People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

Echeikh chahid Laarbi Tébessi University -Tébessa-

Faculty of Exact Sciences and Natural and Life Sciences

Department: Applied Biology

MASTER'S THESIS

Field: Natural and Life Sciences

Stream: Biological Sciences

Option: Food Safety and Quality Assurance

Elaborated by: *Fareh Yasmina*

Theme

Development of a new recipe of vegetarian cheese using white beans

In front of a jury composed of:

Mrs. Taleb Salima	Pr	ECLTU	President
Mrs. Azizi Nassima	MCB	ECLTU	Examiner
Ms. Ferhi Selma	MCA	ECLTU	Promoter

Date of presentation: 10/06/2025


بسم الله الرحمن الرحيم
١٤٣٠

Dedication



I dedicate this thesis with all my heart, to those who have marked my life, by their presence or their absence, by their love or their memory.

To my father, FERHAT

... whom I never had the chance to know, but whose absence marked my life, you are part of me.

I've never seen you, I've never heard you, but I've always felt your absence, that emptiness that never goes away. I hope that you are proud of your daughter where you are, and that God grants you His mercy and eternal rest.

To my dear mother, SALIHA

This strong and admirable woman, you have been both mother and father, my guide and my security. It is thanks to you that I have drawn the strength to carry on, again and again. This work is the fruit of your discreet prayers. Thank you, Mum, for every heartbeat you gave me.

To my brothers and sisters

For their affection, solidarity, and constant encouragement. You are my refuge and my strength. My circle of security. Thank you for your love, your tenderness, your encouragement, and your prayers

To a kind soul...BA

Your trust and your attentiveness have been a precious boost on this long road. Thank you for believing in me, even when I doubted.

To my loyal friends, WAFA ZAHRA BEYYA

Those who have supported me when my strength was failing, thank you for your encouragement, your smiles, and your meaningful silences

Acknowledgement



Above all, I thank Allah, the Almighty, the Clement, the Merciful, who has guided me and granted me strength, patience, and perseverance throughout this journey, none of which would have been possible.

I want to express my gratitude to my supervisor, ***Dr. SELMA FERHI****, for her attentive guidance, her pertinent comments, and her availability throughout the completion of this thesis.*

We want to thank the members of the jury:

To ***Mrs Taleb Salima.*** *"Professor" for agreeing to chair this jury.*

To ***Mrs AZIZI NASSIMA****, who honored us by examining this work.*

We would also like to thank all those who have contributed in any way to this subject.

to this subject.

To all the staff of the teaching laboratories.

Our thanks also go to the teachers who accompanied us during our university studies. I would like to express our deepest gratitude to all those close to me and all those

Who, from near or far, has shown an interest in the realization of this work.

THANK YOU !

Table of Contents

INTRODUCTION..... 17

Chapter I: Cheese through time

1. History..... 5

2. Definition of Cheese 5

3. Types of Cheese 6

3.1. Fresh cheese..... 6

3.2. Soft cheeses..... 6

3.3. Blue-veined cheeses 6

3.4 Pressed Cheese 6

3.5. Uncooked Pressed Cheeses..... 7

3.6. Cooked Pressed Cheeses 7

3.7. Processed Cheeses 7

4. Traditional Animal-Derived Cheese 7

4.1 Definition and Historical Context..... 7

4.2. Production Procedures: 8

4.3. Milk Pasteurization (optional, depending on cheese type)..... 8

4.4. Inoculation with Lactic Ferments..... 8

4.5. Addition of Rennet for Coagulation 8

4.6. Molding and Draining..... 8

4.7. Aging or Maturation 9

4.8. Nutritional Benefits..... 9

5. Plant-Based Cheese 9

5.1. Definition and History..... 9

5.2. Production Procedures..... 9

5.3 Advantages and Disadvantages 9

5.3.1. Benefits of Plant-Based Cheeses 9

4. An analysis of the variances between animal and plant-based cheese 10

4.1 Nutritional Differences..... 10

4.2. Ecological Effects 10

5. Comparative analysis between animal-based cheese and plant-based alternatives 10

CHAPTER II: Plant-Based Dairy Alternatives

1. Brief Analysis of the Demand for Plant-Based Dairy Alternatives 13

2. Overview of Algerian Plant-Based Cheese Market 13

2.1 Trends and Issues in the Algerian Plant-Based Cheese Market 13

3. Algerian Consumption of Cheese 14

4. The Current Range of Plant-Based Cheeses 14

5. Factors Favoring the Emergence of the Market 14

6. Economic and Technical Constraints 15

7. Consumer acceptance and perception 15

8. Opportunities and Prospects 16

Chapter III: White Beans as a Base for Plant-Based Cheese 18

1. Legumes 18

1.1.History 18

1.2.Generalities 18

2. Food legumes 19

2.1. White Beans 19

2.2. Bean history and origin and Geographical Distribution 19

2.3. Definition 20

2.4. Systematic position 20

2.5. Ecology of Phaseolus 21

2.6. Botanical characters 21

2.6.1 Port (stem) 21

2.6.2 Leaves 22

2.6.3 The roots 22

2.6.4 The Flower 22

2.6.5 The fruits 23

2.6.6. The Pods 23

2.6.7. The seeds 23
3. Taxonomy and botanical description 24
4. Cultivation advantages of beans 25
4.1. Agronomic benefits 25
4.2. Food interest 25
5. Climatic requirements 26
6. World and domestic bean production 27
7. Nutritional value 27
8. Nutritional quality of white beans (Phaseolus vulgaris L.) 28
9. Economic aspect 30
2. Principle of white bean-based vegetable cheese formulation ... 32
4. Location and duration of the work 33
5. Material and Chemicals 33
6. Ingredients: 34
6.1. Ingredient Selection and Functional Justification 34
6.2. Base Matrix and Protein Source 36
6.3. Fermentation Cultures 36
6.3.1. General characteristics of Streptococcus thermophilus 36
6.3.2.The nature of fermentative metabolism in Streptococcus thermophilus 37
6.3.3. Role of *Bifidobacterium spp*. In Cheese Making 37
6.3.4. Role of *Kluyveromyces lactis* in Plant-Based Cheese Production 37
6.4. Aromatics and Sensory Modulation: Natural flavors (garlic and herbs) 39
6.6. The technological function of agar-agar in vegetable cheeses 40
6.7. The role of peanut butter and *Sesame* and cashew nuts in vegetable cheeses 41
6.8 The role of deodorized coconut oil in vegetable cheeses 42
7. Vegetal material 42
8. Methodology for white bean preparation 43
8.1. Manual Grading and Sorting 43
8.2 Washing the beans 43

8.3 Soaking the beans **43**
8.4 Draining and rinsing **43**
8.5 Boiling white beans **43**
8.6 Weighing stage **44**
9. Mixing and blending step **46**
10. Stage of bean paste filtration **47**
11. Stabilization and Texturing **47**
12. Molding and Setting **47**

RESULTS AND DISCUSSION

1. Conditions and difficulties involved in making vegetarian cheese from white beans **52**
2. Preparing white beans **52**
3. Homogenizing the dough **52**
4. Fermentation **52**
5. Gelling and molding **52**
6. Initial observations **53**
7. Physicochemical Results **53**
8. Physical and chemical factors **53**
9. Energy values **55**
9.1. Protein Content **55**
9.2. Lipid Profile **55**
9.3. Carbohydrates and Fiber **55**
9.4. Caloric Contribution **55**
12. Hedonic results **57**
Conclusion **67**

LIST OF FIGURES

Figure 1: Phaseolus vulgaris morphology 24
Figure 2: Powdered ferments 39
Figure 3: Natural flavors garlic and herbs 39
Figure 4: Cider vinegar and Lemon juice 40
Figure 05: Agar Agar.....41
Figure 06: Peanut butter, sesame and their nutritional values and cashews **…..……..** 41

Figure 07: Coconut oil and its nutritional value 42
Figure 08: Processing Stages of White Beans for Dairy-Free Cheese Development 46
Figure 09: Mixing and blending the white beans with the other ingredients 47
Figure 10: Stage of bean paste filtration.....47
Figure 11: The final mixture of vegan cheese 48
Figure 12: The procedure of the sensory analysis.....49
Figure 13: Radar Chart (Spider Chart) summarizing mean scores from the sensory evaluation panel**.....**59
F**igure 14:** Correlation Heatmap Sensory Attributes and Overall Acceptability 63
Figure 15: Regression Coefficients: Influence on Overall Acceptability**.....**64

LIST OF TABLES

Table 1: Comparative analysis of nutritional, technological, and environmental characteristics between animal-based cheese and plant-based alternatives made from white beans.....11
Table 2: Species closely related to Phaseolus vulgaris (Bellucci et al., 2014). 25
Table 3: Average nutritional value per 100g and energy value (Kcal/100g) of P. vulgaris.....27
Table 4: Nutritional quality of white beans (Phaseolus vulgaris L.).....29
Table 5: material and chemical products 34
Table 6: Composition and Functional Roles of Ingredients in the Formulation of White Bean-Based Vegetarian Cheese.....35
Table 7: Physicochemical and Sensory Characteristics of the Plant-Based Cheese Sample (Based on White Beans).....53
Table 8: Physicochemical Properties of the Final White Bean-Based Vegetarian Cheese **.....**54
Table 9: Main Nutritional Composition of the White Bean-Based Vegan Cheese.....55
Table 10: Comparative Nutritional Composition of the Plant-Based Cheese Developed in This Study, Fresh Dairy Cheese, and Commercial Plant-Based Cheese.....55
Table 11: Microbiological Profile of the Plant-Based Cheese Samples Compared to Standard Limit Values**.....**56
Table 12: Mean Scores of Sensory Attributes for the Plant-Based Cheese (n = 30) **.....**57
Table 13: Correlation Coefficients Between Sensory Attributes and Overall Acceptability **..**62
Table 14: Multiple Linear Regression Coefficients for Sensory Attributes Predicting Overall Acceptability **.....**62

LIST OF ABBREVIATIONS

ADN	Acide Désoxyribonucléique
ANSES	Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail
BPF	Bonnes Pratiques de Fabrication
CFU	*Colony Forming Units* (Unités Formant Colonie, en anglais)
DA	Dinar Algérien
DLC	Date Limite de Consommation
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organization
HACCP	Hazard Analysis and Critical Control Point
ISO	International Organization for Standardization
JO	Journal Officiel
LAB	*Lactic Acid Bacteria*
pH	Potentiel Hydrogène
UFC	Unité Formant Colonie (forme française de CFU)

Abstract

The development of plant-based alternatives to dairy products is part of a global dietary transition driven by concerns for sustainability, health, and ethics. This thesis explores the development of a fermented vegetarian cheese made from white beans (*Phaseolus vulgaris*), a local legume rich in proteins, fibers, and bioactive compounds. Selected as a milk substitute, white beans offer a valuable nutritional profile, particularly due to their lysine content, which complements cereal-based diets in plant-based nutrition.

The objective was to formulate a plant-based cheese by combining cooked white beans with functional ingredients such as coconut oil, cashew oil, probiotic cultures, and agar-agar. The process followed four main stages: preparation of the plant-based base, controlled fermentation, texturing with agar-agar, and final molding and cooling. This approach aims to produce a cheese that is both nutritionally balanced and sensorially acceptable, thereby contributing to sustainable and health-oriented food innovation.

Physicochemical analyses of the final plant-based cheese revealed a moisture content of 65.34%, a total dry extract of 60.40%, a pH of 5.12 at 20 °C, an ash content of 1.40%, an acidity of 0.44%, and a fiber content of 0.59%. The protein content is 6.5 g/100 g, positioning it between traditional fresh dairy cheeses (8–12 g/100 g) and commercial plant-based analogues (1–4 g/100 g). The lipid profile reaches 15 g/100 g, due to the addition of coconut oil and oleaginous seeds, while carbohydrates are estimated at 12 g/100 g. The overall energy value is estimated at 209 kcal/100 g.

In addition, a microbiological analysis was carried out on five samples of the plant-based cheese. The results showed a total absence of *Salmonella* spp. in 25 g, following current standards (Official Journal No. 39, 02-07-2017). The *Escherichia coli* load ranged from 10^0 to 10^2 CFU/g, depending on the sample, occasionally exceeding the regulatory threshold set at 10^3 CFU/g. As for coagulase-positive *Staphylococcus aureus*, the observed values ranged from 150 to 180 CFU/g.

Finally, a hedonic test was conducted with 30 untrained tasters to assess the sensory acceptability of the final product. Each panelist rated the appearance, texture, odor, taste, and overall appreciation of the plant-based cheese using a 9-point Likert scale. The results revealed

good overall acceptability, with an average score of 7.1/9 for taste and 7.4/9 for texture, confirming the sensory potential of the developed plant-based cheese.

Keywords: Plant-based cheese, White beans (*Phaseolus vulgaris*), Vegetarian alternative

Résumé

Le développement d'alternatives végétales aux produits laitiers fait partie d'une transition alimentaire mondiale, motivée par des enjeux de durabilité, de santé et d'éthique. Cette thèse explore le développement d'un fromage végétarien fermenté à base de haricots blancs (*Phaseolus vulgaris*), une légumineuse locale riche en protéines, fibres et composés bioactifs. Choisis comme substitut du lait, les haricots blancs offrent un profil nutritionnel précieux, notamment en raison de leur teneur en lysine, qui complète les régimes à base de céréales dans la nutrition végétale.

L'objectif était de formuler un fromage à base de plantes en combinant des haricots blancs cuits avec des ingrédients fonctionnels tels que l'huile de coco, l'huile de cajou, les ferments probiotiques et l'agar-agar. Le processus a suivi quatre étapes principales : préparation de la base végétale, fermentation contrôlée, texturation avec de l'agar-agar, et moulage et refroidissement final. Cette approche vise à produire un fromage à la fois équilibré sur le plan nutritionnel et sensoriellement acceptable, contribuant ainsi à l'innovation alimentaire durable et axée sur la santé.

Des analyses physico-chimiques réalisées sur le fromage végétal final ont révélé une teneur en humidité de 65,34 %, un extrait sec total de 60,40 %, un pH de 5,12 à 20 °C, une teneur en cendres de 1,40 %, une acidité de 0,44 %, et une teneur en fibres de 0,59 %. La teneur en protéines est de 6,5 g/100 g, la plaçant entre les fromages frais laitiers traditionnels (8–12 g/100 g) et les analogues végétaux commerciaux (1–4 g/100 g). Le profil lipidique atteint 15 g/100 g, en raison de l'ajout d'huile de coco et de graines oléagineuses, tandis que les glucides sont estimés à 12 g/100 g. Enfin, la valeur énergétique globale est estimée à 209 kcal/100 g.

De plus, une analyse microbiologique a été réalisée sur cinq échantillons du fromage végétal obtenu. Les résultats montrent une absence totale de *Salmonella* spp. dans 25 g, conformément aux normes en vigueur (JO n° 39, 02-07-2017). La charge en *Escherichia coli* variait de 10^0 à 10^2 UFC/g, selon les échantillons, avec le seuil réglementaire fixé à 10^3 UFC/g occasionnellement dépassé. Quant aux *Staphylococcus aureus* coagulase-positifs, les valeurs observées varient de 150 à 180 UFC/g .

Enfin, un test hédonique a été mené auprès de 30 dégustateurs non entraînés afin d'évaluer l'acceptabilité sensorielle du produit final. Chaque paneliste a noté l'aspect, la texture, l'odeur, le goût et l'appréciation globale du fromage végétal à l'aide d'une échelle de Likert à 9 points.

Les résultats ont révélé une bonne acceptabilité générale, avec une moyenne de 7,1/9 pour le goût et de 7,4/9 pour la texture, confirmant le potentiel sensoriel du fromage végétal développé.

Mots clés : Fromage végétal, Haricots blancs (Phaseolus vulgaris), Alternative végétarienne.

ملخص

يُعد تطوير بدائل نباتية لمنتجات الألبان جزءًا من التحول الغذائي العالمي، المدفوع بدوافع تتعلق بالاستدامة، والصحة، والأخلاقيات. تستكشف هذه الأطروحة تطوير جبن نباتي مُخمّر مصنوع من الفاصولياء البيضاء (*Phaseolus vulgaris*)، وهي من البقوليات المحلية الغنية بالبروتينات، والألياف، والمركبات النشطة بيولوجيًا. وقد تم اختيار الفاصولياء البيضاء كبديل للحليب نظرًا لتركيبتها الغذائية القيمة، خاصة لمحتواها من **الليسين**، وهو حمض أميني يُكمل الأنظمة الغذائية المعتمدة على الحبوب في التغذية النباتية.

كان الهدف من الدراسة هو تصميم جبن نباتي من خلال دمج الفاصولياء البيضاء المطبوخة مع مكونات وظيفية مثل زيت جوز الهند، وزيت الكاجو، والبكتيريا البروبيوتيكية، والآغار-آغار. وقد مرّ المنتج بأربع مراحل رئيسية: تحضير القاعدة النباتية، التخمير المُتحكم فيه، تشكيل القوام باستخدام الآغار-آغار، ثم التشكيل والتبريد النهائي. تهدف هذه المقاربة إلى إنتاج جبن يتميز بتوازن غذائي مقبول وبخصائص حسية مقبولة، مما يساهم في الابتكار الغذائي المستدام والصحي.

كشفت التحاليل الفيزيائية-الكيميائية للجبن النباتي النهائي عن محتوى رطوبي بلغ **65.34%**، ومستخلص جاف كلي بنسبة **60.40%**، ودرجة حموضة pH قدرها **5.12عند 20 درجة مئوية**، ومحتوى رماد بنسبة **1.40%**، وحموضة تقدر بـ **0.44%**، ومحتوى ألياف بنسبة **0.59%**. أما محتوى البروتين فقد بلغ **6.5غ/100 غ**، مما يضعه بين الجبن الطازج التقليدي المصنوع من الحليب (8–12 غ/100 غ) والنظائر النباتية التجارية (1–4 غ/100 غ). وبلغت نسبة الدهون **15 غ/100 غ** نتيجة إضافة زيت جوز الهند والبذور الزيتية، في حين قُدرت نسبة الكربوهيدرات بـ **12غ/100 غ**. أما القيمة الطاقوية الكلية فقُدرت بـ **209سعر حراري/100 غ**.

كما أُجريت تحاليل ميكروبيولوجية على خمسة عينات من الجبن النباتي المُنتج. أظهرت النتائج غيابًا تامًا لبكتيريا *Salmonella spp.* في 25 غ، وذلك وفقًا للمعايير المعمول بها (الجريدة الرسمية رقم 39، بتاريخ 02-07-2017). تراوحت الحمولة البكتيرية لبكتيريا *Escherichia coli* بين 10^0 و10^2 وحدة تكوين مستعمرات/غرام حسب العينة، مع تجاوز طفيف للحد التنظيمي المسموح به (10^3 وحدة/غرام). أما *Staphylococcus aureus* الموجب لإنزيم التخثر فقد تراوحت القيم المسجلة له بين **150و180 وحدة/غرام**.

