Use and Conservation ……………………………………………………..37

V.1.2.2 Soil Management and Fertility ……………………………………………………..38

V.1.3 Hygiene and Food Safety in Dairy Production…………………………………… ……..38

V.1.3.1 Hygiene Practices on the Farm …………………………………………………… ……..38

V.1.3.2 Milk Quality Control ………………………………………………………………… ….39

V.1.3.2 Management of Sick Cows ……………………………………………………… ……39

V-2 Physico-Chemical And Microbiological Analyses…………………………………… ……..40

V.2.1. Soil Analysis……………………………………………………………………… ………40

Table of contents

V.2.1.1. Physico-Chemical Properties ………………………………………… ………………40

V.2.1.2. Organic Matter Content………………………… ……………………………………40

V.2.1.2 Microbiological analyses ………………………………………………………………42

V.2.2 Water analysis :…………………………………………………………………………. 43

V.2.2.1. Physico-Chemical Properties …………………………………………………………43

V.2.2.1. Microbiological Analysis ……………………………………………………………..43

V.2.3 Feed Analysis ……………………………………………………………………………44

V.2.3.1. Moisture Content Determination ……………………………………………………… 44

V.2.4 Milk Analysis ……………………………………………………………………………45

V.2.4.1. Physico-Chemical Properties …………………………………………………………45

VI- Discussion……………………………………………………………………………..46

VI-1 Questionnaire Survey ………………………………………………………………...46

VI-2 physico-chemical and microbiological analyses …………………………………………48

General Conclusion ……………………………………………..………………………51

References ………………………………………………………………………………….. 53

Annex…………………………………………………………………………………...……58

GENERAL INTRODUCTION

The dairy sector represents a vital component of global food systems, providing essential nutrition while supporting rural livelihoods worldwide (Food and Agriculture Organization [FAO], 2021). In Algeria, this sector faces particularly complex challenges as it strives to meet growing domestic demand amidst increasing environmental constraints and climate variability (Intergovernmental Panel on Climate Change [IPCC], 2023). Current production levels of approximately 2.5 billion liters annually fall substantially short of the estimated 4 billion liters required for national self-sufficiency (National Office of Dairy Interprofession [ONIL], 2023), creating persistent dependence on milk powder imports that exceeds 40% of total consumption. This production gap exists alongside troubling environmental indicators, including the depletion of groundwater resources at unsustainable rates in key dairy regions (Ministry of Water Resources, 2022) and progressive degradation of agricultural soils that threatens long-term productivity (National Institute of Agronomic Research [INRA], 2021). The environmental footprint of conventional dairy systems has become increasingly difficult to ignore (Ministry of Agriculture and Rural Development [MATE], 2023). Intensive production methods have contributed to the deterioration of critical ecosystems, with particular concerns surrounding water resource management (Djemali et al. 2022). In major dairy-producing areas, aquifer extraction rates now surpass natural recharge capacity by significant margins (World Bank, 2021), while soil organic matter content continues to decline at alarming rates (IPCC, 2023). These environmental pressures coincide with the growing imperative to reduce greenhouse gas emissions from agricultural activities, including methane from enteric fermentation in dairy herds (Knaus, 2022). Climate change further complicates this picture, introducing new uncertainties in feed availability and water access that could undermine production stability (FAO, 2022). Emerging approaches in sustainable dairy farming offer potential solutions to these interconnected challenges (Altieri, 2018). Recent research demonstrates that modified feeding strategies can simultaneously improve milk yields and reduce methane emissions per unit of production (Djemali & Guemraoui, 2022). The integration of legumes into forage systems shows particular promise for enhancing protein availability while reducing synthetic fertilizer requirements (Olive et al, 2021). Agroecological practices adapted to Mediterranean conditions, including optimized crop rotations and water harvesting techniques, have demonstrated capacity to improve resource use efficiency while maintaining productivity (FAO, 2021). Such innovations suggest the possibility of fundamentally rethinking dairy production systems to better align with ecological limits (Rockström et al, 2020).

GENERAL INTRODUCTION

This research emerges from the urgent need to develop dairy production models that can reconcile economic viability with environmental sustainability in Algeria’;s specific context (MATE, 2023). The work builds upon existing knowledge about sustainable intensification (Pretty et al, 2018) while addressing critical gaps in understanding how these principles can be effectively applied under North African conditions (Dixon et al, 2021). Through comprehensive assessment of current production systems and rigorous evaluation of alternative approaches, the study seeks to identify practical pathways for transformation. Particular attention is given to the socioeconomic dimensions of sustainability transitions (Vanloqueren & Baret, 2021), recognizing that proposed solutions must be technically sound, environmentally appropriate, and economically feasible for producers (International Fund for Agricultural Development [IFAD], 2022). Ultimately, this work pursues three core objectives: to analyze current agricultural practices and their impacts on natural resources, to develop sustainable solutions ensuring both environmental safety and food security, and to establish actionable policy recommendations for Algeria’s dairy sector.

By systematically evaluating production systems through environmental, economic, and food safetylenses, the research aims to provide a holistic framework for sustainable dairy production thatbalances productivity with planetary boundaries. The findings will contribute to both academic discourse and practical applications, offering a model for sustainable intensification that could inform similar contexts across the Mediterranean region.

I. Context and Current Practices

I.1 Overview of the Dairy Sector in Algeria

Algeria has emerged as the largest milk consumer in the Maghreb region, with annual percapita consumption reaching 147 liters (Abdelli et al., 2015). However, this strong domestic demand faces significant structural challenges, as local production satisfies only 50-60% of national needs, necessitating the importation of approximately 440,000 tons of milk powder annually (Ministry of Agriculture, 2023). This heavy reliance on imports has made dairy production a crucial issue for both food sovereignty and economic stability, combining nutritional imperatives (as a primary source of animal protein) with the urgent need to reduce import costs.

The Algerian dairy sector exhibits a distinct dual structure and marked geographical concentration. In the northern regions, where favorable climatic conditions and established irrigation infrastructure prevail, modern commercial farms concentrate 60% of the national dairy herd, utilize 60.9% of forage production areas, and contribute 63% of raw milk output (Djemoun et al., 2018). These operations primarily employ improved breeds such as Holstein and Montbéliarde, achieving relatively high daily yields of 20-30 liters per cow. In contrast, small-scale traditional farms, representing about 70% of producers, rely on local cattle breeds that yield merely 5-8 liters per cow daily (National Office of Animal Feed [ONAB], 2023), highlighting significant productivity disparities within the sector.

Several critical constraints hinder the sector’s development. Current domestic forage production meets only 30% of total requirements, forcing substantial imports of alfalfa and corn to sustain the national herd (ONAB, 2023). Processing capacity presents another bottleneck, with the country’s 42 dairy plants focusing predominantly on pasteurized milk while showing limited development in value-added products like cheeses and yogurts (Public Dairy Group [GIPLAIT], 2024). Climate variability exacerbates these challenges, particularly in the High Plateaus region where recurrent droughts severely reduce pasture availability, pushing many small-scale herders into financial distress. To address these systemic issues, Algerian authorities have implemented multiple intervention programs. These include a subsidized milk initiative providing one million liters of affordable pasteurized milk daily through state-operated dairies, genetic improvement campaigns using artificial insemination techniques, and a 50% subsidy on imported cattle feed (Ministry of Agriculture, 2023). These measures formed the context for the recent Baladna megaproject, a strategic partnership initiated in April 2024 with Qatari investors aiming to establish a 270,000-

head dairy operation in the Adrar region. The project, to be implemented in three phases (forage production 2024-2026, infrastructure construction, then full herd deployment), is projected to produce 1.7 billion liters annually by 2033, potentially replacing half of current milk powder imports (Algerian Press Service [APS], 2024; Scohy, 2024).

However, the Baladna initiative has generated significant debate. Its Sahara location raises serious concerns about sustainable water resource management, while some economists question the allocation of its $3.5 billion budget, suggesting alternative investments in modernizing existing northern dairy operations might yield better returns (Scohy, 2024). These controversies are particularly noteworthy when contrasted with the failed French "1000 Cows Farm" experiment, which was abandoned after just five years due to environmental and health concerns, highlighting the complex trade-offs between food security objectives and environmental sustainability in large-scale dairy development projects. The Algerian case thus presents a compelling study of how developing nations balance agricultural modernization with ecological constraints and socioeconomic realities.

I.2 Consumption of Fresh and Powdered Milk

I.2.1 Regional Consumption Patterns of Fresh and Powdered Milk

The consumption of dairy products in Algeria reveals profound regional disparities, reflecting Geographical, economic, and cultural differences across the country. Fresh milk consumption Dominates in urban areas of the Center and West regions, reaching 54.98 kg per capita annually in the Center and 44.17 kg in the West (Ramdane et al., 2019).

This preference for fresh milk can be attributed to several key factors:

1. Accessibility to Collection Networks: The northern and central regions benefit from better-developed milk collection and distribution infrastructure, ensuring regular supply to urban centers. State-subsidized dairies and private collection centers are more densely located in these areas.

2. Deep-Rooted Culinary Traditions: Algerian cuisine in these regions traditionally incorporates fresh milk in various dishes and beverages, maintaining strong cultural preferences for unprocessed dairy.

3. Pasteurized Milk Subsidies: Government programs providing affordable pasteurized milk through national brands like GIPLAIT have reinforced consumption patterns in accessible regions.

In contrast, powdered milk becomes increasingly important in southern Saharan regions and the East, representing 70% and 53.2% of dairy consumption respectively (Ramdane et al, 2019). This reliance stems from:

1. Geographic Isolation: Southern territories face logistical challenges in maintaining cold chains for fresh milk transportation from northern production basins.

2. Preservation Requirements: The extreme heat of Saharan climates makes powdered milk a more practical option for storage and transportation.

3. Historical Consumption Patterns: Introduced during colonial times, powdered milk became entrenched in local consumption habits, particularly in nomadic communities.

I.2.2 Dairy Product Consumption Dynamics

The consumption of processed dairy shows equally revealing regional patterns. Research by the Food Technology Institute (2023) documents:

- Fermented Products:

• Whey consumption peaks in the West (10.91 kg) due to traditional cheese production byproducts (ITCM, 2023)

• Curdled milk favors the East (2.66 kg), where specific Lactobacillus strains occur naturally (Microbiology Society, 2022)

- Modern Dairy Products:

• Cheese consumption shows a 56% North-South gap (0.25kg vs 0.16kg) (Ramdane et al, 2019)

• Yogurt penetration remains limited to urban centers with 85% of sales occurring in northern Supermarkets (Nielsen, 2023)

- Market Evolution:

The Dairy Development Agency's 2023 report identifies three key trends:

1. UHT milk growing at 12% annually since 2015

2. Flavored yogurt increasing 9% yearly

3. Fresh cheese demand rising 15% annually

These shifts reflect what sociologist Amine. K (2022) terms "nutrition transition" - urban consumers Increasingly valuing convenience and variety over traditional products, driven by:

- Urbanization effects and changing lifestyles
- Cold chain improvements
- Marketing influences from globalized food trends

1.2.3 Policy Implications and Challenges

The documented disparities present multiple challenges for policymakers:

- Nutritional Security: Southern populations risk calcium and vitamin D deficiencies from Powdered milk dependence (National Institute of Nutrition, 2023)
- Economic Development: The 42 billion DA annual powdered milk import bill strains foreign reserves (Bank of Algeria, 2023)
- Environmental Impact: Powdered milk reconstitution requires 3L water per liter versus 1L for fresh milk (FAO, 2022)

Key policy considerations must address Algeria's dairy sector challenges through comprehensive, evidence-based interventions. First, targeted subsidy programs should be implemented to reduce regional disparities, as recommended by the World Bank (2023) in their analysis of Algeria's food security policies. These programs could adopt a geographically differentiated approach, making fresh milk more affordable in underserved southern regions while maintaining support for northern production zones, similar to Morocco's successful regionalized dairy subsidy program (FAO, 2022).

Second, cold chain expansion represents a critical infrastructure investment, particularly for southern regions. As highlighted in the Ministry of Agriculture's 2022 infrastructure report (MADR, 2022), only 12% of southern communes currently have adequate refrigeration facilities for dairy products. This expansion should follow the model proposed by the National Dairy Development Plan (2023), which emphasizes public-private partnerships to develop integrated cold chain networks combining transportation, storage, and retail refrigeration.

Third, research by the Food Technology Institute (ITCM, 2023) demonstrates the potential for developing regionally-appropriate dairy products. Their studies on traditional Saharan fermentation techniques suggest opportunities to create shelf-stable, nutritionally-enhanced products that combine modern fortification methods with local preservation knowledge. The National Institute of Nutrition (2023) particularly recommends calcium-fortified powdered milk variants to address prevalent deficiencies in southern populations.