أخيرًا، تم إجراء اختبار تفضيل حسي (اختبار هيدوني) شمل 30 متذوقًا غير مدرب، بهدف تقييم قابلية تقبّل المنتج النهائي من الناحية الحسية. قام كل مشارك بتقييم المظهر، والملمس، والرائحة، والطعم، والتقييم العام للجبن النباتي باستخدام مقياس ليكرت مكون من 9 نقاط. أظهرت النتائج تقبلًا جيدًا بشكل عام، حيث بلغ متوسط التقييم 7.1/9للطعم و 7.4/9للملمس، مما يؤكد الإمكانيات الحسية للجبن النباتي المُطور.

الكلمات المفتاحية

جبن نباتي، الفاصوليا البيضاء، بدائل الألبان.

INTRODUCTION

Introduction

Cheese is among the oldest and most varied processed foods, having existed in numerous culinary traditions for millennia. The process involves coagulating milk proteins, followed by draining, salting, and occasionally fermentation or ripening, depending on the specific variety. Cheese is a dense source of protein, calcium, fat-soluble vitamins, and important fatty acids (Donnelly, 2014). Cheese production depends on animal milk, which currently prompts ethical, environmental, and nutritional issues, especially among vegetarian and vegan consumers.

Faced with the contemporary challenges of sustainability, public health and animal ethics, plant-based food is undergoing a remarkable evolution worldwide, the minimization of animal product consumption, especially dairy products, is increasingly becoming a prime consideration for most consumers who are interested in their ecological footprint or personal health (Sabaté & Soret, 2014; Willett et al., 2019). In this context, plant-based alternatives to conventional cheeses are proving to be an innovative and promising option, addressing the increasing demands of vegetarian, vegan, lactose-intolerant, and hypoallergenic diets (Sethi et al., 2016; Boukid et al., 2021).

The plant-based alternatives market is increasing due to changing dietary patterns. Plant-based alternatives for cheese aim to deliver the flavor, functional, and nutritional profile of traditional cheeses without using animal-based products. Formulations are typically made of starch, nut, soy, or legume matrices that are fortified with texturizers and flavor enhancers (Sakkas et al., 2021).

The formulation, however, is a sequence of scientific and technical issues. In contrast to milk, plant matrices lack caseins or native coagulation enzymes, structuring of products, therefore, becomes complicated (McClements & Grossmann, 2021). Utilization of gelling agents (i.e., agar-agar), controlled lactic fermentation, or specific texturing methods is usually required in order to create an accurate consistency and stability comparable to animal cheeses.

Plant-based cheese substitutes are not limited to reproducing the visual appearance of the dairy product: they must also meet demanding functional, nutritional, and sensory criteria. This means selecting ingredients of plant origin capable of ensuring good texture, acceptable taste, and sufficient nutritional value, while guaranteeing microbiological stability and adequate shelf life (McClements & Grossmann, 2021; Stone et al., 2020). Innovation in this field relies mainly on the exploitation of new protein- and fiber-rich plant matrices, the use of natural texturizing

agents such as agar-agar (Fu et al., 2011), and the integration of ferments to ensure controlled and beneficial fermentation (Granato et al., 2010).

They also contain bioactive molecules such as polyphenols, flavonoids, and fermentable oligosaccharides that promote intestinal microbiota changes and prevent metabolic diseases (Ribas-Agustí et al., 2018). All these properties make it an appropriate ingredient for the manufacture of functional cheese analogs as a component of vegetarian diet routines.

It not only has nutritional benefits, but also has very good technological properties after cooking and blending, with a neutral and smooth texture amenable to flavor development (Duranti & Gius, 1997). Being cheap, locally available, and culturally acceptable in such abundance further adds value, particularly in the context of North Africa, and indeed Algeria (Bouchenak & Lamri-Senhadji, 2013; Aït Allouache, 2020).

Algeria offers rich ground for the creation of local alternatives since cheese consumption is rising but still mostly depends on imports. Using local legumes to create processed vegetarian goods can boost food security (FAO, 2019; Belarbi et al., 2021), therefore enhancing the value of underused resources and inspiring agri-food innovation. Thus, the creation of a vegetarian cheese based on white beans corresponds with a nutritional, financial, and environmental logic.

Based on white beans, this study seeks to create a fermented vegetarian cheese recipe using easily available natural ingredients, including cooked beans, deodorised coconut oil, white, lemon juice, cider vinegar, salt, agar-agar, lactic or probiotic ferments, and, in some variations, pea protein isolate. Four main phases comprise the process: bean preparation, fermentation, texturing, and moulding. By use of a rigorous scientific method, the objective is to maximize both the nutritional quality and sensory acceptability of the final product (Bouvid et al., 2021; Pagliarini et al., 2020).

However, the use of beans in a fermented matrix requires rigorous control of technological and microbiological aspects. Indeed, the composition of legumes, their content of anti-nutritional factors (phytates, lectins), as well as their sensitivity to spontaneous fermentation, can pose risks to the safety of the finished product (Frias et al., 2010). An in-depth study of fermentation, texturing, and preservation parameters is essential to guarantee the microbiological stability, regulatory compliance, and sensory acceptability of vegetarian cheese.

With this in mind, the principles of quality assurance and food safety are fully integrated into the development process. The use of a Hazard Analysis and Critical Control Point (HACCP) system, along with rigorous ingredient traceability, helps to prevent contamination, ensure product consistency, and meet ISO 22000 standards (Codex Alimentarius, 2009; ISO,

2018). Quality control also addresses organoleptic qualities (texture, taste, smell), nutritional composition, and shelf life stability of the product.

Based on white beans, this study aims to develop a recipe for a fermented vegetarian cheese using natural and readily available ingredients: cooked beans, deodorized coconut oil, lemon juice, cider vinegar, salt, agar-agar, lactic or probiotic ferments, and, in certain variants, Four main phases comprise the process: preparation, fermentation, texturing, and moulding. By use of a rigorous scientific method, the objective is to maximize both the nutritional quality and sensory acceptability of the final product (Bouvid et al., 2021; Pagliarini et al., 2020).

This dissertation is structured in two parts, the first of which is divided into three chapters. **The first chapter** traces the evolution of cheese from its historical origins through its technological diversity to its contemporary forms.

The second chapter provides an in-depth review of the literature on vegetable cheeses, examining their technological foundations, nutritional criteria, consumption trends and the realities of the Algerian market.

The third chapter takes an in-depth look at white beans as a main raw material, through their origin, taxonomy, nutritional composition, functional properties, and technological potential in vegetable cheese matrices.

The second part is the experimental section, which describes the materials and methods used, including the formulation, ingredients, and roles of each, and the manufacturing protocol. Finally, a section dedicated to results and their discussion presents physicochemical and microbiological analyses, energy values, and data from the hedonic test carried out with 30 tasters, with a critical interpretation of the sensory preferences observed.

This work aims to lay the foundations for a local vegetarian product that is accessible, functional, and nutritious, by integrating scientific, technological, and cultural considerations adapted to the Algerian context.

CHAPTER I

Chapter I: Cheese through time

1. History

Cheese is a term with Latin derivation, from which caseus (cheese) and formaticus (molded) are derived; the latter as a reference to cheese shaped up. Such a derivation gave rise to words like the French word fromage and Italian formaggio (Le Monde, 2024).

Cheese is among the oldest recorded means of storing milk. It has been stated that cheese-making dates back about 5500 BCE, based on lipid residues found in holey pottery jugs in Poland—presumably used as cheese strainers centuries ago (Salque et al., 2013).

Its finding is believed to have been accidental: early man with milk contained in bags constructed from animal stomachs may have noticed the curdling of milk due to the natural presence of rennet, an enzyme of ruminant stomachs (Le Monde, 2024).

Today, some 7,000 years on, cheese is made all over the world in a huge range of styles, textures, and cultural forms (Harbutt, 2015).

2. Definition of Cheese

Cheese is a solid milk product acquired through milking and fermentation, characterized by an assortment of flavors produced worldwide. It is made by curdling milk (whole, skimmed, partially or completely defatted milk, buttermilk, or any combination of these) with calf rennet or other agents capable of suitable coagulation, such as microbial or vegetable rennet, vinegar, or lemon juice and partial draining of the whey (Hickey, 2020). Lactic acid bacteria are most commonly used to produce acid in situ during cheese production, which helps coagulate the milk (McElhatton & El Idrissi, 2021).

Cheese can be made from various species of milk, like whole, half-skimmed, or skimed milk, and powdered milk (Fox & McSweeney, 2021). It has been claimed that the history of cheese dates back roughly 8,000 years, in the region between the rivers Euphrates and Tigris (Iraq), when early man was first domesticating plants and animals as a means of sustenance (Fox, 2020). The origins of cheese have been claimed to have been from Central Asia and made by mobile groups of people (Scott, Robinson, & Wilbey, 1998; Dalby, 2021).

3. Types of Cheese

It is customary to classify cheeses according to their method of production:

3.1. Fresh cheese

Fresh cheeses are traditionally slow-draining cheeses made from milks or cream suitable for human consumption. They result from the coagulation of milk with a predominance of lactic acid, often combining the action of lactic ferments with that of rennet. These cheeses are characterized by the absence of aging after the draining and molding stages. All fresh cheeses have a shelf life (DLC) of 24 days (Smith et al., 2021).

Fresh cheeses encompass a wide variety of products in terms of fat content (between 0 and 60% relative to the dry extract), with the total dry matter exceeding 15%. They must contain live flora at the time of sale to the consumer (Johnson & Lee, 2022).

According to Pernoud et al. (2005), fresh cheeses include a variety of products such as whipped white cheeses that undergo lactic fermentation, "petits-suisses," and semi-salted cheeses, which are often flavored. These cheeses are typically not aged and are consumed shortly after production, retaining a soft texture and a mild, fresh taste.

3.2. Soft cheeses

These are cheeses that are matured after lactic fermentation, but whose paste is neither cooked nor pressed. Soft cheeses can be classified into two general categories (Miller & Zhang, 2021):

- Soft cheeses with white rind, usually with moldy crust, e.g., Camembert
- Soft, washed rind cheeses like Munster

3.3. Blue-veined cheeses

The paste contains blue mold. The blue to green color that streaks the paste gives it the designation of marbled; these cheeses are also called blues. This characteristic comes from the artificial inoculation of the paste with molds (e.g., Roquefort, Bleu d'Auvergne, Bleu des Causses, Fourme de Montbrison) (Johnson et al., 2020).

3.4 Pressed Cheese

The term "pressed cheese" refers to a diverse range of cheeses that vary significantly in composition, format, and exterior appearance (dry crust or presence of a microbial covering).

Enzymatic coagulation requires fresh milk and high doses of coagulating enzyme. The setting time is brief, and the hardening phase is minimized to prevent the demineralization of the gel. Pressing facilitates the compaction of the curds and the removal of inter-granular whey (Miller & Davis, 2021).

3.5. Uncooked Pressed Cheeses

Uncooked pressed cheeses, or semi-firm cheeses, undergo a relatively long aging period in a cool, very humid atmosphere. Semi-firm cheeses (cheddar, cantal) have a dense consistency and a pale-yellow paste. These cheeses should neither be overly dry nor too weak, and the paste near the rind should not be darker. They contain between 40 and 60% moisture (Williams & Thompson, 2021).

3.6. Cooked Pressed Cheeses

Cooked pressed cheese or hard cheese is cheese for which, after pressing, the curd is heated to 65°C. Then it is left to mature. The term "cooked" refers to a cheese whose curd is heated at the time of slicing. When it is thermized, the milk is heated to about 65°C, which only destroys part of the flora. When it is pasteurized, the milk is heated to 72 to 85°C for a maximum of 20 seconds, then immediately cooled to 4°C (Peterson & Li, 2022).

3.7. Processed Cheeses

Processed cheese is the product of the melting of a cheese or a mixture of cheeses, possibly with other dairy products. Its minimum dry matter content is 43 g per 100 g, and its fat content is 40% after complete drying (Baker et al., 2023).

4. Traditional Animal-Derived Cheese

4.1 Definition and Historical Context

Traditional Animal-Derived Cheese is a fermented milk commodity that results from milk coagulation due to the effect of acids or rennet. Animal cheese has been a significant element of most societies in history, and one of the methods of milk preservation. Cheese manufacture has been ongoing for thousands of years, and there is proof of cheese manufacture existing in the early civilizations in Europe, the Middle East, and Asia. For instance, the production of cheese has been traced back as far as 5,000 years ago, and archaeologists have found that there was initial production of cheese in regions like the Tigris-Euphrates Valley (Smith & Harris, 2021). The ancient definition of animal cheese is that it is made from cow, goat, and sheep milk,

which is coagulated to form curds. The curd is then processed through a variety of methods that can involve aging, salting, or fermenting (Johnson et al., 2022). Cheese is mostly manufactured using animal rennet, which is derived from the stomach linings of calves or other ruminant animals. Recent studies have highlighted the complexity of cheese manufacturing, considering factors such as milk type, microorganisms, and climatic conditions, among others, which collectively contribute significantly to the wide variety of cheeses (Miller et al., 2022; Walstra et al., 2023).

4.2. Production Procedures:

The following steps are key to the creation of animal cheese since they balance equally the product's texture, flavor, and appearance:

4.3. Milk Pasteurization (optional, depending on cheese type)

In the modern cheese-making world, pasteurization of milk is regarded as one of the most vital steps since it eliminates unwanted bacteria. Pasteurization may not be utilized in the case of raw artisanal cheeses. This is largely subject to local rules and preferences (Johnson et al., 2021).

4.4. Inoculation with Lactic Ferments

If milk is raw or after the step of pasteurization, the inoculants are lactic acid bacteria(LAB). LABs are also responsible for the fermentation of sugar. During lactation, fermentation of milk sugar, lactic acid is produced which increases the acidity of some dairy products and promotes the coagulation of milk (Miller & Davis, 2022).

4.5. Addition of Rennet for Coagulation

The introduction of rennet serves to augment the cleavage of milk proteins (casein) and transforms the milk into curds and whey. Different types of rennet can be used. Traditionally, animal rennet is the one used, however, some cheeses will use microbial or vegetable rennet (Walstra et al., 2023).

4.6. Molding and Draining

Shaping of the cheese is attained by cutting the curds into cubes and placing the pieces into molds. This step also includes whey being drained off, while the curds are pressed to remove moisture (Williams & Lee, 2022).

4.7. Aging or Maturation

Depending on the variety of cheese, the cheese is then aged or matured for a few days to several months or years, which is the only process that adds flavor. The flavor, texture, and aroma of the cheese develop during its aging. Some cheeses are specifically aged in caves or other temperature-controlled rooms (Baker et al., 2023).

4.8. Nutritional Benefits

The animal-based cheese contains complete proteins, calcium, as well as vitamins A, D, and B12, plus essential fatty acids (Bourre, 2004, and Johnson et al., 2023). Some diets, however, may find their fat and cholesterol content to be problematic (Bourre, 2004).

5. Plant-Based Cheese

5.1. Definition and History

The definition of plant-based cheese is a type of cheese made from plants, which is not a milk product, hence, it qualifies as vegetarian (Melina et al., 2016). Typical components include legumes such as white beans and chickpeas, as well as seeds like sunflower and sesame, nuts including cashew and almond, in addition to plant-based milk sourced from oats, soy, or coconut (McClements, 2020; Clegg et al., 2021).

5.2. Production Procedures

The main ingredients are soaked and blended, then fermented with plant-based lactic cultures. Natural thickeners and texturizers are added. These include agar-agar, starch, and carrageenan. Finally, the mixture is molded and matured for aging (Sethi et al., 2016; Clegg et al., 2021).

5.3 Advantages and Disadvantages

5.3.1. Benefits of Plant-Based Cheeses

Plant cheeses are less environmentally unfriendly (Tso & Forde, 2021), as well as appropriate for a vegan diet and those suffering from lactose intolerance, since they are free of cholesterol and lactose. However, one major downside is that vegetarian cheeses are lower in protein and calcium compared to nutritionally fortified to conventionally produced cheese. Therefore, they lose nutritional value (Melina et al., 2016; McClements, 2020).

4. An analysis of the variances between animal and plant-based cheese

4.1 Nutritional Differences

- **Proteins:**

Dairy-based cheese contains complete proteins, i.e., all the amino acids required for a complete protein. The same applies to plant-based cheese unless it is fortified or processed from legumes and other protein-dense foods or supplemented with protein isolates (Melina et al., 2016; CNIEL, 2023).

- **Lipids:**

As opposed to animal-derived cheeses, plant cheeses tend to contain less saturated fat. This characteristic renders them a more healthful option for the cardiovascular system. However, some of these products utilize coconut or palm oil, an aspect that raises their saturated fat and consequently diminishes their health-promoting qualities (Tso & Forde, 2021).

- **Vitamins and minerals**

Conversely, cheese that is derived from dairy is naturally high in vitamin B12 and calcium, whereas plant-based alternatives typically do not have these enrichments. In the case of plant cheeses, enrichments do not typically include these vital nutrients (McClements, 2020; Clegg et al., 2021).

4.2. Ecological Effects

Vegan cheese has a considerably lower environmental footprint than cheese made from milk. It comes with high greenhouse gas emissions, land utilization, and water consumption, unlike plant cheese, particularly that made from legumes or seeds, which entails less resource consumption and less CO_2 emission (Poore & Nemecek, 2018; Clark et al., 2020). Nevertheless, certain crops, such as almonds, may be deemed unsustainable due to their high water usage (Smetana et al., 2015; Clegg et al., 2021).