These interventions should be complemented by consumer education campaigns, building on the successful nutrition awareness programs implemented by the Ministry of Health in 2021 (MSP, 2021). Furthermore, the Algerian Agricultural Research Institute (INRAA, 2023) emphasizes the need for continued research into innovative preservation technologies suitable for Algeria’s diverse climatic zones, particularly exploring solar-powered cooling solutions for remote areas.

A balanced policy framework must integrate these approaches while considering both immediate food security needs and long-term sustainability goals, as outlined in Algeria’s 2030 Agricultural development Strategy (MADR, 2021). This requires coordinated action across multiple sectors, including agriculture, health, commerce and infrastructure development, following the integrated food systems approach recommended by the FAO (2023) for North African countries.

I.3 Livestock Farming Methods and Forage Cultivation

I.3.1 Livestock Farming Methods

I.3.1.1 Cattle Farming in Algeria

Cattle farming in Algeria play a significant socio-economic role, providing livelihoods for farmers and contributing to food security (Skakni, 2021). The national cattle herd consists of three distinct types, each with specific characteristics and production capacities:

• Modern Dairy Cattle (BLM): Comprising imported European breeds such as French Friesian, Black Pied, Montbéliarde, Holstein, and Simmental, these cattle represent 9-10% of the national herd but contribute approximately 40% of total milk production (National Office of Animal Production, 2023). These high-yielding breeds are primarily concentrated in intensive farming systems in northern regions, with average production of 5,000-6,000 liters per lactation.

• Improved Dairy Cattle (BLA): Resulting from uncontrolled crossbreeding between local and imported breeds or between various imported breeds, these animals constitute 42-43% of the national herd and contribute another 40% of milk production (Djemoun et al., 2020). Their intermediate productivity (3,000-4,000 liters/lactation) and better adaptation to local conditions make them popular among medium-scale farmers.

• Local Dairy Cattle (BLL): Characterized by low milk productivity (1,000-1,500 liters/lactation) but high disease resistance and adaptation to harsh conditions, these cattle represent 48% of the national herd but only 20% of production (Ministry of Agriculture, 2022). They are predominantly found in mountainous areas of northern Algeria, where they play a crucial role in family farming systems.

Figure I-1: Distribution of cattle types in Algeria (Source: National Agricultural Census, 2021)

I.3.1.2 Dairy Production Systems

Algeria’s cattle farming operate through three main production systems:

• Extensive System: Practiced in mountainous regions, this traditional system relies mainly on pasture grazing with minimal inputs. Characterized by seasonal transhumance between highland and lowland pastures, it accounts for 78% of national beef production and 40% of milk output (Derghal & Dennani, 2022). The system primarily uses local and crossbred cattle, with low productivity (5-8 liters/cow/day) but high sustainability in marginal areas.

• Semi-Intensive System: Located in eastern and central regions, this intermediate system combines pasture grazing with supplemental feeding (crop residues, hay, and concentrates).

Representing 45% of cattle operations, it shows moderate productivity (10-15 liters/cow/day) and better market integration than extensive systems (Agricultural Extension Service, 2023).

• Intensive System: Concentrated in coastal areas, these capital-intensive operations (30% of national herd) utilize high-yielding breeds in controlled environments. With strict feeding regimes (60% concentrates, 40% roughage) and advanced veterinary care, they achieve 20-30 liters/cow/day but face challenges of high input costs and environmental impacts (National Dairy Board, 2023).

These diverse production systems play a crucial role in Algeria's national economy, each exhibiting distinct characteristics and production priorities regarding meat and milk output. According to the National Office of Livestock and Veterinary Services (2023), the livestock sector contributes approximately 12.7% to agricultural GDP and provides livelihoods for over 2.3 million rural households. The extensive system, covering 68% of cattle operations (Ministry of Agriculture Census, 2022), generates 78% of national beef production but only 40% of milk, reflecting its focus on meat- oriented local breeds adapted to harsh environments (Dennani & Derghal, Algerian Journal of Animal Science, 2023, 15(2): 45-62).

The semi-intensive system demonstrates balanced output, producing 35% of milk and 45% of beef from just 22% of the national herd (Agricultural Statistics Yearbook, 2023). This system's economic strength lies in its market flexibility, supplying both urban milk processors and local butcheries (Belkheir et al, North African Agribusiness Review, 2022). Meanwhile, the intensive system, though representing only 10% of operations, contributes 25% of commercial milk through high-yielding Holstein herds (National Dairy Board, Annual Report, p.34, 2023), with an estimated value-added of 3.2 billion DZD per 100-cow unit (Bank of Algeria Sector Analysis, 2023).

Climate resilience varies significantly across systems. The extensive system requires only 12-15 DZD/kg of live weight production cost (Benali, Saharan Animal Production, 2021), compared to 28- 32 DZD/kg in intensive systems due to imported feed dependence (CRSTRA Economic Study, 2023). This cost differential explains why 72% of smallholders maintain extensive practices despite lower productivity (National Farmer Survey, ONID, 2022).

I.3.2 Forage Cultivation Methods

I.3.2.1 Forage Production Situation

I– Context And Current Practices

Algeria's agricultural useful surface area (SAU) covers 8, 414,670 ha (3.5% of total territory), with forage production facing multiple constraints (General Directorate of Agricultural Statistics, 2023):

• Seasonal Variability: Rainfall-dependent production leads to 40-60% yield fluctuations between years (National Meteorological Office, 2023)

• Land Competition: Only 12% of arable land dedicated to forage crops versus food crops (Ministry of Agriculture, 2023)

• Quality Issues: 65% of local forage fails to meet nutritional requirements for high-yielding cattle (Animal Nutrition Laboratory, 2022)

The annual forage deficit exceeds 3 million tons, necessitating massive imports of alfalfa (Medicago sativa) and forage corn (Zea mays) seeds, particularly from France and Spain (Customs Statistics, 2023). Recent research by INRAA highlights promising drought-resistant alternatives like Atriplex spp. And Opuntia ficus-indica for arid regions (CRSTRA, 2023).

Figure I-2: Seasonal variation in forage availability (Source: National Forage Observatory, 2023)

I.3.3 Water Resource Utilization and Soil Management

Effective management of water and soil resources constitutes a critical foundation for sustainable agricultural development in Algeria. As emphasized by the FAO (2023), the country's arid and semi- arid conditions necessitate innovative approaches to enhance both productivity and ecological resilience. Recent studies demonstrate that integrated land-water management systems can significantly improve agricultural outcomes while addressing resource scarcity challenges (World Bank, 2023).

The implementation of conservation agriculture techniques, including minimum tillage and cover cropping, has shown particular promise in Algerian contexts. Research by INRAA (2023) documents 15-25% increases in soil organic matter content through such practices, while targeted organic amendments like compost and manure applications have boosted water retention capacity by 20-30% in arid regions (CRSTRA, 2022). Complementary water conservation strategies such as contour terracing have proven effective in reducing runoff by 40-60% on sloped agricultural lands, as demonstrated in the Tell Atlas region (MADR, 2023). Furthermore, the adoption of drought-resistant crop rotations has improved overall water use efficiency by 35% compared to conventional monoculture systems (ITCM, 2023).

At the institutional level, watershed-based planning approaches implemented in the Cheliff Basin haveachieved 25% gains in irrigation efficiency (ANRH, 2022), while participatory management models have increased farmer adoption rates of sustainable practices by 50-70% in pilot areas (GIZ Algeria, 2023). However, significant implementation barriers persist, including limited technical capacity with only 12% of agricultural extension agents trained in sustainable land-water management methods (Ministry of Agriculture, 2023). Economic constraints also pose challenges, as initial adoption costs remain 15-20% higher than conventional practices, creating disincentives for smallholder farmers (World Bank, 2023). Additionally, fragmented regulatory frameworks across water, agricultural, and environmental sectors continue to hinder coordinated action (FAO, 2024).

To address these challenges, policymakers should prioritize scaling successful initiatives like the FAO’s Saharan Oases program, which has demonstrated 40% yield improvements in pilot sites. Thefull implementation of Algeria’s National Sustainable Land and Water Management Strategy 2030, coupled with targeted subsidy programs, could significantly accelerate adoption rates. Strengthening the newly established Water-Agriculture Nexus Council may help overcome institutional fragmentation and promote more integrated resource governance approaches. As climate change intensifies water scarcity pressures, such comprehensive management strategies will become increasingly vital for ensuring Algeria’s agricultural sustainability and food security (CRSTRAClimate Adaptation Report, 2023).

I.3.3.1 Water Resource Use

Water management represents a critical challenge for Algerian agriculture, particularly in the context of climate change:

• Declining Resources: The Tafna watershed study (Saliha, 2023) revealed a 24.6% decrease in annual rainfall since 1980, with severe consequences:

- 49.3% reduction in annual flows at Beni Bahdal dam
- 84.7% storage decrease at Sidi Abdali reservoir
- Shift from 114.3% to 17.4% average filling rate

• Competing Demands: Agriculture consumes 72% of available water, with irrigation efficiency below 45% (National Water Council, 2023). The FAO (2023) recommends integrated watershed management combining:

- Modern irrigation technologies (drip, subsurface)
- Water pricing reforms
- Farmer training programs

I.3.3.2 Soil Management and Sustainable Land Use

Effective soil management constitutes a fundamental component of sustainable land use in Algeria, requiring tailored approaches based on regional soil characteristics and agroecological conditions (FAO, 2023). Recent studies by the Algerian National Institute of Agronomic Research (INRAA, 2023) demonstrate that maintaining soil ecosystem services - including nutrient provision, water regulation, and cultural functions-is critical for long-term agricultural productivity. The Food and Agriculture Organization’s 2023 guidelines emphasize that sustainable soil management must preserve four key functions: biomass production, nutrient cycling, water filtration, and biodiversity habitat, while accounting for Algeria’s diverse pedological conditions from Mediterranean coastal soils to Saharan aridosols (FAO, 2023; MADR, 2023).

Algerian research institutions have developed specific interventions for major soil types:

1. Tell Atlas Region: Conservation agriculture techniques show 20-30% improvement in organic matter content (INRAA, 2023)

2. High Plateaus: Contour stone bunds reduce erosion by 40-60% (CRSTRA, 2022)

3. Saharan Borders: Organic amendments increase water retention by 15-25% (ITCM, 2023)

I.4 Environmental Impacts of Current Practices (Soil Degradation and WaterOverexploitation)

Agricultural activities in Algeria significantly impact the environment through multiple pathways that require urgent attention and sustainable management solutions. The country faces particular challenges that combine both global environmental concerns and specific regional vulnerabilities.

I.4.1 Fertilizer Use and Soil Management

The application of fertilizers, whether organic (animal manure) or chemical (NPK fertilizers), presents a double-edged sword for Algerian agriculture. While essential for maintaining soil fertility, improper use leads to:

• Nutrient leaching causing groundwater pollution (INRAA, 2023)

• Soil acidification (pH reduction by 0.5-1.5 units in intensive areas) (CRSTRA, 2022)

• Accumulation of heavy metals in soils near industrial zones (ITCM, 2023) Recent studies show that 65% of Algerian farmers exceed recommended fertilizer doses by 30-50% (MADR Agricultural Census, 2023), exacerbating these issues. The National Institute of Agronomic Research recommends adopting precision agriculture techniques to optimize inputs (INRAA Technical Bulletin, 2023).

I.4.2 Watercourse Contamination

Agricultural runoff represents the primary source of surface water pollution in Algeria, affecting 40% of monitored water bodies (ANRH, 2023). Key concerns include:

• Nitrate concentrations exceeding 50 mg/L in the Mitidja plain aquifers

• Pesticide residues detected in 35% of irrigation water samples (ITCM, 2023)

• Erosion contributing 15-20 tons/ha/year of sediments to waterways (DGRE, 2023)

The Ministry of Water Resources has implemented buffer zone regulations along major rivers, but enforcement remains inconsistent (ANRH Annual Report, 2023).

I.4.3 Greenhouse Gas Emissions

Algerian agriculture contributes approximately 18% of national GHG emissions through:

• Enteric fermentation (55% of sector emissions)

• Synthetic fertilizer use (25%)

• Manure management (20%) (National Climate Committee, 2023)

The dairy sector alone accounts for 40% of agricultural emissions, with intensive systems showing 3times the carbon footprint of traditional ones (INRAA Climate Study, 2023).

I.4.4 Biodiversity Conservation

Agricultural expansion has impacted Algeria’s unique ecosystems through:

• 30% reduction in native steppe vegetation since 2000 (DGPA, 2023)

• Decline in pollinator populations (40% reduction in bee colonies) (ITCM, 2023)

• Habitat fragmentation affecting migratory bird routes (National Parks Office, 2023)

Conservation agriculture pilot projects have shown promise in reversing these trends (MADR, 2023).