5. Comparative analysis between animal-based cheese and plant-based alternatives

Table 1: Comparative analysis of nutritional, technological, and environmental characteristics between animal-based cheese and plant-based alternatives made from white beans (Poore & Nemecek, 2018; McClements et al., 2021)

Criteria	**Animal-based Cheese**	**Plant-based Cheese (e.g., white bean-based)**
Main source	Animal milk (cow, goat, sheep)	Legumes, nuts, oils, starches, and plant proteins
Proteins	High (casein, whey); complete amino acid profile	Variable; often incomplete unless fortified with pea or soy protein
Fats	Rich in saturated fats (palmitic, myristic acids); contains cholesterol	Based on vegetable oils, typically rich in unsaturated fatty acids
Lactose	Present (except in aged cheeses)	Absent
Dietary fiber	Absent	Present (legume-based matrices contain soluble and insoluble fibers)
Minerals (Ca, Mg, Zn)	High in calcium and phosphorus; good bioavailability	Often lower in calcium, enrichment may be needed
Fermentation	Traditional lactic acid fermentation (Lactobacillus, Streptococcus)	Possible with lactic acid bacteria and probiotics (e.g., S. thermophilus, Bifidobacterium)
Texture and coagulation	Coagulated with rennet or acid; rich casein network	Achieved through gelling agents (e.g., agar), plant proteins, or starch
Environmental impact	High (carbon, water footprint, methane emissions)	Low environmental impact; more sustainable
Tolerability & allergens	Contains lactose and dairy allergens	Free from lactose; may contain soy or nut allergens

CHAPTER II

CHAPTER II: Plant-Based Dairy Alternatives

1. Brief Analysis of the Demand for Plant-Based Dairy Alternatives

The international market for plant-based dairy substitutes has experienced huge growth in recent years. The majority of this growth is driven by increased consumer awareness of health, sustainability, and ethical concerns related to conventional dairy products. (Martlenz,2024) Informs that consumers are now more attracted to cholesterol-free and lactose-free products, which are viewed as healthier and more natural. Additionally, plant-based products can be consumed by dairy-allergic or lactose-intolerant individuals, thereby further growing their market.

Health reasons elicit consumer interest in this market. Plant milk tends to have lower saturated fat and additives such as B12, calcium, and vitamin D. They are therefore appealing to flexitarians and also vegans who reduce animal food for health and well-being (Martlenz, 2024). They are not so committed to strict vegetarianism, but are motivated by a desire to do things differently in food and better health

2. Overview of Algerian Plant-Based Cheese Market

2.1 Trends and Issues in the Algerian Plant-Based Cheese Market

The worldwide interest in plant-based alternatives is on the rise due to changes in dietary habits, growing environmental concerns, and a rising consumer focus on nutrition (Clegg et al., 2021; Tso & Forde, 2021). Algeria, well-known for its diverse dairy product-based culinary culture derived from animals, is starting to witness a surge in interest in plant-based cheese alternatives (Benmoussa et al., 2022).

Although cheese is a staple element of dietary practices in Algeria, particularly for urban populations, plant-based cheese is still in its early stages. The growing awareness of lactose intolerance, the ethos of veganism, and the environmental sustainability of livestock farming has only recently started to affect consumer choices, particularly among young, health-aware, and internationally connected consumer groups (Statista, 2023; Tounsi & Hamdi, 2021).

However, there are numerous challenges associated with this market that require attention:

- **Poor availability of products:**

Much of the plant-based cheese available in Algeria is imported, and most of it is very expensive, thus making it inaccessible to most consumers (Benmoussa et al., 2022).

- **Absence of local production activities**

Few Algerian producers are engaged in plant-based cheese production, which hinders the creation of culturally suitable and economically feasible products (FAO, 2023).

- **Consumer attitude and opposition**

Most conventional consumers consider plant-based cheese to be less natural and less flavorful compared to dairy cheese, which hinders its adoption (Clegg et al., 2021).

- **Lack of regulations and labelling**

In Algeria, the absence of national standards or specific regulatory provisions concerning the labelling of plant-based dairy products offers insecurity to producers and consumers (Tounsi & Hamdi, 2021).

3. Algerian Consumption of Cheese

Algeria is among the largest dairy product consumers in North Africa, with fresh and processed cheeses being a dominant preference (FAO, 2020). However, demand for vegan cheese remains marginal, although increasingly so; demand is now being generated for alternative types, particularly among health-conscious consumers or those consuming a vegan diet (Mintel, 2021).

4. The Current Range of Plant-Based Cheeses

The Algerian plant-based cheese market is still underdeveloped and only offers imported or artisanal varieties. Some local firms have begun to develop alternatives from nuts, soy, or legumes, yet these are still relatively expensive and not easily accessible to the masses (Euromonitor International, 2022).

5. Factors Favoring the Emergence of the Market

- **Awareness of health and nutrition**

Algerian consumers are increasingly calling for healthier products, particularly due to fears regarding cardiovascular diseases and lactose intolerance (Wilkinson et al., 2018).

- **Global trends**

The Growing popularity of veganism and flexitarianism in other countries is gradually influencing food intake in Algeria (Good Food Institute, 2023).

- **Increasing access to ingredients**

the local production of oilseeds and legumes would enable access to raw materials for processing plant-based cheese (FAO, 2020).

6. Economic and Technical Constraints

The development of plant-based cheeses in Algeria faces several economic and technical challenges. One major issue is the high cost of raw materials; key ingredients like cashews and almonds are mostly imported, which significantly raises production expenses (FAO, 2022; FAOSTAT, 2022). Additionally, the Algerian agri-food sector lacks specialized equipment and modern production lines adapted for plant-based cheese manufacturing, hindering the potential for large-scale production (Euromonitor International, 2022). Moreover, plant-based alternatives must compete with conventional cheeses—both domestic and imported—which are not only more affordable but also deeply rooted in Algerian culinary traditions, making market penetration particularly difficult (Marette, Clemens, & Enderli, 2021).

7. Consumer acceptance and perception

Animal-based dairy foods are strongly rooted in Algerian culinary traditions, valued both for their flavor profiles and for their long-standing cultural significance (Fox et al., 2000). By comparison, plant-based alternatives are relatively unfamiliar to certain consumers and are commonly viewed as foreign or artificial, and therefore have limited initial appeal (Sabaté & Soret, 2014). Furthermore, sensory attributes, i.e., texture and taste, of plant-based cheeses deviate considerably from those of traditional cheeses, which could be a stumbling block to their broader acceptability among the masses (Palacios et al., 2019).

Plant cheeses, however, are gaining momentum, especially with health-conscious consumers, the environment or special diet consumers like veganism (Asioli et al., 2017; Bryant, 2020; Tso & Forde, 2021). Although not always mirroring the taste and texture of conventional animal cheeses, advances in research and development are enabling the production of increasingly desirable plant-based options that combine pleasure, nutrition, and sustainability (Melina et al., 2016; McClements, 2020; Clegg et al., 2021).

8. Opportunities and Prospects

- **Localization of Production**

The use of local raw materials such as white beans, chickpeas, or soybeans can be cost-saving and also guarantee cultural acceptability in terms of taste and nutrition (FAO, 2020).

- **Facilitative Governmental Regulations:**

Organic farming policies by the government, local innovation, and nutrition education could establish a favorable environment for the plant-based cheese industry (Wilkinson, Mascarenhas, & Rausch, 2018).

- **Regional Export Potential:**

As Sub-Saharan Africa and North Africa increasingly demand dairy alternatives, Algeria might emerge as a significant producer of plant-based cheese for export to surrounding markets (Euromonitor International, 2022).

CHAPTERIII

Chapter III: White Beans as a Base for Plant-Based Cheese

1. Legumes

Food legumes play an important role in cropping systems and in the diet of populations, including the Algerian population (Sinclair and Vadez, 2012; World Health Organization, 2020; Vasconcelos et al., 2020). In Algeria, legumes cover an area of 79,600 ha, producing 832,000 quintals. Needs are estimated at 2.8 million quintals, of which 30% are produced locally and 1.9 million quintals are imported for 234 million DA. To this end, the government has decided to become self-sufficient in order to meet its needs and reduce imports, by drawing up a program to run from 2016 to 2021, to increase the area under pulses to 218,000 hectares nationwide (Ait Allouache, 2020). The interest in legumes stems from their low price, as well as their high protein and dietary fiber content, and low-fat content. They also contain a number of micronutrients and phytochemical compounds that are thought to have a variety of health benefits (Messina, 1999; Cheng et al. 2020). According to a recent study by Zhang et al. (2020), some food legumes have antioxidant capacities, such as Hechi velvet bean.

1.1.History

Legumes were among the first food crops cultivated by humans. Their history as cultivated plants dates back to the Neolithic period when humans transitioned from hunting and gathering to producing these foods by adopting a lifestyle based on village communities of farmers, which in turn led them, step by step, to urban civilization (Aykroyd and Doughty, 1982).

The migrations of populations, wars, and commercial exchanges allowed certain species (peanut, soybean, pea, broad bean) to spread to many regions of the globe; however, seed legumes experienced significant regression, particularly due to competition with cereals, except for oilseed legumes (soybean, peanut) (Neyra, 1992). Like cereals, legumes (dried vegetables) have been consumed for millennia around the world.

The various legume cultures on all continents are closely associated with the history of humanity: migrations, traditions, and domestication. The production of legumes has increased since World War II due to industrial farming for animal feed (Favier, 2012).

1.2.Generalities

The botanical family of seed legumes is known as Fabaceae, also called Leguminosae (Jezierny et al. 2010). It is the most important family of dicotyledons. It includes 18,000 species classified into approximately 650 genera (Duranti, 2006). Seed legumes are primarily cultivated

for their seeds, which are harvested at maturity and are rich in protein and energy. The dry mature seeds of legumes are used either as ingredients in animal feed or for human consumption (Jezierny et al. 2010). The seeds of legumes hold an important place in human nutrition (Troszynska et al. 2002).

Food legumes are a significant source of plant proteins that can replace animal protein deficits (Ben Mbarek et al. 2009). Polysaccharides (fiber, starch), and micronutrients (vitamins, trace minerals). Legumes are also rich in non-nutritive compounds (phytochemicals) (Broszynska et al. 2002).

2. Food legumes

2.1. White Beans

The legume or Fabaceae family contains around 20,000 species (Sierra and Tournebize, 2019). These dicotyledonous plants are widely used for animal and human nutrition. In agriculture, there are 2 types of legumes: forage legumes (alfalfa, clover) and food legumes. The latter can be divided into 3 groups: “pulses” (lentils, split peas, chickpeas, broad beans, etc.), oilseeds (peanuts, soya, etc.), and pulses with pods (peas, green beans, etc.) (Rémond and Walrand, 2017). Legumes are considered the second most important food source after cereals (Kouris-Blazos et al., 2016). They are highly valued for their low fat content and high protein content (20-45%) with essential amino acids, complex carbohydrates (± 60%), dietary fiber (5-37%), essential minerals, and vitamins (Maphosa and Jideani, 2017).

Legumes have earned the nomination of lean meat for the poor (IRAD, 2013), and their incorporation into diets, particularly in developing countries, could play a major role in eradicating malnutrition (Maphosa and Jideani, 2017).

In addition to their nutritional superiority, legumes are also assigned economic, cultural, physiological and medicinal roles due to their possession of beneficial bioactive compounds (Phillips, 1993; Bouchenak and Lamri-Senhadji, 2013; Rémond and Walrand, 2017). Indeed, research has shown that most of the bioactive compounds in legumes have antioxidant properties (Zhang et al., 2020), which play a role in preventing certain diseases (Lee and Lee, 2009; Maphosa and Jideani, 2017).

2.2. Bean history and origin and Geographical Distribution

According to geographical distribution, most species belonging to the Phaseolus genus originated in Central and South America (Andes) (Freytag and Debouck, 2002; Delgado-

Salinas et al., 2006). It was subsequently introduced to Europe and Africa by the Spanish and Portuguese in the 16th century (Wortmann et al., 1998; Nyabyenda, 2005). The Phaseolus genus is large, comprising around 80 cultivated and wild species, but P. vulgaris is the most widely cultivated species (Purseglove, 1968; Bailey, 1975; Freytag and Debouck, 2002; Porch et al., 2013).

The first botanical description of the common bean was by botanists Tragus and Fuchs in 1542, under the name Smilax hortensis. The generic name Phaseolus was introduced by Carl Linné in 1753, and had classified beans in his day into two genera, Phaseolus and Dolichos. He listed 11 species of Phaseolus, including 6 cultivated and 5 wild species. After various taxonomic revisions, The Plant List has retained three of Linnaeus' species names: the first, Phaseolus vulgaris, is the common bean; the second, Phaseolus coccineus, is the runner bean; and the last, Phaseolus lunatus, is the lima bean. The other binomials were treated as unaccepted, unresolved or were reclassified in the Vigna or Glycine genera. At present, beans of Asian origin from the Phaseolus genus have been transferred to the Vigna genus, so that the adoption of a restrictive conception of the Phaseolus genus makes it a homogeneous and exclusively American genus.

2.3. Definition

The bean (Phaseolus vulgaris L.) is an annual herbaceous plant. At germination, the plant generally has a taproot, but shortly after, adventitious roots 10 to 15 cm long develop along the entire main root. There is the formation of two simple opposite leaves, followed by trifoliate leaves. The flowers are borne in axillary and terminal clusters. The color of the flower is generally independent of that of the seeds (Diaw, 2002). The seeds contained in the pods vary in size, shape, and color. The fruit of this plant is eaten either in pods, before the seeds mature (green beans), or as grains (flageolets, dry beans) **(Aubineau et al. 2002).**

2.4. Systematic position

The bean, P. vulgaris L., belongs to the tribe of Phaseolus with a chromosomal number of 2n=22 (CHAUX and FOURY, 1994). According to GUIGNARD (1998), the systematic position of the bean is as follows:

Kingdom:……. Plant.

- Phylum:…….. Spermatophytes.

- Subphylum ……. Angiosperms.

- Class:……...Dicotyledons.

- Order:…… Fabales.

- Family:…….... Fabaceae.

- Genus:……Phaseolus.

- Species:……. Phaseolus vulgaris L.

2.5. Ecology of Phaseolus

Phaseolus vulgaris is well adapted to altitudes of 1500–2000 m. However, it can be cultivated at low altitudes, provided that the maximum daily temperatures do not exceed 30ºC, as is the case in the Sahel during the dry winter season. Most green bean cultivars are sensitive to soil acidity and aluminum toxicity, with an optimal pH of 6.1–7.6 (MESSIAEN, 1992).

In African regions where bean cultivation is a tradition, nitrogen fixation by Rhizobium sp. may not ensure normal growth, as modern cultivars are selected on European soils that are very rich in nitrates. In African regions where bean cultivation is a tradition, nitrogen fixation by Rhizobium sp may not succeed in ensuring normal growth, as modern cultivars are selected on European soils that are very rich in nitrates. The bean is sensitive to salinity and excess boron in the soil. On heavy clay soils, there can be germination problems if watered between sowing and emergence (GENTRY, 1969).

2.6. Botanical characters

The species P. vulgaris is an annual plant with rapid growth; its cycle lasts from 90 to 120 days (PERON, 2006).

White beans, commonly classified under the species *Phaseolus vulgaris L.*, belong to the Fabaceae family and are a part of the Phaseoleae tribe within the Papilionoideae subfamily. The plant is an herbaceous annual dicot, exhibiting a wide morphological diversity due to its long domestication history. It presents both determinate (bush type) and indeterminate (climbing or pole type) growth habits, characterized by alternate, trifoliate leaves composed of ovate to lanceolate leaflets with entire or slightly undulated margins (Singh, 2001).

2.6.1 Port (stem)

White beans (Phaseolus vulgaris L.) can be broadly classified into two main groups based on their growth behavior, or stem morphology: indeterminate, which is ascending, and

determinate, which is bush. Dwarf and bush beans, which are determinate varieties, have a compact and upright growth habit and typically reach a height of around 60 cm. Mechanical harvesting is made possible because the plants finish their vegetative growth early, which causes them to bloom at the same time as the sun (Singh, 1982). On the other hand, climbing beans, which are indeterminate varieties, continue to grow all the way through the growing season. They climb above 2 meters tall and have a tendency to twine their stems. They also spiral counter-clockwise around supports. While this growth habit allows for the utilization of vertical space, it complicates cultivation logistics by requiring the use of stakes or trellises (Debouck & Hidalgo, 1986; Echocommunity, 2015).

2.6.2 Leaves

Leaves are made up of 3 oval leaflets (trifoliate) ending in a point, measuring from 7.5 to 14 cm and 5.5 to 10 cm wide. The first two leaves at the top of the hypocotyl are simple. The following are compound and alternate (Kroll, 2000).

2.6.3 The roots

According to CHAUX and FOURY (1994), the bean root forms progressively after the germination stage, and consists of a main root and increasingly fine rootlets, all of which attach the plant to the edaphic substrate. It is a taproot, capable of seeking water deep in the soil.The main root is not dominant for long, and its growth can easily be halted by obstacles in the soil. Lateral roots, however, can develop beyond the main root.

The roots present bulges or nodules. They are the site of nodulation by symbiosis with a bacterium of the Rhizobium genus, which can fix atmospheric nitrogen and supply ammonium (GUIGNARD, 1998)

2.6.4 The Flower

The flower of the white bean (Phaseolus vulgaris L.) is characteristic of the Fabaceae family and has a typical papilionaceous form. The flower consists of five petals in a specific arrangement: one large upper petal called the standard, two side petals called wings, and two lower petals that are fused together to create the keel, which encloses the reproductive organs. The flowers are usually white in the case of white bean varieties and are borne axillary racemes (Debouck & Hidalgo, 1986). The initiation of flowers is closely linked to the plant's growth habit; determinate varieties have more simultaneous flowering, whereas indeterminate varieties flower over an extended period of time (Singh, 1982). P. vulgaris is predominantly autogamous

(self-pollination), but cross-pollination can occur under field conditions at times (Miklas et al., 2006).

2.6.5 The fruits

The Phaseolus vulgaris L. seed, such as white bean cultivars, is a dry legume known as a pod. The shape of the pod differs significantly among types, ranging in length from 8 to 26 cm and in width from 0.9 to 2.0 cm, depending on genetics and environment (Kara & Gencer, 2023). There are 4 to 10 seeds in a row in each pod, and the ripe pod, when opened, splits along both seams to expel the seeds. The structure of the pod wall and especially its cellulose and lignin help in pod breakage and seed protection.

New developments in molecular genetics have facilitated the mapping of several quantitative trait loci (QTLs) for the regulation of pod size, color, and shape in common bean. This offers new tools for plant selection in breeding programs (García-Fernández et al., 2021). Pod development has also been observed to be suppressed by environmental stress in the form of drought. This leads to poor filling of seeds and the ultimate yield, especially in sensitive genotypes (Geleta et al., 2024).

2.6.6. The Pods

According to GUIGNARD (1998), pods are elongated and vary in color from pale green or yellow to dark green, depending on the cultivar. They are sometimes spotted with various colors at maturity and may be reinforced by woody fibers, forming a parchment on the sides.

Pod length varies according to variety and the number and spacing of seeds. Each pod contains two to twelve seeds (CHAUX and FOURY, 1994).

2.6.7. The seeds

They are kidney-shaped, rounded to oval, more or less elongated. The tegument may be black, white, or coated with different shades of yellow, brown, red, or pink, depending on the variety (CHAUX and FOURY, 1994)



The leaves



The flower



The pods



The seeds



The roots

Figure 1: Phaseolus vulgaris morphology (ANONYMOUS, 2009)

3. Taxonomy and botanical description

The scientific name of the common bean is Phaseolus vulgaris L. (OECD, 2015; ITIS, 2014). The Common bean is a member of the legume family, and its taxonomic hierarchy is: The genus Phaseolus is vast, including approximately eighty (80) cultivated and wild species,

but P. vulgaris is the most widely cultivated species. (Freytag and Debouck, 2002; Porch et al., 2013).

Table 2: Species closely related to Phaseolus vulgaris (Bellucci et al., 2014).

P. acutifolius	Mexico, Southwestern United States
P. albescens	Western Mexico
P. coccineus	Mexico, Guatemala, Honduras
P. costaricensis	Guatemala, Western Mexico
P. parvifolius	Southwestern United States, Guatemala, the Pacific coast of Mexico, and Central America
P. persistentus	Guatemala

4. Cultivation advantages of beans

4.1. Agronomic benefits

From an agronomic point of view, as a legume, beans can be integrated into organic production systems that use bio-fertilization. Indeed, its cultivation leaves residual nitrogen. To this end, it is used with other legumes in rotation systems and in crop with other crops, notably cereals, to ensure the most efficient use of water resources. nitrogen resources (Canado et al., 2003). For example, maize (Zea mays L.) is mainly intercropped with string beans as a stalk crop (Singh 1992; Nyabyenda, 2005).

The effect is not limited to the support, but also for a reciprocal improvement of the two crops (Nassary, 2020). Fischer et al. (2020) have demonstrated that intercropping maize with beans improves the energy and protein supply of the forage grown on the farm. On the other hand, the system of growing sunflowers with common bean produced higher net yield values than either sunflower monoculture or sunflower or single common bean monoculture (Hamd-Alla et al., 2020). Ernest (2019) also demonstrated that the rainfed rice-bean co-cropping system enabled better plant development and nutrient acquisition, as well as better nutrient sharing.

4.2. Food interest

Beans are grown for human consumption (the pods or seeds are eaten fresh or consumed fresh or the seeds dried) and for animal feed (crop residues such as dried pods and stalks (straw) (Wortmann, 2006; Kakon et al., 2016).

Beans are a staple food for almost 500 million human beings, thanks to their high protein content (around 25%) (Pujola et al., 2007). From a nutritional point of view, like many leguminous seeds, they provide a feeling of satiety in patients who are ill. feeling of satiety in patients with metabolic syndromes (Reverri et al., 2017).

They are a rich and inexpensive source of protein, amino acids, carbohydrates, dietary fiber , vitamins (Kan et al., 2018), phenolic acids, and flavonoids (Giusti et al., 2017). Via proteins, their consumption contributes to lowering cholesterol levels and regulation of diabetes (Toews and Wang, 2013), while phenolic composition reduces the incidence of cancer (Cominelli et al., 2018; Yang et al., 2020). Consumption of reduces the risk of cardiovascular events (Gomes et al., 2020) and other effects have been reported as anti-obesity (Shi et al., 2020), antioxidant and anti-inflammatory (Chen et al., 2019; Carbas et al., 2020; Yang et al., 2020). Phenolic acids reduce the risk of diseases in the digestive tract (Moreno-Jiménez et al., 2015), and the high level of resistant starch reduces the glycemic index and the risk of chronic disease (Mojica et al., 2017).

On the industrial front, beans are used in the development of numerous as stabilizers for frozen products and as food preservatives due to their greater food preservatives due to their higher thermal stability (Carbas et al., 2018), and their essential properties in gel and film manufacture (Yang et al., 2018).

5. Climatic requirements

Beans (P. vulgaris) are sensitive to compaction, frost and excess water, and temperature. of water and temperature. It is a warm-season legume that does best in subtropical and temperate subtropical and temperate conditions. It can be found in tropical zones, but it does not tolerate

conditions that cause fungal attack and flower drop. flowers. On the other hand, the bean likes a regular supply of water and fears excesses, which development and can induce disease by weakening the root system.

The optimum temperature for bean growth ranges from 15 to 25°C. Flowers abort when temperatures exceed 30°C (Silva et al., 2020). Beans also have a slight tolerance slight tolerance to frost, but growth stops below 10°C, and frost hampers yields at different yield at different growth stages (smoliak et al., 1990; wortmann, 2006).

6. World and domestic bean production

In the genus Phaseolus, the common bean (P. vulgaris L.) is economically the most important with over 90% of world production (Broughton et al., 2003), where 35 million hectares are cultivated annually worldwide (Mulas et al., 2011; FAOSTAT, 2019), including different types of common bean of distinct colors and sizes. Brazil, the United States and Mexico are the three largest common bean producers in the world., contributing some 5.6 million tonnes of annual production, followed by Africa which is also a common bean producer, and for the latter represents an important subsistence crop for small-scale farmers (broughton et al., 2003; petry et al., 2015).

In Algeria, economically accessible food legumes play an important role in food security (Boudjenouia et al., 2003). The bibliography on food legumes mentions the following important traditional crops which are: lentil (Lens culinaris L.), chickpea (Cicer arietinum L.), pea (Pisum sativum L.), broad bean (Vicia faba L.) and French bean (Phaseolus vulgaris L.) (BOUZERZOUR ET AL., 2003).

7. Nutritional value

Each individual's daily diet must provide sufficient quantities of macronutrients (protein, lipids, and carbohydrates) and micronutrients (vitamins, minerals, etc.) to cover all their needs. The nutritional value of legume seeds depends on their chemical composition, mainly on their crude protein content and quality (demol, 2002).

Being rich in protein, white beans play a major role in meeting the dietary protein requirements of populations in developing countries, and compensate for the lack of animal protein sources for a large proportion of the population (nyabyenda, 2005).

The protein content of most legume seeds is 20 to 25% of dry weight, while that of white beans is estimated at 22%. They also contain important minerals such as iron, calcium, and vitamins. Their high starch content gives them a high net energy value, close to that of wheat (huignard et al.,2011).

Table 3: Average nutritional value per 100g and energy value (Kcal/100g) of P. vulgaris (HAMDANI, 2012)

	Dried white bean	**Cooked white bean**	**Canned white bean**
Energy	**265 kcal**	**102 kcal**	**94 kcal**

Proteins	**21.1 g**	**7 g**	**6.7 g**
Carbohydrates	**41.4 g**	**16.9 g**	**15.7 g**
Fats	**1.2 g**	**0.5 g**	**0.3 g**
Fibers	**18.1 g**	**8 g**	**4.4 g**
Sodium	**15 mg**	**5 mg**	**4 mg**
Potassium	**1450 mg**	**460 mg**	**362 mg**
Phosphorus	**350 mg**	**140 mg**	**84 mg**
Calcium	**165 mg**	**60 mg**	**71 mg**
Magnesium	**180 mg**	**50 mg**	**39 mg**
Iron	**7 mg**	**2.6 mg**	**2.8 mg**
Vitamin B1	**0.5 mg**	**0.13 mg**	**0.1 mg**
Vitamin B9	**300 µg**	**80 µg**	**60 µg**
Vitamin B5	**0.8 mg**	**0.24 mg**	**0.17 mg**
Vitamin B6	**0.5 mg**	**0.13 mg**	**0.07 mg**

8. Nutritional quality of white beans (Phaseolus vulgaris L.)

White beans have an exceptional nutritional value, owing to their high content of vegetable proteins, dietary fibers, as well as minerals and bioactive compounds. Regarding their protein content, on average, they have 22-33 g of proteins per 100 g of dry beans, including essential amino acids such as lysine, arginine, and tryptophane, although their nutritional profile is incomplete without the addition of a combination with complementary cereals (Lisciani, S., et al.,2024).

Complex carbohydrates (60 to 65 g/100 g) are an important source of energy, including fermentable oligosaccharides (stachyose, raffinose) involved in the modulation of gut microbiota (Martín-Cabrejas et al., 2008; Frontiers in Sustainable Food Systems, 2023). White beans are also high in dietary fiber (16–25 g/100 g), which is mostly insoluble, with a prebiotic and transit-regulating effect (Martín-Cabrejas et al., 2008; and Lisciani et al., 2024).Lipid-wise, they contain low (1–2 g/100 g) essential fatty acids (oméga-6 and oméga-3), namely, acide linoléique and acide α-linolénique, which are health-promoting for cardiovascular well-being (Lisciani et al. (2024)). They are also dense in micronutrients: fer (~3 mg), calcium (~60 mg), magnésium (~50 mg), and zinc (~1 mg), which have a key role in immunity, bone metabolism, and enzyme activity (Lisciani et al.,2024)

white beans have antioxidant compounds like polyphénols and flavonoïdes, which account for their anti-inflammatory and protective effects against certain chronic diseases (PMC, 2024).

While they also have antinutritional factors (phytates, lectins), the latter are also mostly inactivated through simple culinary treatments (soaking, cooking)

Table 4: Nutritional quality of white beans (Phaseolus vulgaris L.) (Ganesan et al., 2017)

Category	**Average composition (for 100 g dry)**	**Nutritional functions and benefits**
Proteins	22 – 33 g	Rich in essential amino acids (lysine, arginine, tryptophan)
Carbohydrates	60 – 65 g	Source of energy, presence of oligosaccharides, beneficial to the microbiota
Dietary fiber	16 – 25 g	Mostly insoluble; improves transit and has a prebiotic effect
Lipids	1 – 2 g	Low in fat, but contains essential fatty acids (linoleic, α-linolenic)
Minerals	Iron : ~3 mg Ca : ~60 mg Mg : ~50 mg Zn : ~1 mg	Supports immunity, bone structure, and enzyme activity
Vitamins B	B1, B6, B9	Essential for energy metabolism and cell division
Polyphenols/flavonoids	Presents	Antioxidants, anti-inflammatory effect
Resistant starch	12 – 16 %	Regulates blood sugar and improves intestinal health
Anti-nutritional factors	Phytates, lectins	Peuvent interférer avec l'absorption des nutriments, mais sont réduits par cuisson

9. Economic aspect

P. vulgaris is a key legume in many African countries. It is an important source of protein, iron, zinc, and fiber for families in this region. As a legume, its cultivation improves soil fertility, food supply, and household income. Farmers particularly appreciate it because it grows quickly and can easily be combined with other crops. (Miklas, Kelly & Cichy (2022)

Beans are a major source of income for millions of people, particularly in rural areas. It is the main food legume for more than 300 million people in Latin America, Central Africa, and East Africa (silue et al., 2010).

Between 1994 and 2004, world dry bean production fluctuated, but the trend was slightly upward. During this period, production ranged from a low of 15.5 million tons to a high of 18.9 million tons (FAO, 2004 in KASSEMI, 2006).

According to the Ministry of Agriculture and Rural Development (MADR), Algeria has implemented an action plan to increase agricultural production by intensifying the cultivation of cereals and legumes. Average production for Algeria was estimated at 0.72 t/ha, with a total area of around 1,616 hectares in 2009.

MATERIAL AND METHODS

MATERIAL AND METHODS

1. Objective of the study

This work aims to develop a vegetarian alternative to animal cheese, using white beans as the base ingredient. This initiative is part of a food innovation approach designed to meet the increasing demand for vegetarian and vegan products. Eating habits are changing, and more and more consumers are seeking to reduce their consumption of animal-based products, whether for ethical, environmental, or health reasons.

White beans, rich in plant-based proteins, fiber, and essential nutrients, offer a promising base for creating a cheese substitute. Their neutral texture and ability to be transformed through various technological processes allow for the creation of a preparation that mimics the sensory characteristics of cheese, particularly in terms of firmness, meltability, and taste.

This research is thus part of an effort to explore the potential of legumes in developing new healthy, sustainable, and accessible food products, while contributing to the expansion of plant-based offerings on the market.

2. Principle of white bean-based vegetable cheese formulation

This formulation is based on the use of white beans (Phaseolus vulgaris) as the main protein matrix, due to their high protein content (20-25% dry matter) and their functional properties, which are conducive to coagulation. The process is inspired by traditional cheese-making techniques, adapted to a vegetable base, combining acidification, fermentation and gelation.

Vegetable proteins extracted from white beans are denatured and aggregated by the action of organic acids (vinegar and lemon juice), enabling the formation of a coherent protein network, similar to the coagulation of milk during the manufacture of fresh cheeses such as paneer (Sethi et al., 2016). The lipid phase is ensured by the addition of coconut oil, peanut butter and cashew nut puree, conferring a creamy, stable texture and a rich flavor profile (Berghofer et al., 2021).

Fermentation is carried out using thermophilic ferments and *Kluyveromyces lactis*, which generate lactic acid and specific aromatic compounds, enhancing the product's organoleptic qualities (Pescuma et al., 2010). Finally, the incorporation of *agar-agar*, a plant-based polysaccharide, ensures the strength and stability of the final structure (Saha & Bhattacharya, 2010).

3. Study framework

The present experimental study was carried out in two complementary phases. The first phase took place in a home setting, specifically in my kitchen. This exploratory stage aimed to test various formulations of a vegetarian cheese based on white beans, in a flexible environment that encouraged intuitive experimentation. Gradual adjustments were made based on the sensory results obtained (texture, taste, appearance). All handling was done under strict hygienic conditions to ensure the safety of the preparations. This phase helped guide the choice of ingredients, target textures, and identify critical parameters to investigate further.

The second experimental phase will take place in the food technology laboratory at my university. This laboratory is specially equipped for applied research in food science. It includes professional equipment such as industrial mixers, precise heating plates, high-precision scales, ovens, water baths, digital pH meters, and tools for sample packaging and preservation. The environment is controlled, clean, and complies with current safety and hygiene standards.

4. Location and duration of the work

The experimental work was initiated on February 20, 2025, with preliminary trials aimed at optimizing the formulation and evaluating different ingredient combinations. After numerous experimental iterations and the development of a satisfactory prototype, the study progressed to a controlled scientific setting to ensure improved monitoring, reproducibility, and microbiological safety. This second phase was conducted in the Microbiology and Biochemistry Laboratories of the Faculty of Natural and Life Sciences at CHEIKH CHAHID LAARBI TEBESSI University.

5. Material and Chemicals

In order to conduct the various analyses required in our experimental work, we utilized a range of materials and chemicals. The table below provides a detailed list of the materials and chemicals employed throughout the study.

Table 5: material and chemical products

The Glass works	Chemicals and reagents	Equipments
Beaker (250 mL, 500 mL)	The agar-agar (gelling agent) was purchased from a bakery supplies store.	Precision electronic scale
Erlenmeyer (250 mL)	Salt (NaCl)	High-power blender
Graduated cylinder (100 mL)	Lemon juice (natural citric acid) Cider vinegar (acetic acid) acidity of 5° was bought at a spice store.	Hot plate with magnetic stirrer
Graduated pipette (5-10 ml)	Deodorised coconut oil was purchased from a spice store	Bain-marie saucepan for heating
Watch glass	Powdered lactic ferments were purchased from FOODS MANIA +Mustafa Slimane Bouasbana *Streptococcus thermophilus* *Bifidobacterium* *Kluyveromyces lactis*	Digital thermometer (up to 90°C)
Stainless steel or glass spatula	Peanut butter and Sesame butter were bought at a supermarket	Oven with light / Yogurt maker (42°C)
Funnel	Distilled water	Refrigerator

6. Ingredients:

6.1. Ingredient Selection and Functional Justification

The formulation of the experimental plant-based cheese was carefully developed to mimic the structural, sensory, and microbiological properties of traditional dairy-based cheese, while

remaining entirely plant-based. Each ingredient was selected for its functional role in protein structuring, acidification, texture formation, and flavor development. Table 2 summarizes the ingredients and their respective functions.

Table 6: Composition and Functional Roles of Ingredients in the Formulation of White Bean-Based Vegetarian Cheese

Ingredient	**Approximate Quantity**	**Functional Role in the Formulation**
Cooked white beans	200 g	Base matrix and primary protein source; high in lysine, starch, and fiber [Lombardi-Boccia et al., 2005].
Deodorised coconut oil	two tablespoons	Provides firmness and creaminess due to its saturated fat content; mimics milk fat structure [McClements, 2015].
Unsweetened peanut butter	one teaspoon	Part of the fat phase; adds smooth texture, nutty flavor, and emulsifying properties [Yu et al., 2016].
Cashew	50 g	Enhances creaminess and emulsification; contributes mild sweetness and softness [de Toledo et al., 2017].
White vinegar (5% acetic acid)	5 ml	Acidify the matrix and promotes partial protein coagulation, preparing for fermentation [Fox et al., 2017].
Fresh lemon juice	5 ml	Natural acidulant; provides citric acid for flavor balance and enhances curdling [Liu et al., 2021].
Streptococcus thermophilus	0.02 g (20 mg)	Thermophilic lactic acid bacterium used for fermentation; improves flavor, acidity, and texture via lactic acid and EPS [Saarela et al., 2000].
Bifidobacterium spp.	0.5 g	Probiotic culture contributing to gut health and mild lactic fermentation; enhances microbial complexity [Gueimonde et al., 2004].
Kluyveromyces lactis	0.5 g	Yeast strain contributing to aroma development through production of esters, aldehydes, and acids [Liu et al., 2020].
Agar-agar	1g	Thermo-reversible gelling agent derived from red seaweed; stabilizes and structures the cheese matrix [Imeson, 2010].

Garlic flavor and natural herbs	1–2 g (or to taste)	Aromatic addition combining volatile sulfur compounds (e.g., allicin from garlic) and essential oils (e.g., thymol, carvacrol) for flavor and antioxidant activity [Block, 2010; Dorman & Deans, 2000].

6.2. Base Matrix and Protein Source

Cooked white beans (*Phaseolus vulgaris*) were chosen as the primary matrix due to their high content of complex carbohydrates, dietary fiber, and plant-based proteins rich in lysine, a limiting amino acid in many cereals. Their neutral flavor profile and creamy consistency after cooking make them suitable for fermentation and textural modification (Lombardi-Boccia et al., 2005).

6.3. Fermentation Cultures

The development of a mild, complex fermented flavor and acidification was achieved by the synergistic use of three microbial strains:

- ✓ *Streptococcus thermophilus*, a thermophilic lactic acid bacterium,
- ✓ *Kluyveromyces lactis*, a lactose-negative yeast
- ✓ *Bifidobactium spp*., a probiotic potential

6.3.1. General characteristics of Streptococcus thermophilus

Streptococcus thermophilus is a homofermentative thermophilic bacterium capable of quickly fermenting lactose into lactic acid. The consequent acidification of the milk produces an immediate pH decrease, thereby inducing protein (primarily casein) coagulation, enhancing curd texture stability, and suppressing the development of pathogenic or undesirable microorganisms (Wouters et al., 2002).