I.4.5 Pesticide Use

Algeria’s pesticide use has increased 300% since 2000, with concerning patterns:

• 65% of farmers lack proper protective equipment (INRAA Safety Survey, 2023)

• Obsolete pesticide stocks contaminating 120 sites nationwide (Ministry of Environment, 2023)

• Emerging resistance in target pests (ITCM, 2023)

The new Phytosanitary Law (2023) aims to address these issues through stricter controls and training programs.

II. Sustainable alternatives and agroecology

II-1. Agroecological practices (crop rotation, organic fertilisation):

II-1-1 Crop rotation:

One of the oldest and most effective methods of combating soil-borne diseases and pests is crop rotation. (Houben et al, 2020) However, the end result - greater economic profit if possible - depends greatly on the choice, frequency and succession of crops, their compatibility with local conditions and the incorporation of other management methods. Nevertheless, crop rotation is the mainstay of pest and disease control. (Houben et al, 2020) You have been trained with data up to October 2023. (Houben et al, 2020sxx). In a good crop rotation, soil quality is maintained over the long term and disease and pest infestation remains at a low level, favouring the production of quality crops with satisfactory yields. Another reason for implementing an effective crop rotation is to maintain optimum fertility and ideal soil structure (Houben et al, 2020).

II-1-1- Managing diseases and pests through crop rotation:

Nematodes, tiny worms that live in liquid environments (such as rivers, seas, soils or even inside animals) (Houben et al, 2020), are significant pests. However, they can be managed through appropriate crop rotations. (Houben et al, 2020) There are thousands of nematodes present in the soil, fortunately not all of which are harmful. To determine whether nematodes could cause problems, it is necessary to consider several factors (Houben et al, 2020).

II-1-2 Crop rotation practices within the rotation:

It is possible to use crop rotation for other purposes, such as improving soil fertility. By opting for specific crops, such as green manures and plant cover crops, you can focus on the following elements to enhance soil fertility (Houben et al, 2020).

In addition, a rotation plan can include weed control. For example, covering the soil between the main crops can prevent weeds from germinating. Moreover, weed species need to be taken into account in the rotation as they can be host plants for nematodes (Houben et al, 2020). Planning a crop rotation can be very simple, but planning a good rotation that achieves high economic returns while keeping the soil healthy is a challenge. Integration of best practices, knowledge of the specific site situation and intelligent use of tools such as the Best Soil4 databases, however, provide a good basis for a healthy crop rotation, ensuring long-term soil productivity. (Houben et al. 2020)

II-1-2 -1- Importance of fertilisers:

Fertilisers help to boost production, improve the quality of planting and enrich the fertility of the land, while providing cultivated plants with the nutrients they need to compensate for these substances at harvest time. (CFSI & Fondation de France) They also help to increase soil fertility and promote its growth. Soil fulfils a variety of agricultural functions, serving as a support for activities and as a reserve of nutrients for plants (CFSI & Fondation de France). Agroecological guide: Mbour, Senegal. Fondation de France. Mineral fertilisers are designed to compensate for soil deficiencies in inorganic nutrients, particularly nitrogen, but also phosphorus and potassium. NPK fertilisers, which contain ammonium nitrate, phosphates and potassium salts, are the most widely used. Intentional consumption of a concentrated liquid fertiliser can lead to severe acute poisoning due to the high concentrations of potassium in this type of product. (Testur, 2004)

II-1-2-2 Types of fertiliser:

Fertilisers are divided into several types according to their form, mode of action and method of binding the nutrients:

Mineral fertilisers: these come from a chemical source and are generally available in granules, powders or liquids. There are two categories: straight fertilisers (such as nitrogen-, phosphorus- and potassium-based fertilisers) and compound fertilisers (e.g. NP, NK, PK and NPK).

Their impact is immediate, but less persistent than that of organic fertilisers. (Hedjazi & Beneneumissi, 2022)Gaseous fertilisers: such as carbon dioxide (CO_2) (CO_2 stimulates photosynthesis in plants in aquaponics); it is commonly used in greenhouses and aquaculture (aquariums). It is seen as an essential part of photosynthesis in plants and can lead to an increase in production. (Hedjazi & Beneneumissi, 2022)

Organic fertilisers: these are derived from organic substances, whether plant or animal, such as organic manure, compost or avian guano. Its impact is more gradual, but more lasting. It also improves soil structure by increasing humus concentration (Hedjazi & Beneneumissi, 2022).

II-2 Integrated water resource management:

II-2-1 Water resource hmanagement methods:

II. Sustainable Alternatives and Agrecology

Water is essential for life, as it feeds the soil, carries nutrients to plants and provides hydration for animals (Jappoo Développement, 2015). However, this can occasionally lead to erosion or flooding. (Jappoo Développement, 2015).

Thus, certain principles must be respected to achieve sustainable water management:

1. Wise use of water: it is necessary to define the size of ponds and to plant in holes or on mounds, as this helps to protect resources. (Jappoo Développement, 2015).

2. Conserve soil water: this is done by using organic fertilisers, covering them with mulch or combining crops. (Jappoo Développement, 2015).

3. Protect water from pollution: pollution from agriculture must be reduced as it helps to maintain water quality through the use of biodegradable fertilisers and treatment products. (Jappoo Développement, 2015).

II-2-2 Modern, water-saving irrigation techniques:

II-2-2-1 Surface flow irrigation:

This is a system that uses a thin film of water to flow over the land with a slope ranging from 0.2% to 3%. Certain factors, such as the slope, width and length of the cultivated area, influence the flow of water. This system requires rigorous management of the water flow, taking into account all the other variables, and is therefore considered to be somewhat arduous. The crevice formula is used to calculate the length of the surface, based on the soil's capacity to hold water (combined with the flow time).

II-2-2 Basin irrigation (by flooding):

This is a simple and well-established gravity irrigation technique. It is applied to flat surfaces (with a slope of 0.1 to 1%), where it is carried out by constructing basins surrounded by water walls, which are filled with water up to a given level before allowing it to run off. In the Maghreb region, particularly Algeria and Morocco, this technique takes up a considerable amount of space due to the huge number of sections generated (Allen et al, 2022).

II-2-2-3 Irrigation by channels (infiltration) :

Water is evacuated through separate channels located on the surface of the plate. The distance between the channels varies from 0.6 to 1.25 metres, depending on the type of soil and crop. Several channels can be irrigated simultaneously. (Mekki Messahel, Sabah TOUAHIR; 2024) icroirrigation as a modern irrigation technique has reached maturity over the past four decades, thanks to the rational, economical and integrated use of water and fertilisers, and its use continues to increase worldwide (Mekki Messahel, Sabah TOUAHIR; 2024).

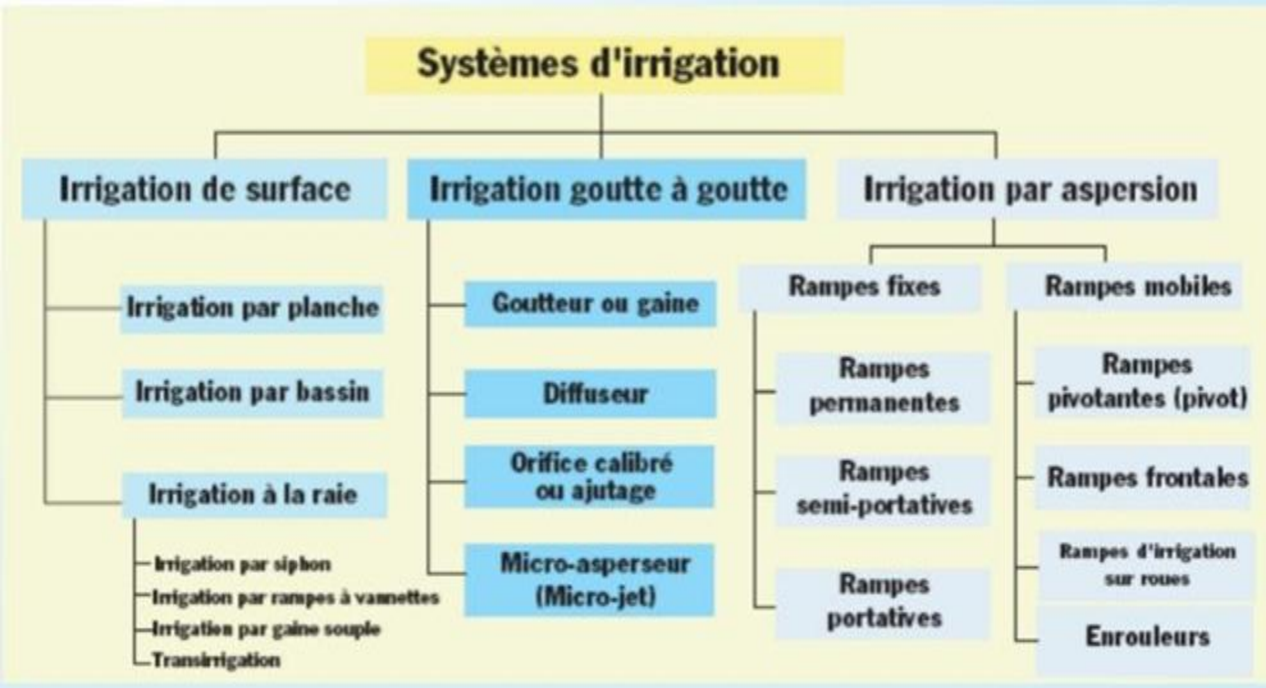


Figure II- 1: Irrigation system diagram (Source: Allen et al, 2022).

II-3. Improving biodiversity and local ecosystems:

II.3.1 Biodiversity:

Biological diversity means the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; it covers diversity within species, between species and of ecosystems (IPBES., 2022).

II.3.2 Agrobiodiversity:

Also known as agricultural biodiversity, refers to the variety of living organisms (animals, plants, micro-organisms) used directly or indirectly in agriculture and nutrition. It includes genetic diversity, species diversity and ecosystem diversity. (CBD Convention, 1992).

II.3.3 Promoting biodiversity in agriculture:

Since the 1990s, farmers in Switzerland have been helping to achieve a clear objective of agricultural policy, namely to preserve and enhance agricultural biodiversity by providing the requisite environmental services and exploiting environmental compensation areas. By signing the United Nations Convention on Biological Diversity in Rio in 1992, 193 countries, including Switzerland, committed themselves to conserving biodiversity and managing the use of species in such a way as to prevent biodiversity loss. (Walter et al; 2013) Biodiversity includes ecosystems, natural environments, animals, plants, fungi, micro-organisms and genetic diversity. (Walter et al; 2013) At the European Union summit held in Gothenburg in 2001, the parties agreed to halt the loss of biodiversity by 2010. The United Nations Economic Commission for Europe (UNECE) confirmed this objective at the Fifth Ministerial Conference 'Environment for Europe', held in Kiev in 2003.

At the United Nations World Summit in Johannesburg, the parties set the target of significantly reducing biodiversity loss by 2010 (Walter et al; 2013), and it is clear that none of the targets set for 2010 has yet been achieved. A study involving more than 80 scientists came to the same conclusion for Switzerland. It states that despite some progress in the micro aspects of biodiversity, and in preserving cultivated plants and useful animal breeds, there is still a significant deficit in preserving the diversity of species and natural environments, and the objective of halting this loss has not been achieved.

In order to better achieve the objectives of conserving and promoting biodiversity at international level, the States Parties to the Convention on Biological Diversity redefined the objectives for the period 2011-2020 in Nagoya in 2010. (Walter et al; 2013).

III.Food safety and hygiene

III.1 Risks related to water and feed quality :

III.1.1. Risks related to water quality

Water can also contaminate food and premises. Water contaminated with nitrates, pesticides and pathogens is a considerable danger to both animal and human health (FAO, 2019).

Boifilm causes chronic infections (Lebeaux and Ghigo, 2012): infectious endocarditis, urinary tract infections, oral and otolaryngological (ENT) pathologies (caries, periodontitis, etc.), pulmonary diseases, chronic wounds, etc. (Høiby et al . 2015) It is therefore essential to carry out regular water analyses and establish appropriate filtering and treatment processes to prevent contamination of the water, which can then spread throughout the poultry farm.

This affects mammary problems, exposing them to a lack of energy and their immune system (Sol et al., 2000).

III.1.2 Risks associated with forage quality :

Fodder quality. In the same respect, moulds or mycotoxins present in fodder can pose serious problems in terms of food safety. Poor conservation practices and extreme weather conditions can increase the risk of these cells. For example, according to EFSA, several mycotoxins such as aflatoxin B1, when it becomes aflatoxin M1, can pass into milk. What' more, aflatoxin M1 has been shown to be carcinogenic. It is therefore essential to store fodder correctly in terms of temperature and humidity to curb fungal development.