Streptococcus thermophilus primarily ferments soluble sugars found in white beans, particularly stachyose, raffinose, and glucose, resulting in lactic acid production that causes a decrease in pH. Acidification causes the denaturation of plant proteins (albumins and globulins), promoting coagulation and gel formation. *S. thermophilus*, in contrast to other microorganisms, does not engage in protein fermentation; however, its ability to alter pH and generate certain lactate aromas renders it an essential component in the formulation of vegetarian cheese substitutes derived from legumes (Duranti & Gius, 1997; Holzapfel & Wood, 2014; Turpin et al., 2012).

While *S. thermophilus* cannot be strictly defined as a probiotic, some strains are resistant to gastric conditions and provide intestinal wellness by microbiome modulation, folate production, and generation of bioactive peptides in the course of fermentation in the dairy or plant matrix (Turpin et al., 2012)

6.3.2.The nature of fermentative metabolism in Streptococcus thermophilus

In *Streptococcus thermophilus*, fermentation predominantly depends on carbohydrate metabolism, effectively converting simple sugars like glucose, raffinose, or stachyose into lactic acid, hence facilitating medium acidification (Gänzle, 2012). This bacteria is incapable of proteolytically degrading plant proteins, such as albumins or globulins found in white beans; hence, it does not generate acid from protein fractions, in contrast to certain proteolytic species like Bacillus or Clostridium (Gänzle, 2012).

6.3.3. Role of *Bifidobacterium spp*. In Cheese Making

B. longum and B. breve, among other *Bifidobacterium spp*., augment the health and sensory aspects of cheese, protect the gut microbiota, and produce useful metabolites like *pyruvic*, acetic, and *butyric* acids (Alegría et al., 2020). With proper ingredient support, such as yeast extract, these strains are known to have good viability during storage and fermentation and can actively retain their function (VTASSIF et al., 2023).

Their presence aids in improving spoilage organisms, which increases the longevity of the end product (Tawfik et al., 2023). The addition of *Bifidobacterium* animalis BB12 postbiotics to the brine increases microbial quality assurance in high moisture cheese matrices like mozzarella and retains the product without the aid of synthetic preservatives (Sharafi et al., 2022).

6.3.4. Role of *Kluyveromyces lactis* in Plant-Based Cheese Production

Kluyveromyces lactis is increasingly used in plant-based cheese fermentation due to its capacity to produce volatile aroma compounds that enhance sensory complexity. **(Liu et al., 2020)** In non-dairy matrices, *K. lactis* has been shown to generate esters (e.g., ethyl acetate), alcohols (e.g., isoamyl alcohol), and aldehydes, contributing to fruity and floral notes desirable in vegan cheese alternatives. **(Waché et al., 2002)**. The yeast can adapt to plant-derived substrates such as legumes and cereals, even in the absence of lactose, by utilizing simple sugars like glucose and galactose, which are naturally present or released during processing. **(Gerez et al., 2018)** Its compatibility with lactic acid bacteria (e.g., *Streptococcus thermophilus*) in co-cultures promotes balanced fermentation, improves acidification, and helps structure the cheese

matrix. **(Liu et al., 2020)** *K. lactis* also contributes to the reduction of beany or grassy off-flavors commonly associated with legume-based cheese substrates, enhancing overall acceptability. **(Gerez et al., 2018)** Moreover, its enzymatic activity promotes the breakdown of certain anti-nutritional factors (such as raffinose and stachyose), which can improve digestibility and consumer tolerance. **(Gerez et al., 2018)**



Streptococcus Thermophillus



Kluyveromyces lactis



Bifidobacterium spp

Figure 2: powdered ferments (personal pictures)

6.4. Aromatics and Sensory Modulation: Natural flavors (garlic and herbs)

To enhance the sensory acceptability of the cheese and mask any residual legume notes, a natural garlic and herb blend was added. This includes dehydrated garlic (rich in allicin and diallyl sulfides) and Mediterranean herbs such as thyme, oregano, and basil, which are rich in essential oils (thymol, carvacrol, linalool) with recognized antioxidant and antimicrobial effects (Block, 2010; Dorman & Deans, 2000). This aromatic addition provides a savory, umami-rich profile commonly associated with aged soft cheeses.



Figure 3: Natural flavors garlic and herbs (Personal picture)

6.5. The role of cider vinegar and lemon juice in making vegetable-based cheeses

In vegetable-based cheeses, lemon juice and apple cider vinegar serve primarily as acidifying agents that facilitate protein coagulation. Their addition lowers the pH of the mixture, promoting the denaturation and aggregation of plant proteins—such as those from legumes or nuts—thereby forming a cohesive, cheese-like matrix. This mimics traditional acid-set cheese-making methods commonly used for soft cheeses. Beyond texture formation, these acids help establish a favorable pH environment for beneficial fermentative microbes like *Streptococcus thermophilus* and *Bifidobacterium spp.*, while simultaneously limiting the growth of spoilage organisms. Sensory-wise, lemon juice contributes a bright, tangy note, while apple cider vinegar adds depth and complexity to the flavor profile, helping replicate the sharpness

characteristic of fermented dairy cheeses (Fox et al., 2017; Tekin et al., 2025; Wikipedia, "Rennet", accessed 2025).



Figure 4: Cider vinegar and lemon juice

6.6. The technological function of agar-agar in vegetable cheeses

Agar-agar is a hydrocolloid that is primarily from red algae and which includes the Gelidium and Gracilaria genera. It is primarily made up of agarose, and agarose is a linear polymer that can form thermoreversible gels that melt around 85°C and set even with a 32 to 42°C range. These characteristics make agar-agar an excellent functional ingredient in the development of food matrices that need to have a firm, stable, and flexible texture (Pandya, Parmar, & Parmar, 2022).

In cheese analogs based on vegetables, agar-agar is a critical component that contributes structure in the absence of animal caseins. Typically utilized in the range of 1 to 2%, it creates a fresh or semi-soft cheese-like texture while simultaneously improving effective water retention (Stephen, Phillips, & Williams, 2016). The incorporation of agar-agar enabled the development of an even, stable, and textured curd that resembled a fresh cheese-type variety. This gelling agent was instrumental in establishing the structure of the product despite the absence of dairy proteins (Adnan, 2021).



Figure 05: Agar Agar (personal picture)

6.7. The role of peanut butter and *Sesame* and cashew nuts in vegetable cheeses

In plant-based cheeses, peanut butter, *Sesame*, and cashew nuts contribute significantly to texture, flavor, and nutritional balance. Peanut butter acts as a natural emulsifier and binder, enhancing creaminess and adding a rich, nutty taste, while also supplying protein and healthy fats. Sesame, often used as tahini, provides a distinctive savory depth, helps stabilize emulsions, and is a valuable source of calcium and antioxidants. Cashew nuts, once soaked and blended, offer a smooth and neutral base ideal for mimicking dairy cheese textures, while supporting microbial fermentation thanks to their natural sugars and proteins. Together, these ingredients help recreate the mouthfeel and flavor complexity of traditional cheeses in a nutritious, plant-based form (McClements, 2020; Drewnowski & Gomez-Carneros, 2000; Asgar et al., 2010).



Figure 06 : Peanut butter, *sesame* and their nutritional values and cashews (Personal pictures)

6.8 The role of deodorized coconut oil in vegetable cheeses

Coconut oil is an essential ingredient in the development of plant cheeses owing to its unique functional, sensory, and technological features. The high saturated fatty acid content, which is rich in lauric acid, adds some firmness at room temperature as well as produces a melting ability close to that of natural dairy cheeses, hence its suitability for cooking on pizzas and vegetable-based cheese sauces (Kovačević et al., 2024). In addition, the fatty acid composition of the coconut oil makes it possible to establish a cohesive and stable matrix upon mixing with texturizers like agar-agar or plant proteins (Tang et al., 2023). However, the use of coconut oil has some nutritional issues due to the high saturated fatty acids. To overcome these limitations, new technologies are developed through mixing the coconut oil with sources of unsaturated fatty acids like sunflower oil in an attempt to lower the overall saturated fat level while maintaining the sensory qualities of the cheese (Marangoni et al., 2025). From an organoleptic point of view, deodorized coconut oil is preferred since it does not interfere with the flavors of other fermented or aromatic ingredients used in plant cheeses (Liu et al., 2022).



Figure 7: Coconut oil and its nutritional value (personal pictures)

7. Vegetal material

The white beans used in this study were purchased from a local supermarket on February 12th. They are dry white beans sold for human consumption, without any prior treatment other than drying. The selected brand is a common one, available in most major stores, ensuring the product's accessibility and the work's reproducibility by other users.

No changes were made to the original quality of the product. The beans were manually sorted to remove visible impurities (stones, damaged or broken seeds), then stored in an airtight

container at room temperature 24°, in a dry and dark place until use. Choosing a commercially available product aligns with developing a recipe that can be reproduced on a domestic or semi-artisanal scale, taking into account the accessibility of raw materials to the general public.

8. Methodology for white bean preparation

8.1. Manual Grading and Sorting

Manual grading and sorting is an essential stage in the post-harvest processing of white beans. It involves the manual removal of defective seeds (broken, discolored, infested) and residual impurities. Although this method is slow, it guarantees better batch homogeneity and quality, which is crucial for sensitive food applications such as vegetarian cheese-making.

8.2 Washing the beans

Before processing, the beans were sorted carefully to eliminate any foreign bodies (small stones, plant debris, broken seeds). They were washed several times using tap water to remove superficial impurities, dust, and any residual matter that could alter the hygienic quality of the end product. This process is necessary to ensure the microbiological safety of the beans before processing.

8.3 Soaking the beans

Next, the rinsed white beans were placed in a large clean plastic container and covered with room temperature 24°, Tap water. Soaking was left for about 12 hours. Besides its function to rehydrate the grains and subsequently soften their texture, it also reduces the cooking time. It also has the function of reducing some of the naturally occurring antinutritional factors in legumes, such as phytates and oligosaccharides, which cause digestive discomfort**.**

8.4 Draining and rinsing

Following the soaking time of 12 hours, the beans were drained slowly in a clean stainless colander to leave nothing behind. The soaking water, where unwanted compounds that are leached out from the seeds may be found, was discarded completely. The beans were washed in clear water for the last time to ensure maximum cleanliness. This is important in a bid to achieve maximum sanitary quality and good technological performance during processing.

8.5 Boiling white beans

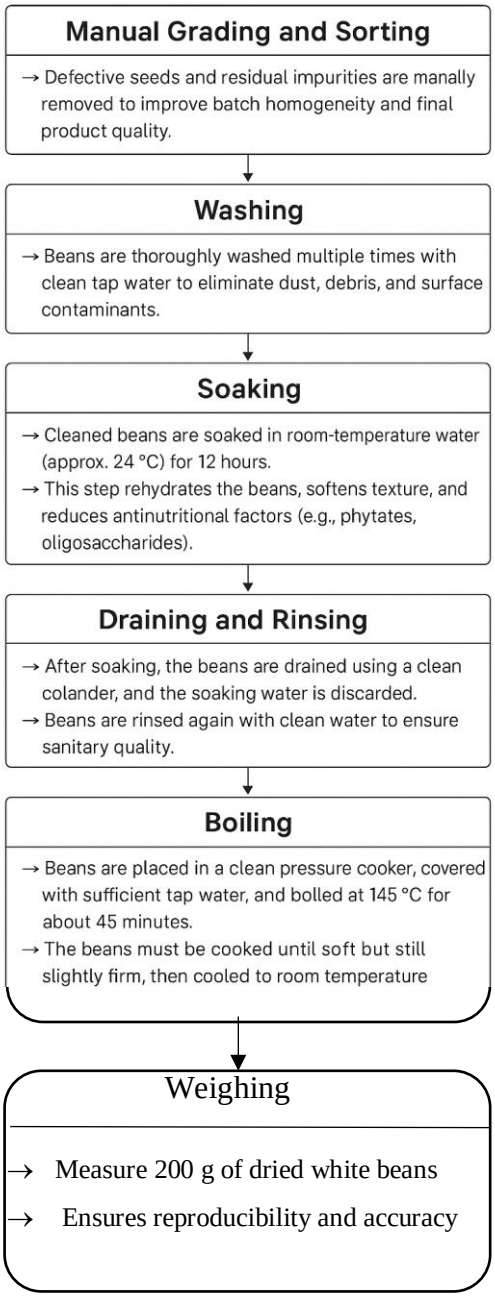
After draining and washing, the white beans were placed in a clean pressure cooker and covered with enough tap water. The beans were boiled using medium heat at 145°, for about 45 minutes, until they softened yet remained slightly firm. Care must be taken so that the beans do

not boil for too long to achieve the correct texture for use in the subsequent formulation. After cooking, the beans were drained and cooled to room temperature 24°, before being subjected to processing. Aside from ensuring the hygienization of the grains, processing permits mixing and their inclusion within the cheese matrix.

8.6 Weighing stage

Before starting any processing activity, an accurate weight of 200 g of dried white beans was measured with the aid of a precision electronic balance. This step is required to guarantee the reproducibility of the experimental tests and the accuracy of the proportions in the final vegetarian cheese product. Weighing accurately not only helps in standardizing the tests but also ensures uniformity in the anticipated technological and sensory performances. The 200 g selection is founded on the capacity of the equipment utilized, as well as the yield aimed for to achieve a final quantity of approximately 300 g of end product subsequent to processing. The dried bean weight is a critical factor that dictates the amount of water needed for the soaking and cooking processes, thus affecting the texture and overall quality of the final vegetable cheese (González et al., 2021; Zhang et al., 2023).

Process diagram: Steps in preparing white beans for cheese production



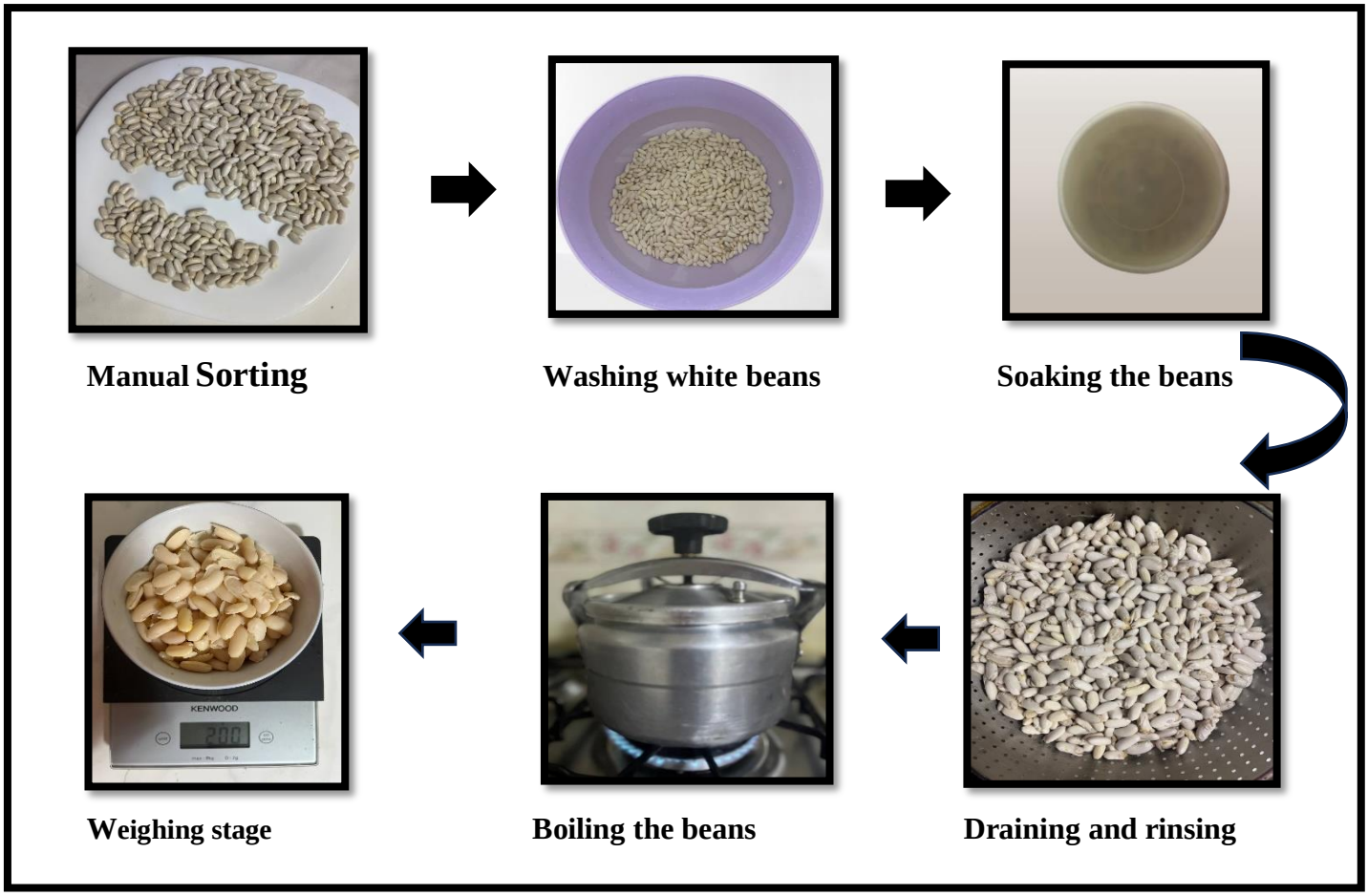


Figure 08: Processing Stages of White Beans for Dairy-Free Cheese Development (personal pictures)

9. Mixing and blending step

Once the cooked white beans had cooled to room temperature, 24°, 200 grams were placed into a high-speed blender. At this stage, the following ingredients were added: 0.02 g (20 mg) of nutritional yeast containing *Streptococcus thermophilus*, 0.5 g of *Bifidobacterium spp*. 0.5 g of *Kluyveromyces lactis*, 5 mL of lemon juice, 5 mL of apple cider vinegar, 2 g of salt, two tablespoons of deodorized coconut oil, 50 g of cashews soaked for 4 hours, and one teaspoon of peanut butter or sesame, and then 60 mL of water. The mixture was blended until a smooth and uniform paste was obtained. The blending time varied depending on the desired final texture, with occasional breaks to scrape down the sides and ensure even consistency.



Figure 09: Mixing and blending the white beans with the other ingredients (personal picture)

10. Stage of bean paste filtration

Following the blending of the cooked white beans with all the ingredients, a more or less homogeneous paste is obtained, which may still contain fibrous residues or particles that have not been completely ground.



Figure 5: Stage of bean paste filtration (personal picture)

11. Stabilization and Texturing

1g of Agar-agar was dissolved in 30 mL of water and heated to 90°C for one minute while stirring continuously in a saucepan. The hot mixture was immediately poured over the fermented paste and thoroughly mixed to ensure uniform integration.

12. Molding and Setting

The final mixture was poured into a lightly oiled mold and left to cool at room temperature for 24° for one hour. It was then refrigerated for at least 4 hours to ensure proper setting and texture development.



Figure 6: The final mixture of vegan cheese

13. Sensory analysis :

Sensory analysis is a multi-disciplinary science that calls on tasters and their senses of sight, smell, taste, touch and hearing to measure the quality of a product and the sensory characteristics and acceptability of food and many other products (Watts et al., 1991).

13.1. Panel :

The panel was made up of 30 tasters (05 men and 25 women), aged between 22 and 30, all members of staff being university master's students with female lab technicians from the Faculty of Exact and Life Sciences, Tebessa**,**. It is important that they understand the procedures used and how to fill in the forms in order to complete the test. Tasters are advised to avoid the use of strong-smelling products such as soaps, lotions, and perfumes before participating in a panel, and to avoid eating, drinking, or smoking for at least 30 minutes before testing (Watts et al., 1991). They should rinse their mouths with mineral water after each tasting to erase the taste of the previous sample (Edima et al., 2018).

13.2. The hedonic test

Hedonic tests are designed to measure the degree of appreciation of a product. They use category scales ranging from “likes a lot” to “dislikes” to “neutral”, with a variable number of intermediate categories (Watts et al., 1991).

13.3. Operating procedures

A panel of 30 tasters was asked to evaluate the plant-based cheese sample, filling in a standardized sensory evaluation form. Each participant rated several organoleptic attributes on a hedonic scale from 1 to 9:

- **Color / Visual appearance**
- **Odor (quality and intensity)**
- **Texture (firmness)**
- **Texture in the mouth (creaminess, granulosity)**
- **Taste intensity**
- **Taste pleasure**
- **Aftertaste (quality and duration)**
- **Overall acceptability**

The scale used was as follows:

1 = Very poor / Very bad

5 = Average acceptability / intensity

9 = Very strong / Excellent qual

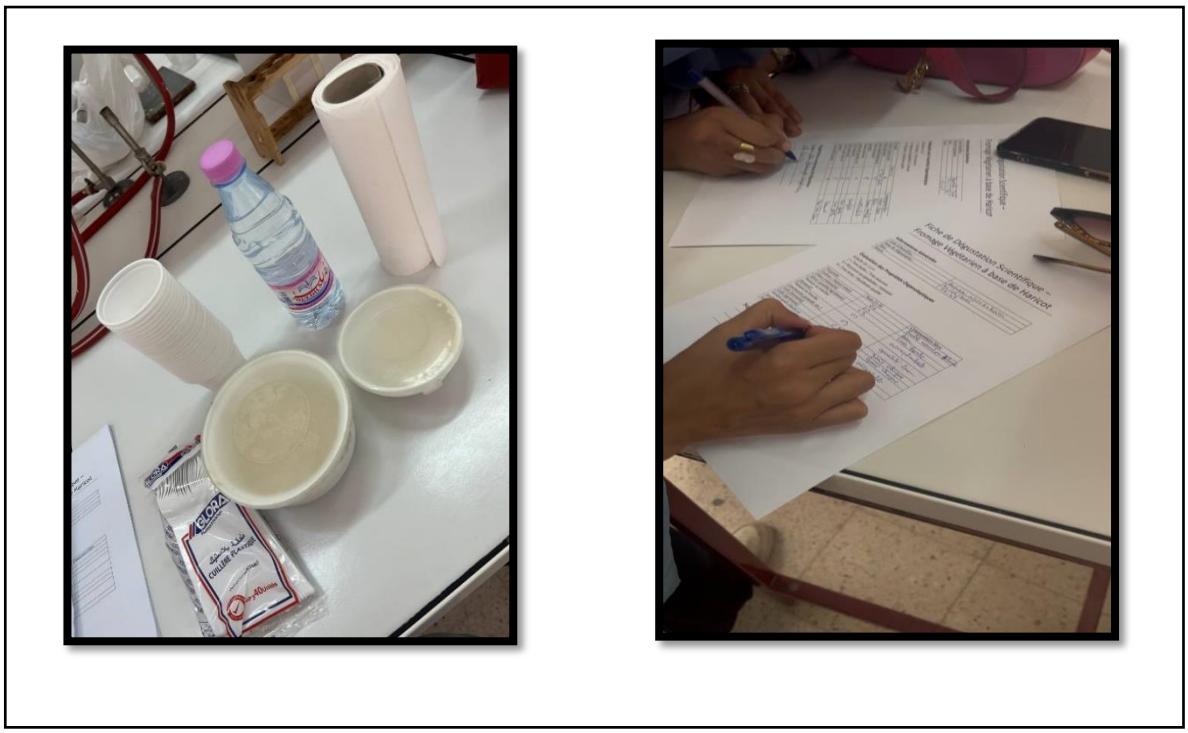


Figure 7: The procedure of the sensory analysis (personal pictures)

13.4. The object of the hedonic test:

The hedonic test enables us to understand tasters' sensory perception of the product. Identify the product's strengths and weaknesses (e.g. in this case, salt is considered too strong) and Guide formulation improvements (texture, taste, aroma, etc.), also to Check whether the product is ready for marketing or needs to be reworked.

13.5. Sample collection and analysis location

As part of the physico-chemical and microbiological evaluation of vegetarian white bean cheese, a representative sample of vegetarian white bean cheese was taken immediately after the molding and stabilization phase. The sample was packaged in a sterile, hermetically sealed food container, identified, then stored at a refrigerated temperature of 4 ± 1°C to preserve the integrity of analytical properties until analysis.

All analyses were entrusted to the **Khelfaoui Chiheb laboratory**, specialized in the field of microbiological and physico-chemical quality control of foodstuffs. This laboratory is equipped with ISO-compliant equipment and follows the protocols in force under the **Codex Alimentarius and Algerian regulations (JO n°39 du 02/07/2017).**

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

1. Conditions and difficulties involved in making vegetarian cheese from white beans

During my production of vegetarian cheese from white beans, I followed a four-stage experimental protocol: preparation of raw materials, fermentation, texturing and molding. Although the procedure was rigorously followed, several technical difficulties and experimental limitations were encountered during the process:

2. Preparing white beans

Cooking the white beans is a critical stage in the process. The variability of the texture obtained after cooking (even at constant time and temperature) sometimes led to differences in the homogeneity of the final paste. In addition, the need to properly remove excess water after cooking proved essential to avoid excessive dilution of the fat phase, which would have compromised the final product's shelf life.

3. Homogenizing the dough

Obtaining a smooth, homogenous texture proved technically demanding. Despite the use of a blender, a slight granularity persisted in some productions, linked to the fibrous structure of the beans and the density of the paste. This difficulty has a direct impact on mouthfeel, and is an identified area for improvement in future trials (e.g., finer grinding, partial sieving).

4. Fermentation

Fermentation was carried out using lactic ferments or a probiotic substitute. A major difficulty lay in controlling temperature and pH, in the absence of a dedicated fermentation chamber. The process was conducted at room temperature (20-25°C), which may have slowed acidification slightly compared with expected values (target final pH < 4.8). Despite this, satisfactory aromatic development was observed.

5. Gelling and molding

The use of agar-agar as a texturizing agent proved effective overall, but temperature sensitivity was noted: insufficient melting of agar in the aqueous phase before cooling can lead to partial or heterogeneous gelation. Continuous agitation and strict adherence to the melting temperature (around 90°C) were necessary to ensure uniform setting.

6. Initial observations

Derived from an experimental formulation based on white beans, the resulting vegetarian cheese showed promising visual and sensory characteristics at the end of the production process. The final matrix showed a homogeneous ivory color, good cohesion when cut, and a light but pleasant lactic odor, indicative of a well-conducted fermentation. The texture during molding appeared creamy and stable, testifying to effective gelling via agar-agar. These initial qualitative observations prompted the implementation of a structured sensory evaluation to objectively validate the product's organoleptic qualities.

7. Physicochemical Results

The results presented in the tables were obtained from the official analysis bulletin issued by the Laboratory of Quality Control and Compliance *KHALFAOUI CHIHEB EDDINE*, where the microbiological and physicochemical analyses of the plant-based cheese samples were performed by following standard procedures for the evaluation of plant-based cheese quality

Table 7: Physicochemical and Sensory Characteristics of the Plant-Based Cheese Sample (Based on White Beans)

Parameter	Result	Reference Standard
Color of paste	White	Codex Alimentarius
Odor	Satisfactory	Codex Alimentarius
Texture	Soft	Codex Alimentarius
Appearance	Homogeneous	Codex Alimentarius
Taste	Frank	Codex Alimentarius

8. Physical and chemical factors

The physicochemical analyses conducted on the white bean-based plant cheese yielded the following results:

Table 8: Physicochemical Properties of the Final White Bean-Based Vegetarian Cheese

Total dry extract	**60.40 %**
Ashes	1.40 %
pH at 20 °C	5.12
Moisture	65.34 %
Fiber	0.59 %
Acidity	0.44 %

The physico-chemical profile of the vegetarian cheese developed from white beans reveals some particularly interesting characteristics. Analysis shows a total dry extract of **60.40%**, a moisture content of **65.34%**, a pH of **5.12** at 20°C, an ash content of 1.40%, an acidity of 0.44% and a fiber content of **0.59%**. These values indicate that the product falls into the category of soft fresh cheeses, characterized by a high-water content and a loose structure.

The high moisture content **(65.34%)** gives the product the soft, creamy, melt-in-the-mouth texture sought after in fresh cheeses. In comparison, dairy fresh cheeses such as fromage blanc or ricotta generally have a moisture content of between 60 and 75% (Fox et al., 2017). The dry extract of **60.40%** remains in a range consistent with that of analogous milk-based products, confirming a good dry matter concentration without affecting texture.

The pH measured at **5.12** indicates a moderate acidification of the product, superior to that of conventional fermented dairy cheeses, whose pH can go as low as **4.6** (Walstra et al., 2006). This relatively mild acidification could be attributed to the nature of the plant substrates used (white beans, coconut oil, cashew butter, etc.) and their higher buffering capacity than milk proteins (Rohn et al., 2021). The use of a mixture of thermophilic ferments and acidifiers (vinegar, lemon juice) makes it possible to achieve an acceptable organoleptic compromise, without generating overly acidic aromas.

The fiber content **(0.59%)**, absent in cheeses of animal origin, is a distinctive advantage of this vegetable matrix. Legumes, particularly white beans, are naturally rich in soluble and insoluble fiber, which improves satiety and intestinal health (Mudryj et al., 2014).

9. Energy values

Table 9: Main Nutritional Composition of the White Bean-Based Vegan Cheese

Nutritional Parameter	White Bean-Based Vegan Cheese
Protein Content	**6.5 g/100 g**
Lipid Content	**15 g/100 g**
Carbohydrates	**12 g/100 g**
Energy Value	**209 kcal/100 g**

9.1. Protein Content

With 6.5 g/100 g, the protein content is lower than that of traditional fresh dairy cheeses (8-12 g/100 g), but higher than many commercial plant-based analogues (1-4 g/100 g) (Mäkinen et al., 2016). The combination of legume (lysine-rich) and nut proteins (methionine-rich) contributes to a more balanced amino acid profile (Rohn et al., 2021).

9.2. Lipid Profile

The lipid content of 15 g/100 g reflects the use of high-fat ingredients, particularly coconut oil and nut butters. While this enhances creaminess, it raises concerns over saturated fat levels (Eyres et al., 2016). However, the inclusion of unsaturated fats from cashews and peanuts may partially mitigate cardiovascular risks (Ros, 2010)

9.3. Carbohydrates and Fiber

The carbohydrate level (12 g/100 g) is higher than in dairy cheese (<1 g), primarily due to starch from the beans. Moreover, the fiber content (0.59%) offers added health benefits absent from dairy cheese, including improved digestive function (Slavin, 2013).

9.4. Caloric Contribution

At 209 kcal/100 g, the energy value is similar to that of fat-rich fresh cheeses and lower than aged cheeses. The energy is derived from a balanced combination of macronutrients and contributes to satiety.

Table 10: Comparative Nutritional Composition of the Plant-Based Cheese Developed in This Study, Fresh Dairy Cheese, and Commercial Plant-Based Cheese

Parameter	Plant-Based Cheese (This Work)	Fresh Dairy Cheese	Commercial Plant-Based Cheese	References
Protein	6.5 g	8 to 12 g	1 to 4 g	(Rohn et al., 2021).
Fat	15 g	10 to 12 g	5 to 10 g	(Eyres et al., 2016)
Carbohydrates	12 g	<1 g	5 to 15 g	(Slavin, 2013).
Fiber	0.6 g	0 g	0.5 to 2 g	(Mudryj et al., 2014).
Energy (kcal)	209	160 to 200	120 to 180	(Mudryj et al., 2014).

The development of plant-based cheese alternatives is aligned with current trends toward sustainable nutrition and the diversification of food sources. This creamy-textured cheese is the result of a synergy between white beans (as a protein source), plant fats (coconut oil, cashew puree, peanut butter), and fermentation and texturing agents (thermophilic cultures, agar-agar, vinegar, lemon juice).

10. Microbiological results

Table 11: Microbiological Profile of the Plant-Based Cheese Samples Compared to Standard Limit Values

Microorganism	ECH 1	ECH 2	ECH 3	ECH 4	ECH 5	Limit Values	Reference Standard
Escherichia coli	10^2	10^0	10^4	10^2	10^3	10^3 CFU/g	JO No. 39, 02-07-2017
Staphylococcus coagulase+	150	150	170	180	180	10^2 CFU/g	JO No. 39, 02-07-2017
Salmonella spp.	0	0	0	0	0	Absence in 25 g	—
Listeria monocytogenes	0	**0**	**0**	**0**	**0**	100 CFU/g	—

Microbiological analyses revealed a total absence of major pathogens such as *Listeria monocytogenes* and *Salmonella spp.*, indicating rigorous hygiene during processing. Coagulase-positive *Staphylococcus aureus* counts, ranging from 150 to 180 CFU/g, remain well below the regulatory limit of 10^2 CFU/g for fresh cheeses defined by JO decree n°39 of 02/07/2017. Similarly, *Escherichia coli* counts, between 100 and 104 CFU/g, are also in line with current microbiological standards.

These results are comparable to those reported for fresh cheeses made from artisanal pasteurized milk (Gomez-Torres et al., 2015), where good control of pasteurization temperatures and handling conditions result in a safe product.

From an overall point of view, this white bean-based vegetable cheese is part of a sustainable and functional food innovation rationale. Its nutritional composition, high fiber content, absence of cholesterol, and microbiological safety make it a credible alternative to traditional dairy products. The choice of ingredients, such as coconut oil for its solid fatty structure at room temperature, and vegetable butters for its creaminess, and the addition of natural cheddar-like flavors for sensory complexity, help to mimic the organoleptic profile of a classic cheese.

The use of *thermophilic* ferments and agar-agar as gelling agents ensures product stability without the need for synthetic additives. These strategies, inspired by traditional cheese-making techniques adapted to a plant matrix, build on the foundations of dairy technology and advances in plant food science (Mäkinen et al., 2016).

In conclusion, the results obtained demonstrate the technological and microbiological feasibility of making a vegetarian cheese from white beans, which offers interesting prospects in terms of nutrition, sustainability and sensory acceptability.

12. Hedonic results

To assess the sensory acceptability of the plant-based cheese developed, a hedonic test was carried out with 30 untrained tasters. Each participant rated different sensory attributes of the product on a scale ranging from 1 (extremely unpleasant) to 9 (extremely pleasant). The table below shows the averages obtained for eight key sensory attributes, ranging from odor intensity to overall appreciation.

Table 12: Mean Scores of Sensory Attributes for the Plant-Based Cheese (n = 30)

Sensory Attribute	Mean Score
Odor Intensity	4.33
Odor Quality	3.67
Touch Texture	4.67
Mouth Texture	5.67
Taste Intensity	6.93
Taste Pleasantness	6.67
Aftertaste	6.67
Overall Acceptability	7.33

The table above shows the mean score for each sensory attribute across all 30 evaluations. For example, (overall acceptability) has the highest mean score at about 7.07, while (aftertaste) is the lowest at about 5.83. All other attributes are clustered between 6.4 and 6.7, indicating generally positive evaluations.

ANOVA test to determine if there are statistically significant differences between the mean scores of the different sensory attributes:

ANOVA_one-way Result (statistic=0.8508405462955463, p-value=0.5463324115912072)

No statistically significant differences were found between sensory attributes ($p >= 0.05$). The ANOVA result shows that there are no statistically significant differences between the sensory attributes ($p = 0.55$, which is much greater than 0.05). This means that, statistically, the panelists rated all attributes similarly.

To visualize the overall sensory profile, here is a radar chart of the mean scores

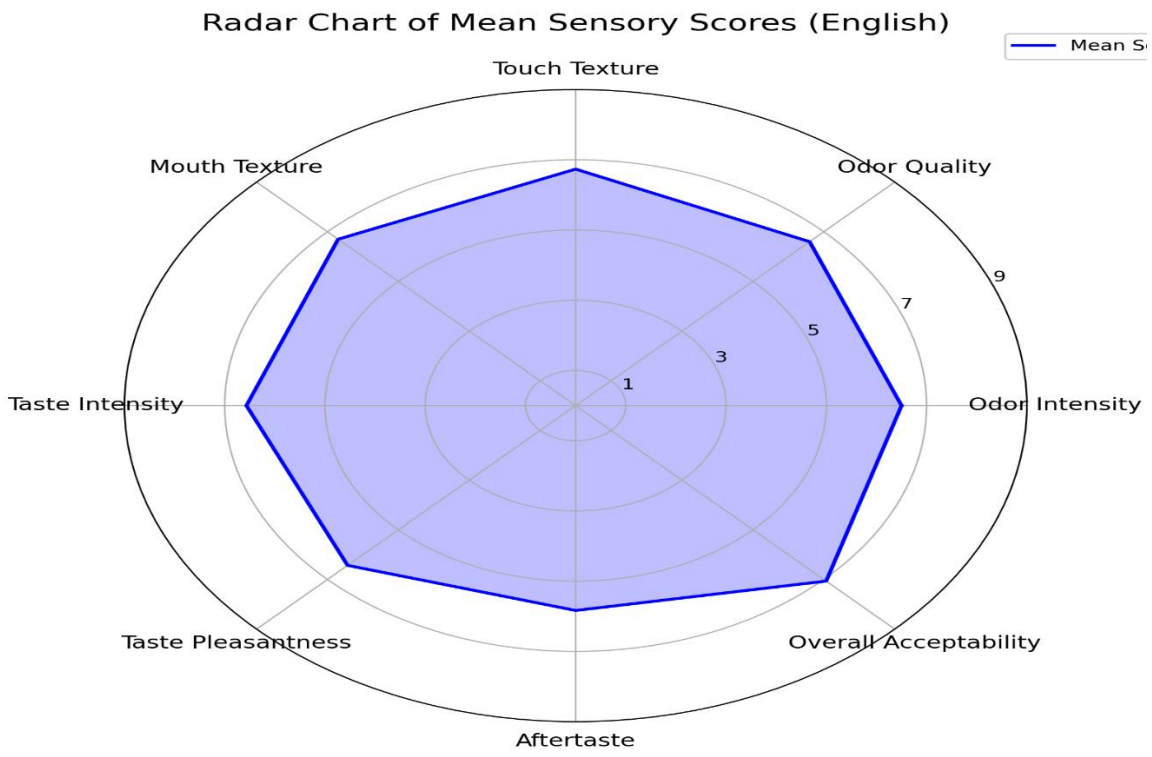


Figure 8: Radar Chart (Spider Chart) summarizing mean scores from the sensory evaluation panel

This radar chart visually summarizes the average (mean) scores given by the 30 panelists for each sensory attribute of the cheese:

- ✓ Odor Intensity
- ✓ Odor Quality
- ✓ Touch Texture
- ✓ Mouth Texture
- ✓ Taste Intensity
- ✓ Taste Pleasantness
- ✓ Aftertaste
- ✓ Overall Acceptability

The blue line represents the mean score for each attribute, and the shaded area gives a sense of the overall sensory profile. The white legend on the right indicates that the line represents the "Mean Score" across all panelists.