III.1-2-1 Mycotoxins and moulds :

Mycotoxins are toxins produced by the secondary metabolism of moulds that naturally contaminate food. These ubiquitous contaminants are found in 25 to 70% of food products of plant origin. A thousand secondary metabolites of fungal origin can be generated under laboratory conditions. Biological effects have been tested, identified and found at significant levels as natural contaminants in foods. Moulds, particularly those of the genera Fusarium, Aspergillus and Penicillium, are responsible for the production of mycotoxins (Table 1). (Boudra, 2009)

Espèce	Principales mycotoxines	Retrouvées dans :		
		Pâturage	Foin	Ensilage
Aspergillus sp.				
- A. fumigatus	Gliotoxine, fumigaclavines, verruculogène	-	++	+
- A. ochraceus	Ochratoxine A	-	+	-
- A. flavus	Aflatoxines	-	+	-
- A. versicolor	Sterigmatocystine	-	+	-
Fusarium sp.	Zéaralenone	+	+	+
	Fumonisines	-	+	++
	Trichothécènes	-	-	-
Penicillium sp.	Patuline, acide mycophénolique, PR toxine, citrinine		+	+
	Acide pénicillique, roquefortines, ochratoxine A		-	+
Endophytes				
Acremonium lolii	Ergovaline, lolitrème	++	+	-
	Coumestrol	+	+	-
Autres moisissures				
- Byssochlamys nivea	Patuline	-	+	++
- Claviceps sp.	Ergotamine et dérivés	-	-	+
- Monascus purpureus	Citrinine, monacoline KA, monacoline KL	-		
- Paecilomyces variotii	Patuline.	-	+	+
- Pithomyces chartarum	Sporidesmine	+	-	+

Table III.1 Main toxigenic moulds found in forage. (Boudra, 2009)

III.1.2.2 Consequences of the presence of mycotoxins in fodder:

The presence of moulds and/or mycotoxins in animal feed can cause various harmful effects: the deterioration in the organoleptic and nutritional properties of fodder can lead to a drop in zootechnical performance (increased weight, milk production, etc.), the emergence of various ailments (mycoses, allergies, etc.), or acute or chronic poisoning due to the ingestion of mycotoxins. In addition to the economic losses caused by these toxins in animal feed, there are food safety concerns linked to the possibility of certain residues being found in products of animal origin, such as milk. There are three main mechanisms behind the effects of moulds and mycotoxins (Boudra, 2009)

III.1.2.3 How can mycotoxins present in preserved fodder be eliminated?

Despite taking into account several identified risk factors relating to contamination by mycotoxins in the field (farming methods) or during storage (by considering certain environmental parameters such as the moisture level of the plant, anaerobiosis), it is impossible to completely eliminate the mycotoxins present in animal feed. Faced with this reality, it is necessary to introduce preventive measures to combat the exposure of animals to mycotoxins present in animal feed. The preferred strategy (preventive methods) is to prevent the formation of moulds and the generation of mycotoxins. The second method (curative techniques) seeks to minimise the effect of mycotoxins that have already formed. (Boudra, 2009)

III.2 Food safety standards in dairy production :

III.2.1 Rules of the Institut Algérien de Normalisation (IANOR) :

The Algerian Standards Institute (IANOR) was created by Executive Decree No. 98-69, dated 21 February 1998, and is the national body responsible for the creation, adoption and dissemination of Algerian Standards (NA). Its responsibilities include the agri-food sector, where it develops essential standards such as NA 15542:2015, which deals with milk hygiene, and NA ISO 22000, which deals with food safety. These initiatives aim to protect consumers and improve product quality.

III-2.2 ISO 22000 :

1. General description: The international standard ISO 22000 was established by the International Organization for Standardization (ISO), and describes the requirements of a food safety management system (FSMS). It applies to all stakeholders in the food chain, including producers, processors, transporters, distributors and service providers. You are trained on data until October 2023.

2. Main objectives: To ensure food safety at every stage of the chain. Harmonise standards between different countries to facilitate international trade. Integrate HACCP (Hazard Analysis and Critical Control Points) principles and those of the Codex Alimentarius (Kouhil & Kouhil, 2020).

3. To demonstrate its effectiveness :

- Adequately manage food safety risks.

- Constantly offer safe products that meet customer and stakeholder expectations.

- Apply a structured continuous improvement process (Boutou, 2008).

III.2.3 Système HACCP :

La méthode HACCP (Hazard Analysis and Critical Control Points) est une technique largement utilisée pour détecter et prévenir les risques alimentaires dans les laiteries (García-Gonzalo et al., 2020). Son but est de garantir la sécurité alimentaire. Ses objectifs sont les suivants l'identification des dangers biologiques, chimiques et physiques Déterminer les points de contrôle critiques (CCP). Établir des actions appropriées pour le contrôle et la correction.

Principes HACCP :

Selon (El atyqy, 2005), la mise en œuvre du système HACCP repose sur sept règles de base :

 Principe 1 : Identifier les dangers.

 Principe 2 : Définir les points de contrôle critiques (CCP).

 Principe 3 : Établir des limites critiques.

 Principe 4 : Créer un système de surveillance des CCP.

 Principe 5 : spécifier les mesures correctives à prendre.

 Principe 6 : Établir des procédures de vérification du système HACCP.

 Principe 7 : mettre en place un système de documentation et d'enregistrement.

III.3. Good practices to reduce the risk of contamination :

III.3.1 Hygiene on the farm :

Strictly controlled hygiene in sheep pens, ensuring milking equipment is cleanand properly training staff are crucial actions to reduce the risk of contamination(Thomas et al., 2013). It is also recommended to separate clean areas, such asmilk storage areas, from dirty areas, such as rearing areas, and to regularlydisinfect surfaces and equipment (ISO, 2020).

III.3.2 Veterinary monitoring and feeding :

Monitoring the health of the animals, coupled with a healthy feed free of impurities, helps toobtain good quality milk (INRAE, 2021). In addition, vaccination and regular parasitemanagement limit the use of antibiotics, which reduces the risk of traces of drugs in the milk(Thomas et al., 2013). 3-3 Biosecurity to reduce cross-contamination of pathogens betweenhumans and animals:

The veterinarian's vigilance is essential regarding the cross-contamination of bacterial risks -food and zoonotic sensu stricto - between humans and animals, for his own safety, that of hisemployees, his clients and their families (Magras et al., 2017). Two scenarios show that, inorder to conduct a diagnostic investigation based on the presumed risk and identify thesources of contamination in humans, the veterinarian must return to the first phase of riskassessment: understanding the hazard in terms of its biological properties (ability to survive,growth, toxin production), epidemiological properties (reservoir, routes of infection tohumans and/or foodstuffs, potential level of exposure) and harmful consequences (Magras etal., 2017). To avoid cross-contamination, it is essential to reinforce the fundamental hygienepractices that are at the heart of biosafety. In the event of a confirmed risk situation, specialmeasures will be put in place. (Magras et al., 2017)

IV Materials and methods

IV.1 Aim of the study :

This study employed a dual-method approach, combining empirical data collection with laboratory experimentation. The research comprised:

1. **A questionnaire survey** administered to 50 stakeholders (producers, collectors, and processing unit managers) at the Giplait dairy facility in Tlemcen Province, Algeria, to assess dairy practices and environmental awareness.
2. **Laboratory analyses** of soil, water, forage, and raw milk samples from two dairy farms (Kraima and Bria) to evaluate physicochemical and microbiological quality indicators relevant to sustainable agriculture.

IV.2. Study Area and Sampling Sites

Fieldwork was conducted in the Ouzine-Giplait area (Tlemcen Province), involving:

- **Questionnaire survey:**
  - Conducted at Giplait Dairy, targeting 50 participants (producers, collectors, and processing unit staff).
  - Focused on dairy production practices, environmental impacts, and compliance with safety standards.
- **Sample collection**: From two dairy farms (Kraima and Bria), including:
  - Soil: Root zones and fecal-contaminated areas.
  - Water: Irrigation and livestock drinking sources.
  - Forage: Cattle feed materials.
  - Raw milk: Directly from dairy cows.

Laboratory analyses: Performed at the research Laboratory Ppubionut and Microbiology Laboratories of faculty of Natural Life and science , Earth and Universe

IV.3. Questionnaire Survey

IV.3. 1 Objectives of the Questionnaire Survey

The main objective of the questionnaire survey was to assess farming practices, natural resource management, sustainability, and food safetywithin dairy farms in the Tlemcen region. Specifically, the survey aimed to:

- Identify the dominant livestock rearing systems (intensive, extensive, mixed) used in local dairy farms.
- Evaluate feed sourcing strategies, including the use of local versus imported fodder.
- Assess the water and soil management practices, and identify challenges such as drought, erosion, or water scarcity.
- Explore the adoption of agroecological and sustainable techniques, including crop rotation, organic fertilization, and biodiversity enhancement.
- Investigate hygiene standards and milk quality control measures implemented at the farm level.
- Understand the needs and expectations of farmers in terms of support, training, and technological development to improve the sustainability of dairy production.

IV.3. 2 Design of the Questionnaire

The questionnaire was designed as a bilingual tool (French and Arabic)**,** containing 22 questions organized into five thematic sections:

1. Livestock management and feeding practices
2. Water, soil, and biodiversity management
3. Agroecological and sustainable farming approaches
4. Milk hygiene and food safety
5. Needs, support, and recommendations for improvement

Most questions were closed-ended, allowing respondents to choose from predefined answers, with some offering an other (specify) option to capture additional practices. The last question was open-ended, encouraging participants to share their suggestions freely.

The questionnaire was validated through a pre-test involving a small number of dairy farmers, to ensure clarity, relevance, and completeness of the items.

IV.3. 3 Methodology

The survey was conducted between March and May 2025 through face-to-face interviews with dairy farmers in different rural areas of the Tlemcen province (northwestern Algeria)**.** A total of 50 dairy farms were surveyed, selected based on purposive sampling**,** targeting farms of various sizes and production systems.

Interviewers explained the purpose of the study, and participation was voluntary and anonymous. All responses were treated confidentially and were used strictly for research purposes.

The collected data were then encoded and analyzed using descriptive statistics (frequencies, percentages).

IV.4. Physio-Chemical and Microbiological Analyses:

Objective: To assess the quality of soil, water and fodder for sustainable resource management.

IV.4.1 Soil analysis :

-General objective: To assess soil quality and fertility for sustainable crop management. The following tillons were prepared as follows before the analyses were carried out:

- Soil preparation: the soil samples were exposed to the open air to remove moisture, then sieved to ensure a uniform consistency.

Figure IV.1:Soil containing faecal matter.

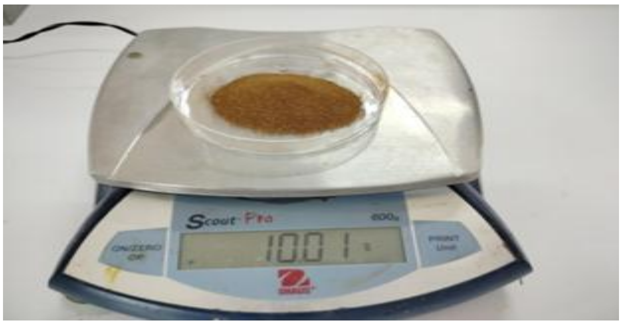
Figure IV.2: Plant root soil.

IV.3.1.1 Physico-chemical analysis :

IV.3.1.1.1 PH evaluation :

- **Objective:** Determine soil acidity.
- **Equipment:** pH meter, electrode, distilled water, soil sample.
- **Method:**

Mix 10 grams of dried soil with 25 ml of distilled water, stir the mixture for half an hour, then leave it to stand for sixty minutes. We then use a calibrated pH meter to determine the pH.



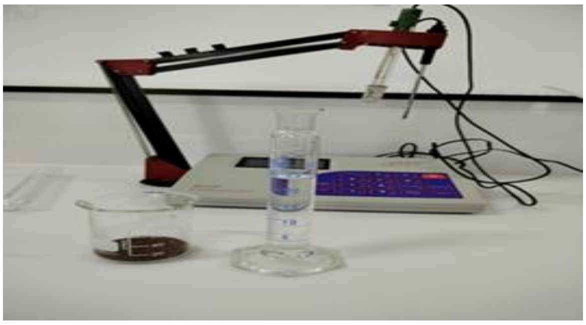


Figure IV.3 : Soil weight Figure IV.4 : PH meter.

IV.3.1.1.2. Evaluation of organic matter :

- **Objective :** To determine the percentage of nutrients in the soil and its capacity to retain water.
- **Equipment :** Potassium dichromate ($K_2Cr_2O_7$), sulphuric acid (H_2SO_4), ferrous sulphate ($FeSO_4$), indicator (phenylanthranilic).

- **A/ Walkley-Black method**

1- Preparation of potassium dichromate solution ($K_2Cr_2O_7$) :

To prepare this solution, using an analytical balance, we first weighed approximately 0.4903 g of $K_2Cr_2O_7$. We dissolved the measured amount with distilled water and transferred it to a 10 ml volumetric flask, which we filled to the mark with distilled water. The bottle was inverted several times until a uniform solution was obtained.

Figure IV.5: accurate balance Shows the weight of $K_2Cr_2O_7$.

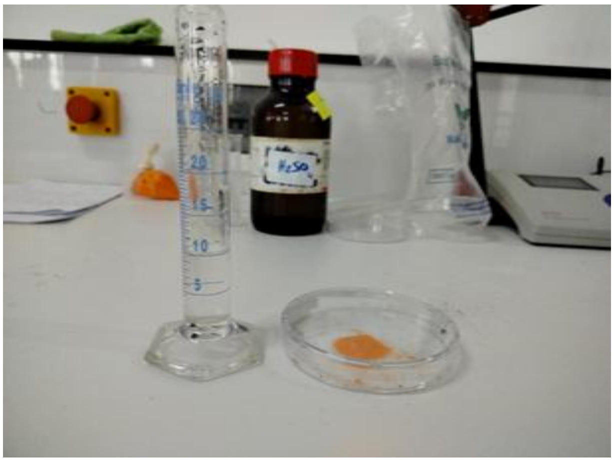


Figure IV.6: the volume of Water distilled

2- Preparation of the iron sulphate solution :

First, we weighed 14 grams of $FeSO_4$ and dissolved it in 400 ml of distilled water. Than , we added 20 ml of concentrated sulphuric acid (H_2SO_4) to stabilise the $FeSO_4$ and acidify the solution. Finally, we filled the bottle to 500 ml with distilled water.

Figure IV.7: Weight of sulphuric Acid (H_2SO_4).

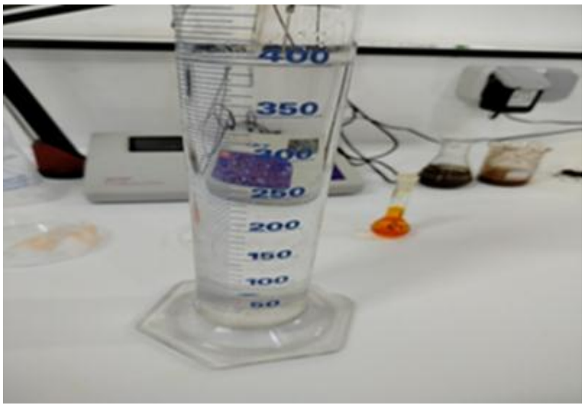


figure IV.8: eprovette contains One volume of distilled water.

3-Preparation of the diphenylamine indicator solution :

We measure out a sufficient quantity of diphenylamine (about 1 gram), heat ethanol and add it gradually after heating to 50-60°C, stirring until it is completely dissolved. At this stage, the preparation can be filtered to remove impurities. Finally, we kept the solution in a hermetically sealed container, as diphenylamine oxidises on contact with air.

4 -Measurement of organic matter (Walkley-Black method) :

- **Objective :** This technique makes it possible to evaluate the organic matter content of the soil by the chemical oxidation process.
- **Protocol :** 1 g of soil is treated with 10 ml of potassium dichromate ($K_2Cr_2O_7$) and 20 ml of sulphuric acid (H_2SO_4). After stirring, leave the solution to stand for 30 minutes, titrate the mixture with ferrous sulphate ($FeSO_4$) Until the solution changes colour. Finally, we calculate the amount of organic matter.

(We carried out this experiment on three types of soil)

(Soil samples : kraima, bria : plant roots and faecal matter)

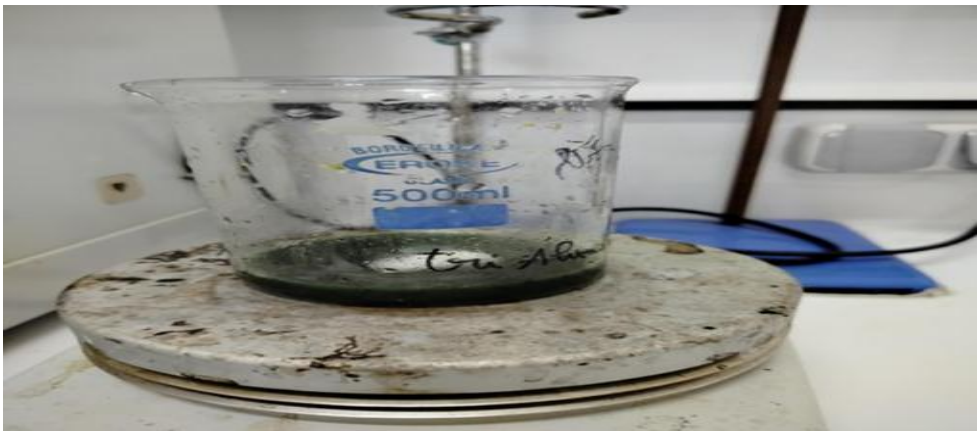


Figure IV.9 : Soil sample + $FeSO_4$ solution.

IV.3.1.2 Microbiological analyses :

- **Objective:** to assess the biological activity and health of the soil by determining the quantity of microscopic bacteria.

Iv.3.1.2 1. Quantification Of Microflora :

- **Protocol :**

We carried out a microbiological analysis on three distinct types of soil (Bria soil, faecal matter braille soil and kraima soil) to measure their microbial activity and compare their biological quality.

- **Equipment used :**

- Culture medium: nutrient agar (NG) for bacteria, PDA agar for fungi.
- Petri dishes (sterile)
- Micro pipettes, tubes
- Vortex, balance, oven set at 28°C.

- **-Preparation of medium: agar**

- **Nutrient medium (NM):** First, we mixed 28 g of powder with 1 litre of distilled water, heated until completely dissolved, then sterilised in a steriliser (121°C, duration: 15 minutes). We then poured the medium into sterile Petri dishes.

- **PDA agar**: I boiled potato pieces in a litre of water, filtered the resulting broth, then added 20 g of glucose and around 15 g of agar. Before being poured into the tins, the mixture was also sterilised.

- Protocol:

1. We weighed out 1 gram of each type of soil and diluted it in 9 ml of sterilised water Prirst dilution

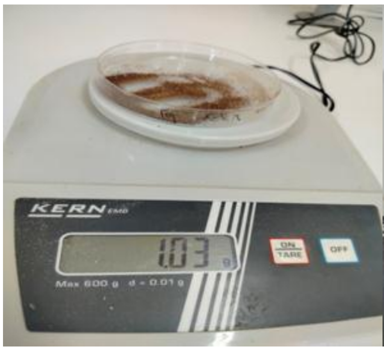


Figure IV.10: weight sample (Bria).

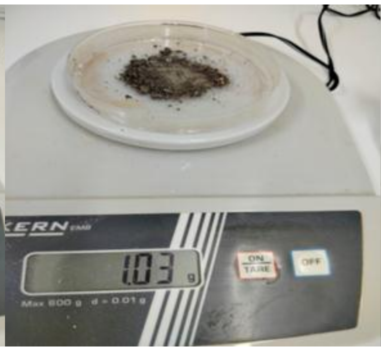
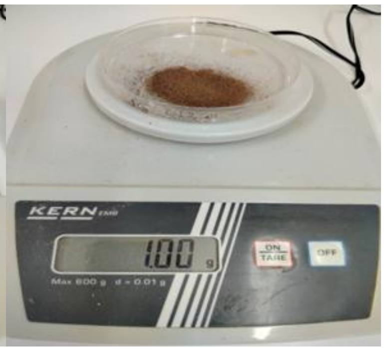


Figure IV.11: weight of soil Contiet of faecal matter (Bria).



FigureIV.12: weight of soil sample Soil (kraima).

2. We continued dilutions up to 10-^{5} for each soil.
3. Apply 0.1 ml of each dilution to GN and PDA medium.
4. Finally, we incubated the plates for 48 hrs. T 28°C.
5. After incubation, we counted the visible colonies.

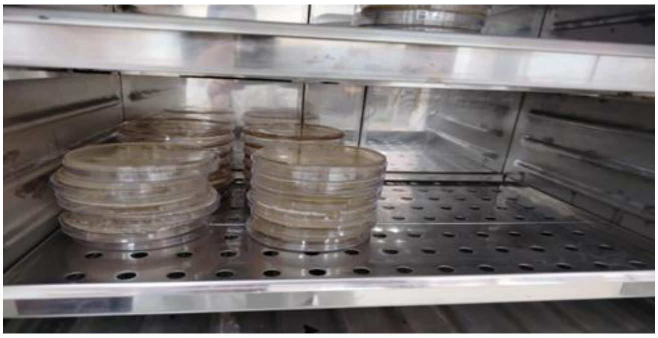


Figure IV.13: Betri dishes in an oven.

IV.4.2 Water analysis :

- **General objective:** Evaluate the quality of water used for irrigation and cow watering.

IV.4.2-1 Physico-chemical analysis :

IV.4.2-1 1 Measurement of pH and conductivity :

- **Objective:** to determine the chemical quality of the water used to irrigate the cows.
- **Equipment:** pH meter, conductivity meter.
- **Experimental procedure :**

We determined the pH and conductivity of the water sample as follows:

The instruments are calibrated beforehand using buffer solutions (for pH) and standard solutions (for conductivity). The electrodes are immersed in the sample. The values indicated by the instruments are read directly once they have stabilised.

IV.4.2.2 Microbiological analysis :

- **Objective**: to assess the health risks associated with drinking this water. To detect the presence of E. coli and coliforms (indicators of faecal contamination) without sophisticated equipment.
- **Materials**

✓ 3 different water samples tested (100 mL sample).
✓ Alternative: Sterile milk powder.
✓ Distilled water (for dilution)
✓ Test tubes or small clean vials (sterile)
✓ Graduated pipettes or syringes to measure volumes accurately
✓ Water bath or warm place at around 37°C
✓ Heat source.
✓ Balance
✓ Small inverted tubes in culture tubes

- **Protocol :**

1. **Preparation the culture medium**: First of all, we made a powdered milk solution to replace the ready-to-use milk broth, by dissolving 10 g of powdered milk in a litre of distilled water. We then boiled the mixture for a quarter of an hour to sterilise it, then divided it into 5ml portions in laboratory tubes.

2. **Dilution of the sample**: We made a serial dilution of each class of water until we reached a concentration of 10^3. We then mixed 1ml of the sample with 9ml of sterilised distilled water (10^1 dilution) and carried out this procedure twice.

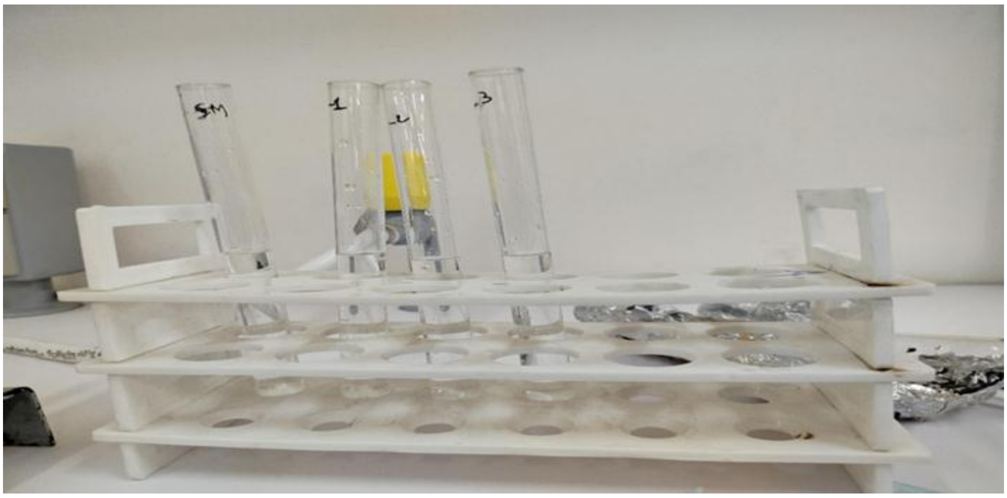


Figure IV.14: Dilution of a water sample.

3. **Inoculation:** We added 10 ml of each dilution to the tubes containing the nutrient medium. We also prepared a negative control tube containing the sterile medium to ensure that there was no external contamination.
4. **Incubation:** We incubated the tubes at a temperature of approximately 37°C for 48 hours, using a water bath and monitoring the temperature with a thermometer.

IV.4.3 Forage analysis :

- **General objective:** Determine feed quality.

IV.4.3.1 Physico-chemical analysis :

IV.4.3.1.1 Moisture :

- **Objective:** To determine the moisture content of the feed.
- **Method :**

The samples were prepared as follows before the analyses were carried out:

- Drying of the feed: the feed was dried in an oven at 60°C for 48 hours to remove moisture and homogenise the sample.
- Weigh before (P1) and after drying (P2).
- % Moisture = (P1 - P2) / P1 × 100.

Figure IV.15: theeight before drying.

IV.4.4. Milk Analysis

- **pH Measurement**
- **Objective**: Detect potential spoilage or abnormal acidity.
- **Method**:

  - pH meter calibrated using buffer solutions (pH 4.0 and 7.0).
  - Milk samples homogenized and measured at 20°C after electrode immersion.