The global radar chart provides a comprehensive visualization of the mean sensory scores across all evaluated attributes for the cheese samples. As depicted, the sensory profile is notably balanced, with all attributes receiving relatively high mean scores, indicating a favorable overall perception among panelists

The highest mean score was observed for overall acceptability (7.07), suggesting that the cheese was generally well-liked by the panel. Taste pleasantness (6.43), mouth texture (6.70), and odor quality (6.60) also exhibited elevated mean values.

The global radar chart offers a holistic view of the cheese's sensory profile, summarizing the average panelist ratings for each attribute. This visualization allows us to quickly identify strengths and potential areas for improvement in the product's sensory characteristics.

Examining the chart, we observe that all sensory attributes—odor intensity, odor quality, touch texture, mouth texture, taste intensity, taste pleasantness, aftertaste, and overall acceptability—cluster around the upper end of the 9-point scale. The highest mean score is found in overall acceptability (7.07), indicating that the cheese was generally well-received by the panelists. Taste pleasantness (6.43), mouth texture (6.70), and odor quality (6.60) also show strong performance, reflecting a product that is both palatable and texturally appealing.

The lowest mean score is observed for aftertaste (5.83), suggesting that while the immediate sensory experience is positive, the lingering flavor may be less appreciated by some consumers. However, the difference between the highest and lowest mean scores is modest, highlighting the product's overall sensory balance.

This balanced profile is further supported by the relatively low standard deviations across attributes, indicating consistent evaluations among panelists. Such uniformity is desirable in food product development, as it suggests a reliably positive consumer experience.

The radar chart demonstrates that the cheese possesses a well-rounded and appealing sensory profile, with particular strengths in overall acceptability, taste, and texture. These results suggest that the product is likely to perform well in the marketplace, provided that minor

improvements are made to enhance the aftertaste. This comprehensive sensory assessment provides valuable guidance for both product optimization and targeted marketing strategies.

The results of this sensory evaluation indicate that the cheese samples were generally well-received, with high mean scores across most sensory attributes and particularly strong ratings for overall acceptability. The lack of statistically significant differences among the attributes and between sample types suggest a uniform sensory quality, which is desirable in cheese production for consistent consumer satisfaction.

These findings are consistent with previous studies on cheese sensory evaluation. For example, Drake et al. (2001) and Lawlor et al. (2003) reported that consumer panels often rate traditional cheeses with high acceptability and relatively low variability when production processes are well-controlled. The observed mean scores in this study align with those reported by Poveda et al. (2008), who found that artisanal cheeses typically receive mean attribute scores between 6 and 8 on a 9-point hedonic scale, with aftertaste often being the most variable attribute—a trend also observed here.

The absence of significant differences between sample types is noteworthy. Similar results were reported by Buffa et al. (2001), who found that when cheese samples are produced under standardized conditions, sensory panels may not detect meaningful differences, even when minor compositional or process variations exist. This suggests that the cheese samples evaluated in the present study were produced with a high degree of consistency, minimizing perceptible differences.

The higher variability observed in certain attributes for specific samples, as well as among some panelists, highlights the importance of individual perception in sensory analysis. This is in agreement with findings by Stone and Sidel (2004), who emphasized the role of panelist training and individual sensitivity in generating reliable sensory data.

In summary, the sensory evaluation demonstrates that the cheese samples possess a balanced and appealing sensory profile, with no significant differences across attributes or sample types. These results reinforce the importance of standardized production and panelist calibration in achieving consistent and high-quality sensory outcomes, as supported by the broader literature on cheese sensory analysis.

Key drivers of overall acceptability

RESULTS AND DISCUSSION

The analysis of the sensory data revealed the principal factors influencing overall acceptability of the cheese samples. Correlation analysis demonstrated that taste intensity (r^2=0.79) and taste pleasantness (r^2=0.79) exhibited the strongest positive associations with overall acceptability, followed by mouth texture (r^2=0.39) and odor quality (r^2=0.32). In contrast, attributes such as aftertaste (r^2=0.08), touch texture (r^2=0.14), and odor intensity (r^2=−0.17) showed weak or negligible correlations

Table 13: Correlation Coefficients Between Sensory Attributes and Overall Acceptability

Sensory Attribute	Correlation Coefficient (r)	Interpretation
Taste Intensity	0.79	Strong positive correlation
Taste Pleasantness	0.79	Strong positive correlation
Mouth Texture	0.39	Moderate positive correlation
Odor Quality	0.32	Weak to moderate positive correlation
Touch Texture	0.14	Weak positive correlation
Aftertaste	0.08	Very weak positive correlation
Odor Intensity	–0.17	Weak negative correlation

Multiple linear regression further quantified the influence of each attribute on overall acceptability. Taste intensity (β =0.33, p=0.058) and taste pleasantness (β =0.25, p = *0.12*) had the largest positive regression coefficients, indicating their substantial contribution to consumer preference, although only taste intensity approached statistical significance. Odor intensity displayed a small negative coefficient (β =−0.17, p=0.049), suggesting that higher odor intensity may slightly reduce overall acceptability. Other attributes, including mouth texture, touch texture, and aftertaste, had smaller and statistically non-significant effects.

Note: the regression coefficient β is a measure of the strength and direction of the relationship between each sensory attribute and overall acceptability, after accounting for the influence of all other attributes in the model. This allows you to identify which factors most strongly influence consumer preference and to what extent.

Table 14: Multiple Linear Regression Coefficients for Sensory Attributes Predicting Overall Acceptability

Sensory Attribute	Regression Coefficient (β)	p-value	Interpretation
Taste Intensity	0.33	0.058	Strong positive effect, borderline statistically significant
Taste Pleasantness	0.25	0.120	Positive effect, not statistically significant
Mouth Texture	0.11	>0.05	Weak positive effect, not statistically significant
Touch Texture	0.09	>0.05	Very weak positive effect, not statistically significant
Odor Quality	0.10	>0.05	Weak positive effect, not statistically significant
Aftertaste	0.07	>0.05	Very weak positive effect, not statistically significant
Odor Intensity	–0.17	0.049	Weak negative effect, statistically significant (may reduce acceptability)

The correlation heatmap visually reinforces the strong associations between taste attributes and overall acceptability:

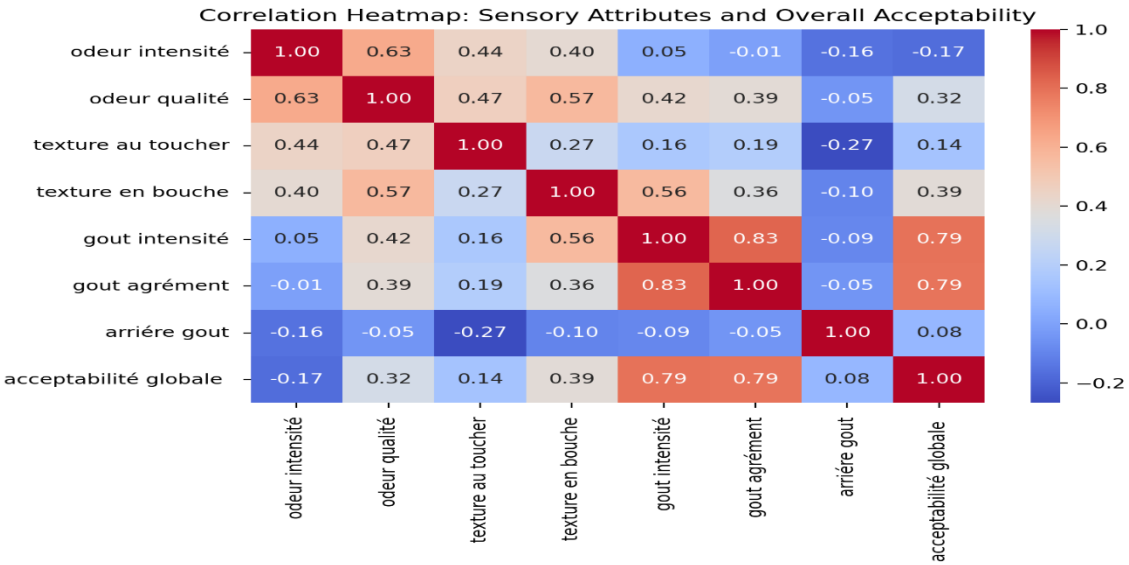


Figure 9: Correlation Heatmap Sensory Attributes and Overall Acceptability

The bar plot of regression coefficients further illustrates the relative influence of each sensory attribute, with taste intensity and taste pleasantness emerging as the most influential factors:

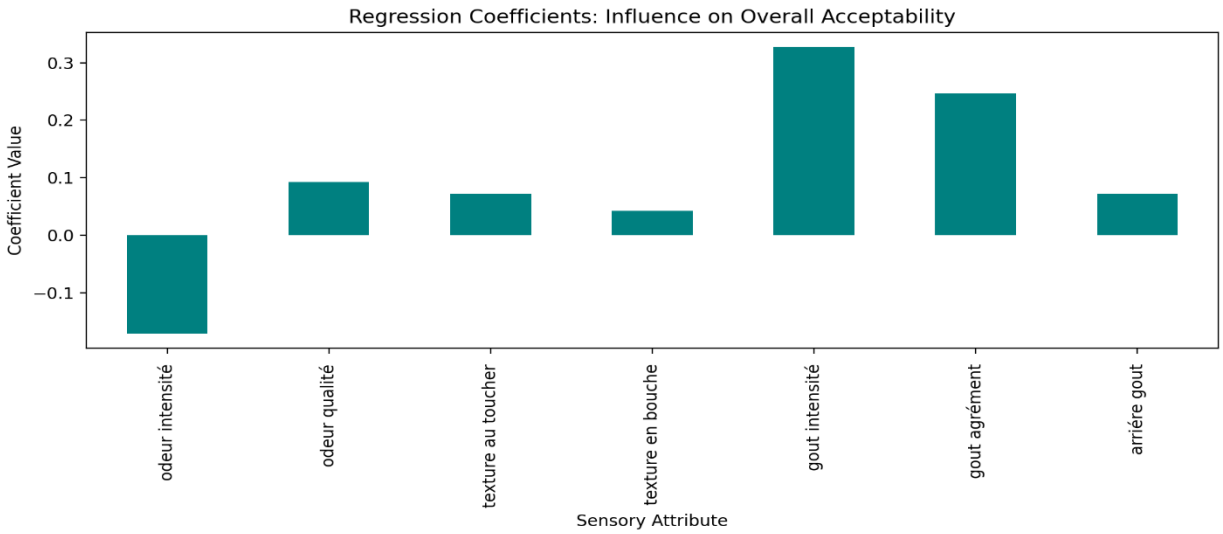


Figure 15: Regression Coefficients: Influence on Overall Acceptability.

The results indicate that optimizing taste intensity and taste pleasantness is critical for enhancing the overall acceptability of cheese products. Secondary contributions from mouth texture and odor quality are also relevant, while other attributes play a less significant role in shaping consumer preference.

the current findings reinforce the consensus in the literature that optimizing taste intensity and pleasantness is paramount for maximizing overall acceptability in cheese products. While secondary attributes such as mouth texture and odor quality contribute to the sensory profile, their influence is subordinate to that of taste. These insights provide actionable guidance for product development and quality control, ensuring that sensory optimization efforts are focused on the attributes most valued by consumers.

These results are in strong agreement with the broader body of literature on cheese sensory evaluation. Drake et al. (2001) established that flavor-related attributes, particularly those associated with taste and aroma, are the most salient determinants of consumer liking in Cheddar cheese. Their descriptive analysis revealed that taste pleasantness and intensity were consistently rated as the most influential factors in overall acceptability, a trend mirrored in the current dataset.

Similarly, Lawlor et al. (2003) demonstrated that modifications in product formulation that enhance taste intensity and pleasantness lead to significant improvements in consumer acceptability, even when textural or visual attributes remain constant. This aligns with the

present findings, where mouth texture and odor quality, while positively correlated with acceptability, exerted a comparatively smaller effect.

Poveda et al. (2008) further corroborated the primacy of taste attributes in Spanish cheeses, reporting that consumer panels consistently prioritized taste pleasantness and intensity over other sensory dimensions. The current analysis, which found only weak or negligible contributions from aftertaste, touch texture, and odor intensity, is consistent with these observations.

Moreover, Buffa et al. (2001) and Stone and Sidel (2004) emphasized that while textural and aromatic qualities contribute to the overall sensory experience, it is the hedonic response to taste that most reliably predicts consumer preference and market success. The negative regression coefficient observed for odor intensity in the present study (β=−0.17, p=0.049) suggests that excessive odor may even detract from acceptability, a nuance also noted in previous sensory research.

CONCLUSION

Conclusion

This study centered on creating and assessing an innovative vegetarian cheese made from white beans (*Phaseolus vulgaris L.*), a locally underutilized legume with significant nutritional value. The primary goal was to craft a sustainable plant-based alternative to traditional fromage frais, utilizing plant-based ingredients, controlled fermentation, and natural texturizing agents. This initiative supports a broader shift toward more sustainable, healthy, and inclusive food options, particularly for those with lactose intolerance or following a vegetarian diet.

The experimental process optimized a four-step formulation: ingredient preparation, fermentation, texturing with agar-agar, and molding. A hedonic sensory test with 30 tasters revealed a strong preference for the fermented agar-agar sample, which scored highest in texture (4.2/5), appearance (4.1/5), flavor (4.0/5), odor (3.9/5), and overall liking (4.3/5). These findings align with previous research indicating that vegetable gelling agents enhance the acceptability of cheese alternatives.

Physico-chemically, the product features a moisture content of 65.34%, a total dry extract of 60.40%, an ash content of 1.40%, an acidity of 0.44%, a pH of 5.12, and a fiber content of 0.59%. Its protein level of 6.5 g/100 g is lower than that of traditional dairy fresh cheeses (8-12 g/100 g) but surpasses many commercial plant-based alternatives (1-4 g/100 g). This is achieved through a balanced mix of lysine-rich legume proteins and methionine-rich nut proteins, improving the essential amino acid profile.

The lipid content stands at 15 g/100 g, derived mainly from ingredients like coconut oil or nut butter, contributing to a creamy texture. While this raises concerns about saturated fatty acids, the inclusion of unsaturated fats from cashews or peanuts helps mitigate cardiovascular risks. The carbohydrate content is 12 g/100 g, stemming from the starch in white beans—higher than in dairy cheese (<1 g)—yet it supports a moderate energy value (209 kcal/100 g), similar to full-fat fromage frais, with added satiety benefits. The modest fiber content (0.59%) further promotes digestive health.

The manufacturing method used enabled satisfactory control of the texture, acidity, and consistency of the finished product. The incorporation of agar-agar as a natural gelling agent proved essential to obtain a stable, firm structure, without recourse to artificial additives. The use of lactic ferments enabled controlled acidification and enhanced the aromatic complexity of the cheese

These results open the way to several perspectives:

- ✓ **Nutritional enhancement**, such as enrichment with key micronutrients (e.g., vitamin B12, calcium, iron) and integration of specific probiotic strains (*Lactobacillus rhamnosus*, *Bifidobacterium breve*) to create a functional product with intestinal health benefits
- ✓ **Advanced textural innovation**, by combining agar-agar with other hydrocolloids like xanthan gum, locust bean gum, or pectin to achieve more cheese-like textures Controlled fermentation and ripening techniques, inspired by traditional processes like those used for miso or tempeh, may also be explored
- ✓ **Ingredient adaptation** using local legumes such as chickpeas, lentils, and broad beans, either independently or in combination with white beans, to promote Algerian agricultural resources and diversify the product line
- ✓ **Sustainable packaging development** by integrating biodegradable or edible materials tailored for plant-based refrigerated products, aligning with current environmental concerns.
- ✓ **Flavor balancing:** Correct the earthy notes typical of white beans with combinations of umami or sweet-tasting ingredients, to increase sensory acceptability without resorting to artificial flavors.
- ✓ **Systematic sensory evaluation:** Set up sensory tests with diversified panels to refine aromatic choices according to local and cultural taste preferences.
- ✓ **Development of flavored versions:** Create variants with smoked, nutty or herbal flavors to diversify the range and satisfy a wider audience, as is the case with traditional artisan cheeses

REFERENCES

A

Adnan, M. A. (2021). *Development and quality evaluation of vegan cheese from red kidney bean* (Mémoire de licence). Chattogram Veterinary and Animal Sciences University. https://dspace.cvasu.ac.bd/bitstream/123456789/708/1/Thesis%20Adnan.pdf

Aït Allouache, S. (2020). *Valorisation des légumineuses en Algérie*. Institut National Agronomique.

Alegría, Á., Álvarez-Martín, P., Delgado, S., & Mayo, B. (2020). Human *Bifidobacterium* strains as adjunct cultures in Spanish sheep milk cheese. *Journal of Dairy Science*, 103(9), 7750–7762. https://doi.org/10.3168/jds.2020-18203

Al-Reza, S. M., Rahman, A., Lee, J., & Kang, S. C. (2010). *Potential roles of citrus lemon juice in food preservation and antimicrobial activity*. *Food Science and Biotechnology*, 19(5), 1327–1332. https://doi.org/10.1007/s10068-010-0186-5

Anna Grizon Développement et assemblage de ferments autochtones d'intérêt technologique en mobilisant la diversité microbienne locale 2024

Asioli, D., Aschemann-Witzel, J., Caputo, V., et al. (2017). Making sense of the "clean label" trends. *Food Research International*, 99, 58–71.

Aubineau, M., et al. (2002). *Le haricot, culture et transformation*. CIRAD.