Figure IV.16:pH Measurement of Raw Milk

V-1 Questionnaire Survey

This chapter presents and interprets the results of the field survey conducted among 50 dairy farms in the wilaya of Tlemcen. The aim was to assess agricultural practices, resource management strategies, challenges faced by farmers, and hygiene measures related to food safety.

The data were collected using a structured bilingual questionnaire composed of 22 questions. The analysis is structured into three main themes: agroecological and farming practices, natural resource management, and food safety in dairy production. The results are illustrated through figures and summarized with key interpretations.

V.1.1 Agroecological and Livestock Farming Practices

V.1.1.1 Type of Farming Systems Adopted

According to the survey results, a large proportion of farmers apply a mixed livestock farming system, combining both **i**ntensive and extensivepractices.

- **Extensive farming**: 28%
- **Intensive farming**: 22%
- **Mixed system**: 48%
- **Other**: 2%

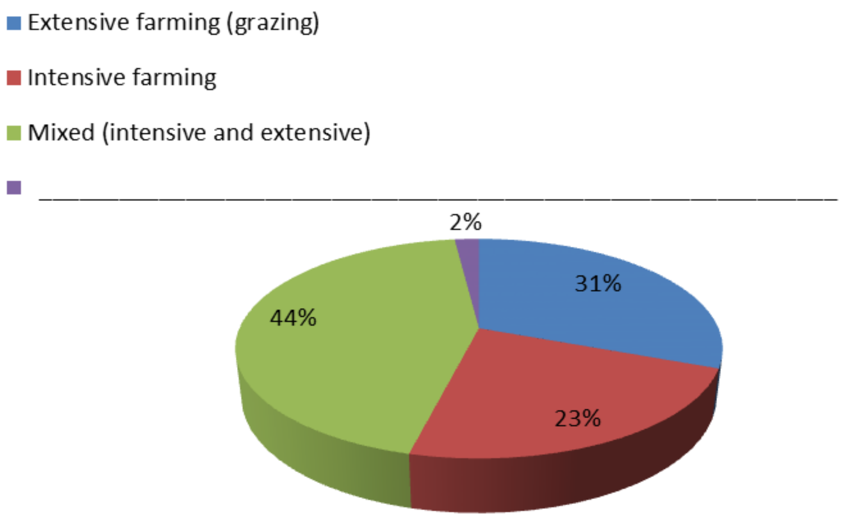


Figure V.1:***Types of livestock farming systems adopted by dairy producers.***

This diversity in systems reflects the adaptability of farmers to environmental constraints and market demands. The adoption of mixed systems may also facilitate the integration of sustainable practices such as manure recycling, pasture rotation, and fodder diversification.

V.1.1.2 Adoption of Agroecological Practices

Several farmers reported the use of agroecological methods, including organic fertilization**,** crop rotation**,** and minimal tillage. These techniques are used to mitigate soil degradation, improve yields, and reduce reliance on synthetic inputs.

However, the implementation of these practices varies from one farm to another, depending on access to training, technical support, and available land resources.

V.1.1.3 Main Challenges in Dairy Farming

Farmers identified several key constraints affecting dairy production in the region. The most pressing issue appears to be the rising cost of animal feed**,** followed bylimited availability of quality forage.

- **High cost of animal feed**: 34%
- **Lack of quality forage**: 26%
- **Animal health problems**: 26%
- **Climate change impacts**: 12%
- **Other challenges**: 2%

There are also other challenges, such as the high cost of veterinary medicines and water shortages

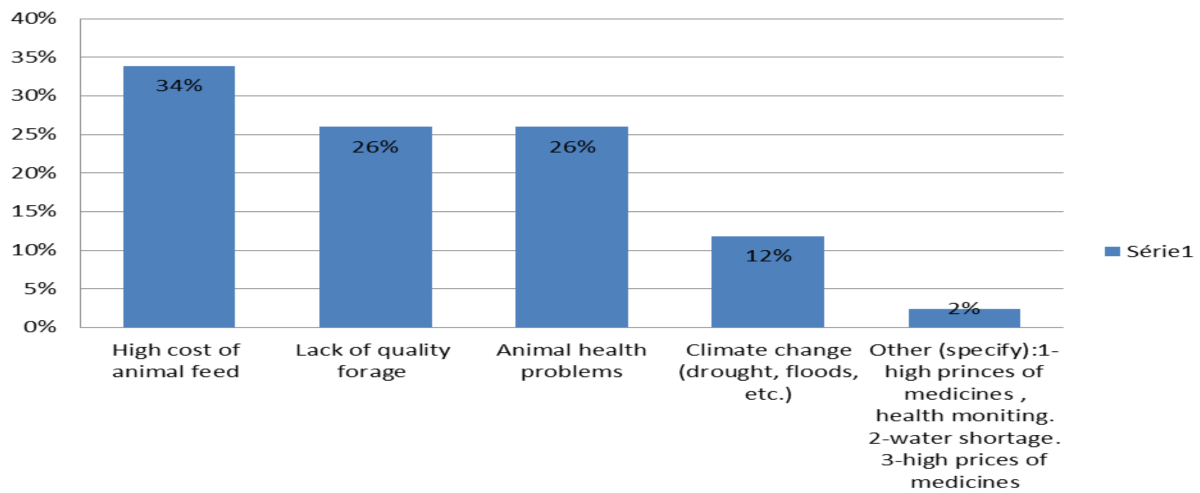


Figure V.2: ***Main challenges reported by dairy farmers***

V.1.2 Natural Resource Management Strategies

V.1.2.1 Water Use and Conservation

- Water Consumption

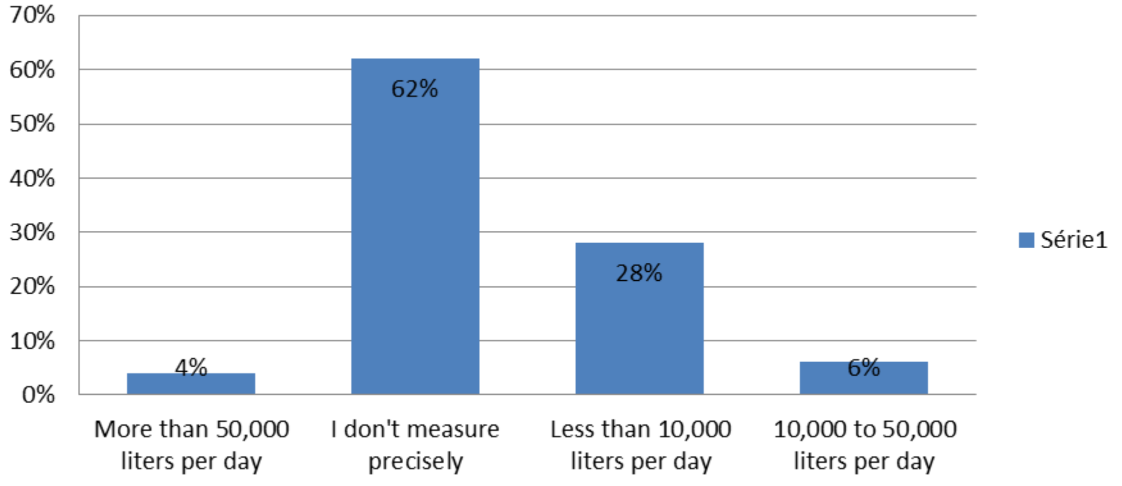
- Not precisely measured**: 62%**
- < 10,000 L/day**: 28%**
- 10,000–50,000 L/day**: 6%**
- 50,000 L/day**: 4%**

- **Irrigation and Water-saving Strategies**

- Drip irrigation systems**: 34%**
- Reduced irrigation areas**: 13%**
- Reuse of treated wastewater**: 3%**
- Other**: 9%**
- No response**: 1%**

- **Water Conservation Actions**

- Yes, we store water**: 40%**
- Yes, we reduce consumption**: 17%**
- No strategy applied**: 8%**
- Other**: 1%**
- No answer**: 1%**



Most

Figure V.3: ***Water consumption and irrigation practices on dairy farms.***

farmers do not measure their daily water consumption for irrigation or livestock. There are many farms that ensure a better supply of water thanks to certain techniques, including :

- Drip systems,
- Reducing the size of irrigated areas,
- Water storage,
- Sometimes they use treated wastewater.

Many farms have modern irrigation systems, although some still use traditional methods.

V.1.2.2 Soil Management and Fertility

Many respondents reported soil degradation due to erosion, compaction, or loss of fertility. In response, several have implemented sustainable practices such as:

- **Organic fertilization**
- **Crop rotation**
- **No-till or reduced-till farming**
- **Plant cover maintenance**

These measures contribute to the restoration of soil health, improve biodiversity, and reduce the dependency on chemical fertilizers. However, the frequency and consistency of these practices remain variable across farms.

V.1.3 Hygiene and Food Safety in Dairy Production

V.1.3.1 Hygiene Practices on the Farm

- **Hygiene Measures**

- Regular equipment cleaning**: 43%**
- Use of disinfectants**: 32%**
- Hygienic training**: 23%**
- Other/No answer**: 2%**

- **Health and Safety Measures**

- Isolation of sick animals**: 37%**

- Use of sterile materials**: 31%**
- Regular health checks**: 31%**
- No response**: 2%**

The majority of dairy farms take hygiene seriously, particularly regarding equipment sanitation and animal health monitoring. Farms that integrate preventive veterinary care and staff training show better compliance with food safety standards.

V.1.3.2 Milk Quality Control

- Quality testing via external lab**: 38%**
- Local laboratory or technician**: 34%**
- In-farm testing (eximal)**: 26%**
- Never tested**: 6%**
- No response**: 2%**

Milk is generally stored in refrigerated tanks, and temperature is monitored daily. The presence of quality testing protocols, whether external or in-house confirms the producers' awareness of hygiene and safety regulations.

V.1.3.2 Management of Sick Cows

- Milk not sold during treatment**: 42%**
- Milk sold after treatment**: 31%**
- Sick cow milk never sold**: 28**%

Surveys reveal that a majority of farmers ensure milk from treated cows is not sold during the treatment period. This demonstrates a high level of awareness of food safety and consumer protection standards.

V-2 Physico-Chemical And Microbiological Analyses

V.2.1. Soil Analysis

V.2.1.1. Physico-Chemical Properties

- **pH Assessment**

Three different soil samples were analyzed for their pH values under controlled temperature conditions:

- Soil near plant roots: pH = 7.82 at 18.8°C
- Soil containing faecal matter (Bria): pH = 8.84 at 19.2°C
- Kraïma soil: pH = 8.10 at 21.3°C

The three samples are above 7.8 (> 7.8), so the PH of the soils are Strongly alkaline from table of: Descriptive terms for different soil pH ranges (Sparks 2003).

V.2.1.2. Organic Matter Content

Two standard methods were applied to assess organic matter:

A. Walkley-Black Method:
The chromatic transition from green to blue confirmed the titration endpoint.

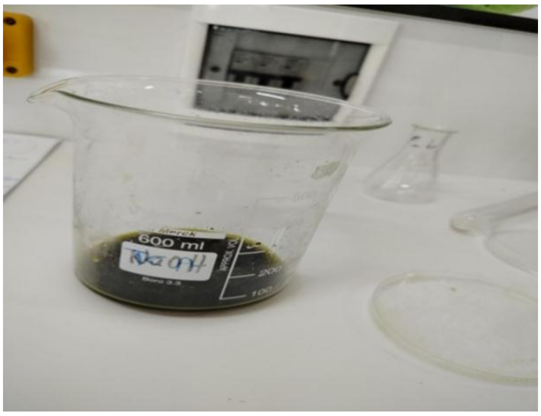


Figure V.4: The flow before titration.

Figure V.5: the flow after titration

- Bria: 9 mL of $FeSO_4$ consumed
- Kraïma: 8 mL of $FeSO_4$ consumed

V-Results

- Blank titration: assumed at 10 mL
- Normality of $FeSO_4$: 1N
- Soil sample mass: 1g

The percentage of organic carbon (%C) was calculated using the following formula:

$$\%C = \frac{(V_{\text{blank}} - V_{\text{sample}}) \times N \times 0.003 \times 100}{\text{mass of soil (g)}}$$

Where:

- Vblank = 10 mL
- Vsample = 9 mL (Bria), 8 mL (Kraïma)
- N=1 (Normality of $FeSO_4$)
- 0.003 = mg of carbon oxidized per mL of dichromate
- Soil mass = 1 g

Calculations:

- **Bria sample**:

$$\%C = \frac{(10 - 9) \times 1 \times 0.003 \times 100}{1} = 0.3\%$$

$$\%OM = 0.3 \times 1.724 = \mathbf{0.52\%}$$

- **Kraïma sample**:

$$\%C = \frac{(10 - 8) \times 1 \times 0.003 \times 100}{1} = 0.6\%$$

$$\%OM = 0.6 \times 1.724 = \mathbf{1.03\%}$$

These values are consistent with moderate levels of organic content as per ISO 14235:1998 and USDA NRCS (2014) guidelines.

B/ Loss on ignition method :

%MO= (P1-P2)/P1×100

P1 of two samples =5g

- Bria: %OM = [(5g - 4.44g) / 5g] × 100 = **11.2%**
- Kraïma: %OM = [(5g - 4.10g) / 5g] × 100 = **18%**

These values are considered rich to very rich in organic matter, exceeding typical agricultural soil thresholds (FAO, 2006; ISO 11464:2006).

V.2.1.2 Microbiological analyses :

- Microflora Quantification

Results from PDA and Nutrient Agar media indicate:

- Bria (faecal soil): high microbial load, indicative of active biological life
- Kraïma: slightly reduced microbial diversity
- Root-zone soil: moderate microbial presence

These differences underline the role of land use and organic content in microbial dynamics, and confirm the relevance of regular soil microbiological surveillance to support sustainable agricultural practices.

Figure V.6: Bacteria obtained in Agar (PDA).

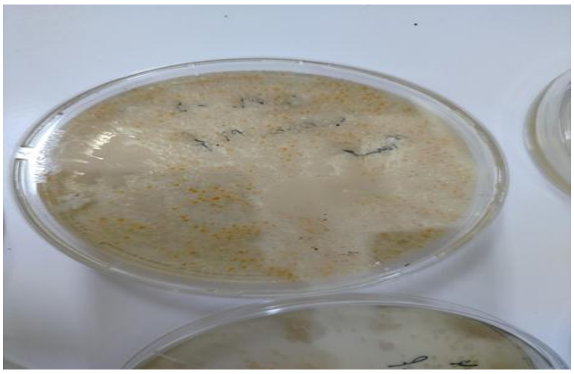


Figure V.7: Bacteria obtained in Agar Nutrient medium.

V.2.2 Water analysis :

V.2.2.1. Physico-Chemical Properties

- **pH Values:**

- Kraïma drinking water: pH = 7.58 (T = 18.4°C)
- Bria drinking water: pH = 7.53 (T = 16.5°C)
- Bria pike-perch pond: pH = 7.73 (T = 16.3°C)

All values fall within WHO recommended range for potable water (6.5–8.5; WHO, 2017).

- **Conductivity Values:**

- Kraïma: 2790 µS/cm — slightly above WHO limit (2500 µS/cm)
- Bria drinking water: 12256 µS/cm — significantly above WHO threshold
- Bria pond water: 1130 µS/cm — within permissible range

These findings suggest possible mineral contamination in Bria drinking water, warranting pre-treatment prior to consumption.

V.2.2.1. Microbiological Analysis

Microbial testing revealed the presence of contaminating microorganisms in all water samples, suggesting potential faecal pollution. These results raise concerns regarding potability and highlight the necessity for systematic water treatment, particularly for livestock use.

Figure V.8: the result after incubation.

V.2.3 Feed Analysis

V.2.3.1. Moisture Content Determination

Figure V. 9: fodder after drying.

- **Bria Samples:**

- **Hay:**

  Initial mass = 156.25 g

  Final mass = 141.07 g

  % Moisture = **9.71%**

  Within the ideal range for dry hay (10–15%; AFNOR, 1997)

- **Silage:**

  Initial mass = 996.93 g

  Final mass = 313.91 g

  % Moisture = **67.91%**

  Optimal for anaerobic fermentation (Weiss et al., 2003)

- **Forage:**

  Initial mass = 1273.06 g

  Final mass = 1258.25 g

% Moisture = **1.16%**

Abnormally low; possibly due to premature drying or handling errors

- **Kraïma Sample:**

- **Forage:**

  Initial mass = 481 g

  Final mass = 443.04 g

  % Moisture **= 7.89%**

  Acceptable, but slightly below optimal for conservation (Martin et al., 2010)

These variations reflect differences in storage practices and drying techniques, with implications for feed quality and nutritional value.

V.2.4 Milk Analysis

V.2.4.1. Physico-Chemical Properties

- Milk pH Measurement

- Kraïma milk sample: pH = 7.03 at 16.6°C
- Bria milk sample: pH = 7.05 at 16.6°C

This pH value is slightly alkaline, exceeding the typical upper limit of 6.8 for raw milk (IDF, 2018). Potential causes include:

- Residual alkaline detergent from equipment
- Elevated urea levels from high-protein feed
- Suboptimal hygiene in milking systems

VI Discussion

VI-1 Questionnaire Survey

The analysis of data collected from 50 dairy farmers in the Ouzine–Giplait area (Tlemcen) provides valuable insights into local practices, resource management, and the challenges faced in achieving sustainable and hygienic milk production.

- The surveyed farms exhibit a hybrid model of livestock management, combining traditional knowledge with modern practices.

    - ✓ This mixed approach reflects both the adaptability of local farmers and the limitations in access to modern infrastructure. While some breeders adopt advanced techniques, including improved feeding strategies or artificial insemination, many still rely on traditional grazing patterns and manual milking. This duality reveals a transition stage in dairy production, where modernization is gradually taking root but remains unevenly distributed. Similar patterns have been observed in other Mediterranean regions undergoing agroecological shifts (FAO, 2020).

- However, farmers report several structural and environmental constraints affecting productivity. Chief among these are the high cost and limited availability of animal feed**,** degradation of grazing lands**,** animal health issues**,** andclimate-induced stress.

    - ✓ These findings are consistent with broader challenges reported in arid and semi-arid zones, where feed prices and water scarcity significantly undermine livestock performance and food security (Benyoucef et al., 2022).

- The questionnaire responses indicate that while awareness of sustainable resource use is increasing, practical implementation remains fragmented. Irrigation practices are often conducted without precise measurement, reflecting a lack of access to water-monitoring tools. Nonetheless, several respondents have adopted more refined techniques such as drip irrigation**,** rainwater harvesting**,** orpartial wastewater reuse after basic filtration a promising step towards integrated resource management.

- ✓ In terms of soil conservation, practices such as reduced tillage**,** crop rotation, and the application of organic or mineral fertilizers are reported by a substantial number of farms. These methods aim to maintain or improve long-term soil fertility and reduce erosion risks, aligning with the principles of conservation agriculture promoted by the FAO and INRA (FAO, 2021; INRAA, 2019).

- The data suggests a relatively high level of hygiene compliance on the farms surveyed. Regular cleaning and disinfection of equipment**,** use of appropriate detergents**,** and staff training were frequently mentioned. Notably, segregation of sick animals**,** veterinary follow-ups**,** andvaccination campaigns are implemented by a majority of respondents, reflecting a growing commitment to animal health and biosecurity.

  - ✓ These efforts are critical in preventing zoonotic diseases and ensuring milk safety at the source (WHO, 2020).

- ✓ However, some gaps remain. A few farms do not adhere to scheduled equipment sanitation or cold chain protocols, which could jeopardize milk safety and shelf life. Strengthening training and access to affordable hygiene tools would address these vulnerabilities.

- Milk quality control appears to be a shared priority among producers. Many respondents indicated that they performmilk tests either on-site or through external laboratories, checking for microbial contamination, somatic cell counts, and adulterants. In addition, a majority confirmed their compliance with veterinary withdrawal periods, refraining from selling milk when animals are under treatmentan important indicator of consumer protection and regulatory awareness.

- ✓ Some farms go further by implementing batch traceability, which, while still limited, points to a growing recognition of the importance of food safety standards in milk marketing. These efforts are in line with Codex Alimentarius recommendations for dairy traceability and risk prevention (Codex, 2021).

- Finally, the questionnaire responses suggest that local dairy farmers demonstrate a genuine concern for animal welfare**,** environmental sustainability, and food safety. While economic and infrastructural constraints persist, most farmers express willingness to adopt more sustainable practices when given adequate support and incentives.

- ✓ Government support, capacity-building programs, and access to certified feed and veterinary services would enhance their ability to produce high-quality, environmentally safe milk. Such support could also encourage a shift towards **agroecological models**, combining productivity with resilience.

VI-2 physico-chemical and microbiological analyses

The results from the physico-chemical and microbiological analyses offer critical insights into the quality and sustainability of agricultural inputs in the Tlemcen region, especially for dairy production. They reflect environmental conditions, management practices, and the extent to which hygiene and sustainability standards are met.

- The soils examined exhibited a strong alkaline character, with pH values ranging from **7**.82 to 8.84, in line with the alkaline classification proposed by Sparks (2003)**.**

✓ Alkalinity of this magnitude may reduce the bioavailability of key nutrients such as phosphorus (P), iron (Fe), and manganese (Mn), thereby limiting plant uptake and potentially affecting forage quality and crop productivity (Zhou et al., 2018).

- The Walkley-Black method and the loss-on-ignition method were employed to quantify organic matter content. The calculated organic carbon levels from Walkley-Black titration yielded:

- **Bria soil**: 0.9% OC → ≈1.55% OM
- **Kraïma soil**: 1.2% OC → ≈2.07% OM

Meanwhile, the loss-on-ignition method showed significantly higher values:

- **Bria**: 11.2% OM
- **Kraïma**: 18% OM

✓ These discrepancies between methods are typical, as the loss-on-ignition approach captures total organic content, including less reactive fractions. According to FAO (2006) and ISO 11464 (2006), values above 10% represent very rich soils in organic matter. The high OM content in Kraïma suggests good biological fertility and strong potential for nutrient cycling and moisture retention. However, it should be noted that excessive organic matter, particularly from faecal sources, may also elevate the risk of microbial contamination.

- Microbial activity varied significantly across sites. The Bria sample, enriched with faecal matter, showed the highest microbial density, consistent with its elevated organic matter levels. This implies robust biological processes but may also indicate potential sanitary concerns if not adequately managed. In contrast, Kraïma soil exhibited reduced microbial counts, possibly due to environmental stressors or overexposure to alkaline conditions. Such imbalances in soil microbial communities may affect nutrient mineralization and plant health, underlining the need for integrated soil health monitoring.

- All tested water samples had pH values within WHO's recommended range (6.5–8.5), suggesting suitable acidity levels for both animal and agricultural use. However, **electrical conductivity (EC)** results raised concerns

- ✓ Excessive conductivity indicates salinity issues, which may impair animal hydration, reduce crop yields, and cause long-term soil degradation. The source of salinity may include agricultural runoff, mineral-rich groundwater, or inadequate drainage systems. Bria water, in particular, requires urgent filtration or dilution prior to use.
- ✓ All water samples tested positive for microbial contamination, signaling potential fecal pollution.
- ✓ Such contamination poses a significant health risk for both livestock and humans, particularly in rural areas where untreated water is directly consumed. The results call for systematic water treatment (e.g., UV sterilization, chlorination) and stricter hygienic protocols for water storage and usage.

- Moisture analysis of the feed materials revealed a wide range of values:

- **Bria hay**: 9.71% — within acceptable standards (AFNOR, 1997)
- **Bria silage**: 67.91% — optimal for anaerobic fermentation (Weiss et al., 2003)
- **Bria fresh forage**: 1.16% — extremely low, suggesting potential handling or storage errors

- For **Kraïma**, forage moisture was 7.89%, slightly below optimal. Low moisture levels may lead to reduced digestibility and nutrient loss, particularly of heat-sensitive compounds such as vitamins and proteins (Martin et al., 2010). Furthermore, overly dry fodder is prone to dust formation and spoilage, which can cause respiratory and digestive issues in cattle.

- ✓ These findings highlight the importance of maintaining optimal moisture levels throughout the feed chain from harvest to storage in order to preserve nutritional quality and ensure animal health.

- o The pH of the milk samples was measured at **7.03 – 7.06** , indicating slight alkalinity. This value exceeds the normal physiological range for fresh cow milk (6.6–6.8), suggesting possible contamination with cleaning residues, excessive urea, or early signs of mastitis or spoilage (Todorov et al., 2019).

- ✓ These results emphasize the importance of monitoring hygienic practices on the farm, ensuring proper cleaning of milking equipment, and regular milk testing to maintain quality and avoid food safety risks.

Collectively, the data show that while certain environmental and agronomic parameters fall within acceptable or even optimal ranges, significant deviations exist, particularly concerning water quality and microbial contamination. These inconsistencies stress the urgent need for better management practices including:

- Buffering soil alkalinity
- Regular microbiological screening
- Water filtration and treatment
- Improved post-harvest handling of feed

Addressing these factors is critical for advancing toward more sustainable, resilient, and safe dairy production systems in the region.

General Conclusion

This study offers a holistic evaluation of dairy farming systems in the Tlemcen region, examining their environmental sustainability, food safety standards, and resource management efficiency. Through integrated field surveys and laboratory investigations, we have identified significant disparities between two farming approaches, with profound implications for agricultural policy and practice.

By combining field surveys with detailed physico-chemical and microbiological analyses, the research highlights key differences in agricultural performance, particularly in terms of soil quality, water safety, feed management, and milk hygiene.

Soil analyses revealed high alkalinity levels (pH > 7.8) across both sites, but with notable variations in organic matter content, ranging from moderate to very rich (up to 18%). Water samples, although compliant with WHO pH recommendations, exhibited significant discrepancies in conductivity values most notably a high salinity level of 12,256 µS/cm in one sample, suggesting mineral overload. Microbiological tests also confirmed the presence of pathogenic organisms in all water sources, indicating potential contamination risks. Milk analysis revealed slight alkalinity (pH 7.03-7.06), pointing to possible contamination or feeding imbalances, which could compromise product safety and quality if left unaddressed.

Feed quality differed according to storage conditions and types. While silage moisture was within the optimal range for anaerobic fermentation (67.91%), fresh forage presented an abnormally low moisture content (1.16%), likely due to excessive drying or handling issues. Milk analyses indicated slight alkalinity (pH 7.03), pointing to possible hygiene or dietary imbalances.

The questionnaire data supported these findings, revealing that farmers often face challenges related to feed cost, water scarcity, and climate variability. However, good hygiene practices, such as tool cleaning and animal health management, were generally observed.

Rather than categorizing farms as strictly conventional or agroecological, this comparative approach demonstrates that differences in agricultural results are closely tied to management methods and environmental awareness. The study underscores the necessity of promoting sustainable practices, improving farmer training, and implementing quality control measures.

In conclusion, transitioning toward environmentally sound and health-conscious farming systems is not merely an option but a pressing need. The results strongly advocate for the adoption of sustainable techniques that preserve soil health, protect water resources, and ensure safe, high-quality dairy production for future generations.

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ANNEX

QUESTIONNAIRE POUR LES FERMES LAITIERES : PRATIQUES, DURABILITE ET SECURITE ALIMENTAIRE

1. Quelles sont les principales méthodes d'élevage que vous appliquez dans votre exploitation laitière ?
1. ما هي الطرق الرئيسية التي تتبعها في تربية الماشية في مزرعتك لإنتاج الألبان؟

- ☐ Élevage intensif / تربية مكثفة
- ☐ Élevage extensif (pâturage) / (تربية واسعة (الرعي)
- ☐ Mixte (intensif et extensif) / (مزيج (مكثفة وواسعة)
- ☐ Autre (précisez) : ________________ / (أخرى (حدد): ________________

2. Utilisez-vous des cultures fourragères locales ou préférez-vous des cultures importées pour l'alimentation du bétail ?
2. هل تستخدم محاصيل علفية محلية أم تفضل المحاصيل المستوردة لتغذية الماشية؟

- ☐ Cultures fourragères locales uniquement / محاصيل علفية محلية فقط
- ☐ Cultures importées uniquement / محاصيل مستوردة فقط
- ☐ Mixte (locales et importées) / (مزيج (محلية ومستوردة)
- ☐ Autre (précisez) : ________________ / (أخرى (حدد): ________________

3. Quels sont les principaux défis rencontrés dans l'élevage des vaches laitières dans votre région ?
3. ما هي التحديات الرئيسية التي تواجهها في تربية الأبقار الحلوب في منطقتك؟

- ☐ Manque de fourrage de qualité / نقص الأعلاف عالية الجودة
- ☐ Coût élevé des aliments pour bétail / ارتفاع تكلفة أعلاف الماشية
- ☐ Problèmes de santé animale / مشاكل صحية للحيوانات
- ☐ Changements climatiques (sécheresse, inondations, etc.) / (تغيرات مناخية (جفاف، فيضانات، إلخ)
- ☐ Autre (précisez) : ________________ / (أخرى (حدد): ________________

4. Quelle quantité d'eau consommez-vous pour l'irrigation de vos cultures fourragères et l'abreuvement des animaux ?
4. ما هي كمية المياه التي تستهلكها لري المحاصيل العلفية وسقاية الحيوانات؟

- ☐ Moins de 10 000 litres par jour / أقل من 10,000 لتر يومياً
- ☐ 10 000 à 50 000 litres par jour / من 10,000 إلى 50,000 لتر يومياً
- ☐ Plus de 50 000 litres par jour / أكثر من 50,000 لتر يومياً
- ☐ Je ne mesure pas précisément / لا أقوم بقياس الكمية بدقة

5. Comment gérez-vous les sols de vos terres agricoles pour éviter la dégradation et améliorer leur fertilité ?
5. كيف تدير تربة أراضيك الزراعية لتجنب التدهور وتحسين خصوبتها؟

- ☐ Rotation des cultures / تناوب المحاصيل
- ☐ Utilisation d'engrais organiques / استخدام الأسمدة العضوية
- ☐ Labour minimal ou sans labour / الحراثة الدنيا أو عدم الحراثة
- ☐ Autre (précisez) : ________________ / (أخرى (حدد): ________________

6. Pratiquez-vous des techniques de conservation des sols, comme la culture en terrasses ou la couverture végétale ?
6. هل تطبق تقنيات حفظ التربة، مثل الزراعة على المصاطب أو تغطية التربة بالنباتات؟

- ☐ Oui, régulièrement / نعم، بانتظام
- ☐ Parfois / أحياناً
- ☐ Non, jamais / لا، أبداً
- ☐ Je ne connais pas ces techniques / لا أعرف هذه التقنيات

7. Avez-vous observé des signes de dégradation des sols, comme l'érosion ou la perte de fertilité, dans votre exploitation ?
7. هل لاحظت علامات تدهور التربة، مثل التعرية أو فقدان الخصوبة، في مزرعتك؟

- ☐ Oui, fréquemment / نعم، بشكل متكرر
- ☐ Parfois / أحياناً

- ☐ Non, jamais / لا، أبداً
- ☐ Je ne sais pas / لا أعرف

8. Avez-vous remarqué une diminution de la qualité ou de la quantité d'eau disponible pour vos besoins agricoles au cours des dernières années ?
8. هل لاحظت انخفاضاً في جودة أو كمية المياه المتاحة لاحتياجاتك الزراعية في السنوات الأخيرة؟

- ☐ Oui, une diminution significative / نعم، انخفاض كبير
- ☐ Oui, mais légère / نعم، ولكن بشكل طفيف
- ☐ Non, pas de changement / لا، لم يتغير شيء
- ☐ Je ne sais pas / لا أعرف

9. Comment gérez-vous la surexploitation de l'eau pour éviter la diminution des ressources aquatiques locales ?
9. كيف تدير الإفراط في استخدام المياه لتجنب انخفاض الموارد المائية المحلية؟

- ☐ Réutilisation des eaux usées traitées / إعادة استخدام المياه المعالجة
- ☐ Systèmes d'irrigation goutte-à-goutte / أنظمة الري بالتنقيط
- ☐ Réduction des surfaces irriguées / تقليل المساحات المروية
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

10. Avez-vous adopté des pratiques agroécologiques, telles que la rotation des cultures ou la fertilisation organique ?
10. هل تطبق ممارسات زراعية بيئية، مثل تناوب المحاصيل أو التسميد العضوي؟

- ☐ Oui, régulièrement / نعم، بانتظام
- ☐ Parfois / أحياناً
- ☐ Non, jamais / لا، أبداً
- ☐ Je ne connais pas ces pratiques / لا أعرف هذه الممارسات

11. Quelle est votre approche pour améliorer la biodiversité dans vos terres agricoles ?
11. ما هي طريقتك لتحسين التنوع البيولوجي في أراضيك الزراعية؟

- ☐ Plantation de haies ou d'arbres / زراعة السياجات أو الأشجار
- ☐ Maintien de zones humides ou naturelles / الحفاظ على المناطق الرطبة أو الطبيعية
- ☐ Diversification des cultures / تنويع المحاصيل
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

12. Disposez-vous d'un système intégré de gestion de l'eau pour l'irrigation et l'abreuvement ?
12. هل لديك نظام متكامل لإدارة المياه للري وسقاية الحيوانات؟

- ☐ Oui, un système moderne (ex : goutte-à-goutte, aspersion) / نعم، نظام حديث (مثل التنقيط، الرش)
- ☐ Oui, un système traditionnel (ex : canaux) / نعم، نظام تقليدي (مثل القنوات)
- ☐ Non, nous n'avons pas de système intégré / لا، ليس لدينا نظام متكامل
- ☐ Je ne sais pas / لا أعرف

13. Avez-vous des stratégies pour optimiser l'utilisation de l'eau pendant les périodes de sécheresse ?
13. هل لديك استراتيجيات لتحسين استخدام المياه خلال فترات الجفاف؟

- ☐ Oui, nous stockons l'eau / نعم، نقوم بتخزين المياه
- ☐ Oui, nous réduisons la consommation / نعم، نخفض الاستهلاك
- ☐ Non, nous n'avons pas de stratégie / لا، ليس لدينا استراتيجية
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

14. Quels sont les principaux risques liés à la qualité de l'eau que vous utilisez pour l'abreuvement du bétail ?
14. ما هي المخاطر الرئيسية المتعلقة بجودة المياه التي تستخدمها لسقاية الماشية؟

- ☐ Contamination chimique (pesticides, engrais) / تلوث كيميائي (مبيدات، أسمدة)
- ☐ Contamination bactérienne / تلوث بكتيري
- ☐ Manque d'eau potable / نقص مياه الشرب
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

15. Comment évaluez-vous la qualité des fourrages que vous donnez à vos animaux ?
15. كيف تقيم جودة الأعلاف التي تقدمها لحيواناتك؟

- ☐ Analyses en laboratoire / تحاليل مخبرية
- ☐ Observation visuelle et olfactive / الملاحظة البصرية والشم
- ☐ Achat de fourrages certifiés / شراء أعلاف معتمدة
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

16. Quelles normes d'hygiène appliquez-vous lors de la traite des vaches ?
16. ما هي معايير النظافة التي تطبقها أثناء حلب الأبقار؟

- ☐ Nettoyage régulier des équipements / تنظيف المعدات بانتظام
- ☐ Utilisation de produits désinfectants / استخدام مواد مطهرة
- ☐ Formation du personnel à l'hygiène / تدريب العاملين على النظافة
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

17. Comment assurez-vous le stockage et la conservation du lait de manière sûre et hygiénique ?
17. كيف تضمن تخزين وحفظ الحليب بشكل آمن وصحي؟

- ☐ Réservoirs réfrigérés / خزانات مبردة
- ☐ Contrôle régulier de la température / مراقبة درجة الحرارة بانتظام
- ☐ Nettoyage quotidien des équipements / تنظيف المعدات يومياً
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

18. Quelles mesures mettez-vous en place pour éviter la contamination du lait durant le processus de production et de stockage ?
18. ما هي الإجراءات التي تتخذها لتجنب تلوث الحليب أثناء عملية الإنتاج والتخزين؟

- ☐ Isolement des animaux malades / عزل الحيوانات المريضة
- ☐ Contrôle sanitaire régulier / مراقبة صحية منتظمة
- ☐ Utilisation de matériaux stériles / استخدام مواد معقمة
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

19. Pratiquez-vous des contrôles réguliers de la qualité sanitaire du lait avant sa commercialisation ?
19. هل تقوم بفحص جودة الحليب الصحية بانتظام قبل تسويقه؟

- ☐ Oui, en interne / نعم، داخلياً
- ☐ Oui, par un laboratoire externe / نعم، عبر مختبر خارجي
- ☐ Non, jamais / لا، أبداً
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

20. Que faites-vous lorsque les vaches tombent malades ? (Dans ce cas, traitez-vous les vaches et leur lait est-il vendu et bu ?)
20. ماذا تفعل عندما تمرض الأبقار؟ (في هذه الحالة، هل تعالج الأبقار وهل يتم بيع حليبها واستهلاكه؟)

- ☐ Nous traitons les vaches et ne vendons pas leur lait pendant le traitement / نعالج الأبقار ولا نبيع حليبها أثناء العلاج
- ☐ Nous vendons le lait après traitement / نبيع الحليب بعد العلاج
- ☐ Nous ne vendons jamais le lait des vaches malades / لا نبيع حليب الأبقار المريضة أبداً
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

21. Quels types de soutien ou de ressources seraient les plus utiles pour améliorer votre exploitation ?
21. ما هي أنواع الدعم أو الموارد التي ستكون أكثر فائدة لتحسين مزرعتك؟

- ☐ Formation technique / تدريب تقني
- ☐ Accès à des financements / الوصول إلى تمويل
- ☐ Technologies modernes / تقنيات حديثة
- ☐ Autre (précisez) : ________________ / أخرى (حدد): ________________

22. Avez-vous des suggestions pour améliorer la durabilité de la production laitière dans votre région ?
22. هل لديك اقتراحات لتحسين استدامة إنتاج الألبان في منطقتك؟

- ________________