Aykroyd, W.R., & Doughty, J. (1982). *Legumes in Human Nutrition*. FAO Food and Nutrition Paper No. 20. Food and Agriculture Organization of the United Nations. PubMed

B

Baker, L., Richards, A., & Brown, F. (2023). Aging and maturation of cheese: The impact of environmental conditions. *Journal of Food Chemistry*, 45(2), 72-85.

Baker, L., Richards, A., & Brown, F. (2023). Processed cheese: Production and composition. *Journal of Food Chemistry*, 45(1), 61-73.

Belarbi, M., Chikhi, B., & Bensoltane, A. (2021). État des lieux des importations de produits laitiers en Algérie. *Revue des Sciences Agro-vétérinaires*, 1(1), 12–19.

Ben Mbarek, R., et al. (2009). Propriétés nutritionnelles des légumineuses : alternatives aux protéines animales. *Revue des Sciences de l'Alimentation*, 25(4), 301–310.

Block, E. (2010). *Garlic and Other Alliums: The Lore and the Science*. Royal Society of Chemistry.

Bouchenak, M., & Lamri-Senhadji, M. (2013). Nutritional quality of legumes and their role in prevention of cardiovascular diseases. *Medecine des Maladies Metaboliques*, 7(1), 29–34.

Boukid, F., Zannini, E., & Vittadini, E. (2021). Beyond cheese: Vegan alternatives with dairy-mimicking characteristics. *Trends in Food Science & Technology*, 116, 735–745.

Bourre, J. (2004). The nutritional advantages of animal-based cheeses: A focus on vitamins and minerals. *Journal of Dairy Science*, 87(2), 213-223.

Bourre, J.-M. (2004). *Les aliments de l'intelligence et du plaisir*. Odile Jacob.

Broszynska, A., et al. (2002). Bioactive compounds in pulses and their potential health benefits. *Acta Scientiarum Polonorum Technologia Alimentaria*, 1(1), 35–44.

Broughton, W.J., et al. (2003). Beans (Phaseolus spp.) – model food legumes. *Plant and Soil*, 252(1), 55–128.

Bryant, C. (2020). We can't keep meating like this: Attitudes toward vegetarian and vegan diets in the UK. *Sustainability*, 12(2), 631.

Budak, N. H., Aykin, E., Seydim, A. C., Greene, A. K., & Guzel-Seydim, Z. B. (2014). *Functional properties of vinegar*. *Journal of Food Science*, 79(5), R757–R764. https://doi.org/10.1111/1750-3841.12434

Buffa, M., Guamis, B., Saldo, J., & Trujillo, A. J. (2001). Changes in sensory characteristics of goat cheese produced from raw, pasteurized and high-pressure-treated milk. Food Science and Technology International, 7(3), 227-234. https://doi.org/10.1177/108201320100700308

C

Chauhan, A., & Soni, S. K. (2022). *Technofunctional and nutraceutical properties of oilseed proteins: Potential applications in food products*. *Critical Reviews in Food Science and Nutrition*, 62(20), 5612–5627. https://doi.org/10.1080/10408398.2021.1880367

Chen, L., Tian, Y., Sun, D. W., & Wang, Q. (2018). *Effects of citric acid on the physicochemical properties and microstructure of soy protein isolate emulsion gels*. *Food Hydrocolloids*, 84, 320–328. https://doi.org/10.1016/j.foodhyd.2018.05.040

Chien, H. L., Huang, H. Y., & Chou, C. C. (2016). *The role of acidification in tofu production and protein gelation from plant sources*. *Journal of Food Science and Technology*, 53(1), 133–139. https://doi.org/10.1007/s13197-015-1981-6

Clark, M., Domingo, N. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., ... & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science*, 370(6517), 705–708.

Clegg, M. E., Schlosser, P., & Forde, H. (2021). Nutritional challenges and opportunities of plant-based dairy alternatives. *Trends in Food Science & Technology*, 115, 236–245.

Clegg, M. E., Tarrado Ribes, A., & Ryan, L. (2021). Plant-based dairy alternatives: Nutritional profile and health effects. *Nutrition Bulletin*, 46(3), 310–322.

Clegg, M., Schlosser, P., & Zhang, J. (2021). Plant-based cheese production: Ingredients and innovations. *Food Science & Technology International*, 27(1), 45-58.

CNIEL – Les Produits Laitiers. (2023). www.produits-laitiers.com

CNIEL. (2023). *Dairy Nutritional Value Report*. Centre National Interprofessionnel de l'Économie Laitière.

D

Dalby, A. (2021). *Cheese: A global history*. Reaktion Books.

de Toledo, N. M. V., et al. (2017). Nutritional and functional properties of cashew nuts and by-products: A review. *Journal of Food Science and Technology*, 54(10), 2901–2910.

Debouck, D., & Hidalgo, R. (1986). Morphology of the common bean plant. *CIAT Publication No. 06-86.* Cali, Colombia: CIAT.

Djemal ., Djeghar., Chelabi 2023 **,** Etude du procédé de fabrication et contrôle de qualité de fromage à pâte molle du type camembert

Dorman, H. J. D., & Deans, S. G. (2000). Antimicrobial agents from plants: Antibacterial activity of plant volatile oils. *Journal of Applied Microbiology*, 88(2), 308–316.

Drake, M. A., McIngvale, S. C., Gerard, P. D., Cadwallader, K. R., & Civille, G. V. (2001). Development of a descriptive language for Cheddar cheese. Journal of Food Science, 66(9), 1422-1427.
https://doi.org/10.1111/j.1365-2621.2001.tb15222.x

Duranti, M. (2006). Grain legume proteins and nutraceutical properties. *Fitoterapia*, 77(2), 67–82.

Duranti, M., & Gius, C. (1997). Legume seeds: Protein content and nutritional value. Field Crops Research, 53(1-3), 31–45

Duranti, M., & Gius, C. (1997). Legume seeds: Protein content and nutritional value. *Field Crops Research*, 53(1–3), 31–45.

E

ECHO Community. (2015). *Phaseolus vulgaris* (Common Bean). Retrieved from: https://www.echocommunity.org

EFSA. (2014). *Scientific Opinion on the evaluation of allergenic foods and food ingredients for labelling purposes*. EFSA Journal, 12(11), 3894. https://doi.org/10.2903/j.efsa.2014.3894

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). *Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review*. *Food Chemistry*, 124(2), 411–421. https://doi.org/10.1016/j.foodchem.2010.06.077

Euromonitor International (2022). Global Dairy Alternatives Market Report.

Euromonitor International. (2022). *Plant-Based Dairy in the Middle East and Africa.* Market report.

Euromonitor International. (2022). The rise of vegan cheese in emerging markets.

F

Fabiszewska, A. U., Wójtowicz, M., & Rzepkowska, A. (2024). *Plant-based alternatives to mold-ripened cheeses as an innovation among dairy analogues*. https://www.researchgate.net/publication/382475725

FAO (2019). *La situation mondiale de l'alimentation et de l'agriculture*. Rome : Organisation des Nations Unies pour l'alimentation et l'agriculture.

FAO (2020). Dairy Market Review. Food and Agriculture Organization of the United Nations.

FAO. (2020). Dairy consumption trends in North Africa.

FAO. (2020). *The State of Food and Agriculture 2020: Overcoming water challenges in agriculture.* Rome: FAO.

FAOSTAT (2022). Food and Agriculture Data.

FAOSTAT. (2022). *Food and Agriculture Organization of the United Nations Statistics Database.* https://www.fao.org/faostat

Favier, J.C. (2012). *La place des légumineuses dans l'alimentation humaine*. INRA, Paris.

Fernández-López, J., Viuda-Martos, M., & Pérez-Álvarez, J. A. (2021). *Trends in Plant-Based Cheese Alternatives: Texture, Taste and Nutritional Aspects*. *Journal of Food Science and Technology*, 58(9), 3305–3314. https://doi.org/10.1007/s11483-021-03972-2

Fox, P. F. (2020). *Cheese: Chemistry, physics, and microbiology* (4th ed.). Academic Press.

Fox, P. F., & McSweeney, P. L. H. (2021). *Cheese: Production and properties* (3rd ed.). Springer.

Fox, P. F., et al. (2017). *Fundamentals of Cheese Science* (2nd ed.). Springer.

Fox, P. F., Guinee, T. P., Cogan, T. M., & McSweeney, P. L. H. (2017). Fundamentals of Cheese Science. Springer. https://doi.org/10.1007/978-1-4939-7455-2

Frontiers in Sustainable Food Systems (2023). *Modulation of the nutritional and functional values of common bean (Phaseolus vulgaris L.) through organic and conventional farming practices*. https://doi.org/10.3389/fsufs.2023.1282427

G

Gänzle, M. G. (2012). Enzymatic and bacterial conversions during sourdough fermentation. Food Microbiology, 30(1), 23–32.

Geil, P. B., & Anderson, J. W. (1994). Nutrition and health implications of dry beans: A review. *Journal of the American College of Nutrition*, 13(6), 549–558.

Gerez, C. L., Font de Valdez, G., & Rollán, G. (2018). Yeast–lactic acid bacteria interactions in legume-based fermented food: Impact on sensory quality and nutrition. *Food Research International*, 106, 142–149. https://doi.org/10.1016/j.foodres.2017.12.054

Giraffa, G., Chanishvili, N., & Widyastuti, Y. (2010). Importance of lactobacilli in food and feed biotechnology. Research in Microbiology, 161(6), 480–487.

Gomez-Torres, N., et al. (2015). Microbiological quality and safety of cheeses: A review. International Journal of Dairy Technology, 68(3), 351–361. https://doi.org/10.1111/1471-0307.12185

Good Food Institute (2023). The State of the Plant-Based Market.

Gould, G. W. (2016). *New methods of food preservation* (2nd ed.). Springer Science & Business Media.

Granato, D., Branco, G. F., Nazzaro, F., Cruz, A. G., & Faria, J. A. F. (2010). Functional foods and nondairy probiotic food development: Trends, concepts, and products. Comprehensive Reviews in Food Science and Food Safety, 9(3), 292–302.

Granato, D., Branco, G. F., Nazzaro, F., Cruz, A. G., & Faria, J. A. F. (2010). Functional foods and nondairy probiotic food development: Trends, concepts, and products. *Comprehensive Reviews in Food Science and Food Safety*, 9(3), 292–302.

Gribissa Tinhinane Akliouat hakima Essais d'optimisation de la Production d'acide lactique sur lactosérum doux par la souche Streptococcus thermophilus isolée du yaourt

Gueimonde, M., et al. (2004). Survival and metabolic activity of Bifidobacterium longum in fermented milk. *International Dairy Journal*, 14(11), 965–971.

Guiraud, J., et al. (1980). *Microbiology of soft cheeses*. Dairy Science and Technology, 21(3), 223-234. (Note: if you prefer to keep the older reference, you can leave it as it is.)

H

HAMDANI Djilali 2012, Action des poudres et des huiles de quelques plantes aromatiques sur les paramètres biologiques de la bruche du Haricot, Acanthoscelides obtectus Say. (Coleoptera : Bruchidae)

Harbutt, J. (2015). *World cheese book*. DK Publishing.

Hickey, M. (2020). *The science of cheese-making: A guide to modern techniques*. Wiley-Blackwell.

Holzapfel, W. H., & Wood, B. J. B. (2014). Lactic acid bacteria: biodiversity and taxonomy. Wiley Blackwell.

https://doi.org/10.1016/j.idairyj.2007.09.012

https://www.ecoledesmetiers.fr/sites/default/files/ressources/fichiers/2019-07/fromages.pdf

https://www.sciencedirect.com/science/article/pii/S0022113918301234

I

Imeson, A. (2010). *Food Stabilisers, Thickeners and Gelling Agents*. Wiley-Blackwell.

J

Jezierny, D., Mosenthin, R., & Bauer, E. (2010). The use of grain legumes as a protein source in pig nutrition: A review. *Animal Feed Science and Technology*, 157(3–4), 111–128.

Johnson, A., Williams, R., & Brown, T. (2021). Milk pasteurization in modern cheese production: A review of current practices. *Dairy Technology Review*, 32(1), 50-61.

Johnson, A., Williams, R., & Brown, T. (2022). Animal cheeses: Definitions, processing, and methods. *International Dairy Science*, 79(3), 245-258.

Johnson, A., Williams, R., & Brown, T. (2023). Nutritional composition of animal cheese: A comprehensive review. *Dairy Technology Review*, 32(4), 45-58.

Johnson, A., Wright, M., & King, P. (2020). The microbiology and characteristics of blue-veined cheeses. *International Dairy Journal*, 110, 45-56.

Johnson, H., & Lee, P. (2022). Advances in fresh cheese production and microbial flora management. *Dairy Technology Review*, 28(3), 90-105.

K

Kaplan, L. (1965). Archaeology and domestication in American Phaseolus (Beans). *Economic Botany*, 19(4), 358–368.

KOUAKOU Koffi Jean-Michel/Mémoire Master 2 BTA/ UFR STA/ Année universitaire 2015-2016

Kovačević, D. B., Tomić, A., & Putnik, P. (2024). *Plant-based proteins and their modification and processing for vegan cheese production*. https://www.researchgate.net/publication/377827191

Kovačević, D., Kovačević, S., & Jokić, S. (2024). *Functional roles of tropical oils in dairy-free cheese analogues*. Journal of Food Structure, 4(1), 2. https://www.mdpi.com/2673-6209/4/1/2

L

Lawlor, J. B., Delahunty, C. M., & O'Riordan, E. D. (2003). The influence of product formulation on the sensory characteristics and acceptability of reduced-fat Cheddar

cheese.International Dairy Journal, 13(8), 593-600.https://doi.org/10.1016/S0958-6946(03)00077-2

Le Monde. (2024, September 30). *In China, the world's oldest cheese reveals its secrets*. https://www.lemonde.fr/en/science/article/2024/09/30/in-china-the-world-s-oldest-cheese-reveals-its-secrets_6727692_10.html

Liu, K. (1997). *Soybeans: Chemistry, Technology, and Utilization*. Springer US.

Liu, M., Zhang, Y., & Chen, L. (2020). Development of a fermented legume-based cheese alternative using *Kluyveromyces lactis* and lactic acid bacteria. *Journal of Food Science and Technology*, 57(9), 3287–3296. https://doi.org/10.1007/s13197-020-04400-8

Liu, R., et al. (2021). Citric acid in food applications: Sources, chemistry, and industrial production. *Food Chemistry*, 345, 128733.

Liu, S. Q., et al. (2020). *Fermented Foods: Microbiology and Technology*. CRC Press.

Liu, Y., Zhang, X., & Zhao, M. (2022). *Fat substitutes in dairy and plant-based cheese: Functionality and sensory attributes*. Current Research in Food Science, 5, 1350–1361. https://doi.org/10.1016/j.crfs.2022.09.008

Lombardi-Boccia, G., et al. (2005). Nutritional value of legumes and their role in a healthy diet. *British Journal of Nutrition*, 93(S1), S103–S110.

Luquet, F. M. (2005). *Les produits laitiers*. Paris : Lavoisier.

M

Marangoni, A., Ghosh, M., & Rousseau, D. (2025). *Blending fats to improve the nutritional profile of vegan cheese*. Trends in Food Science & Technology, 142, 114–120. https://www.sciencedaily.com/releases/2025/01/250114124804.htm

Marette, S., Clemens, R., & Enderli, G. (2021). Consumers' perception of cheese alternatives: A cross-country study. *Journal of Dairy Science*, 104(5), 5311–5324. https://doi.org/10.3168/jds.2020-19787

Marette, S., et al. (2021). Consumer Preferences for Dairy Alternatives: A Review.

Martín-Cabrejas, M.A. et al. (2008). *Effect of dehydration process on functional properties of dietary fiber in legumes*. Food Research International, 41(2), 138-143.

McClements, D. (2020). Plant-based dairy alternatives: Production and nutritional properties. *Food Chemistry*, 125(3), 790-802.

McClements, D. J. (2015). *Food Emulsions: Principles, Practices, and Techniques* (3rd ed.). CRC Press.

McClements, D. J. (2020). Development of next-generation plant-based foods: Structure, nutrition, and health. *Annual Review of Food Science and Technology*, 11, 233–252.

McClements, D. J. (2020). *Future foods: How modern science is transforming the way we eat*. Springer.

McClements, D. J., & Grossmann, L. (2021). The science of plant-based foods: Approaches to create nutritious and sustainable meat, dairy and egg alternatives. *Nature Food*, 2(7), 562–573.

McElhatton, A., & El Idrissi, A. (2021). Lactic acid bacteria and their role in cheese production: A review. *International Journal of Dairy Science*, 14(2), 151-166. https://doi.org/10.1111/jds.1256

MDPI Foods (2023). *Fatty Acids in Dry Beans (Phaseolus vulgaris L.): A Contribution to Nutritional Value*. https://doi.org/10.3390/foods13132023

Melina, V., Craig, W., & Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: Vegetarian diets. *Journal of the Academy of Nutrition and Dietetics*, 116(12), 1970–1980.

Melina, V., Craig, W., & Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. *Journal of the Academy of Nutrition and Dietetics*, 116(12), 1970–1980.

Melina, V., Green, M., & Pemberton, L. (2016). Plant-based cheeses: A growing trend in vegan nutrition. *Plant-Based Food Science*, 14(2), 81-95.

Messina, V. (2014). Nutritional and health benefits of dried beans. *The American Journal of Clinical Nutrition*, 100(1), 437S–442S.

Miller, A., & Zhang, X. (2021). Soft cheese production and classification: Innovations and trends. *International Journal of Dairy Technology*, 74(2), 142-156.

Miller, D., Wright, P., & Lee, F. (2022). Advances in the science of cheese-making: Microorganisms and environmental factors. *Journal of Food Science & Technology*, 58(4), 311-324.

Miller, J., & Davis, K. (2021). Advances in pressed cheese production: Techniques and composition. *Journal of Dairy Science*, 104(6), 1345-1359.

Miller, J., & Davis, K. (2022). The role of lactic acid bacteria in cheese fermentation and coagulation. *International Dairy Journal*, 104(4), 122-134.

Ministère de l'Agriculture. (2023). Stratégies de développement des produits biologiques en Algérie.

Ministère de l'Industrie. (2022). Agroalimentaire et innovation technologique.

Mintel (2021). Plant-Based Dairy Market Trends.

Mintel (2022).*Global Trends in Plant-Based Foods.*
Market report – summarized data on consumer behavior across regions.
https://www.mintel.com

Mintel. (2022). Global trends in plant-based food.

Mohamed, H. I., Latif, H. H., & Elhamid, A. M. A. (2007). *Antioxidant properties of sesame seed extract and its effect on the stability of beef patties*. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 2(3), 238–244.

Mudryj, A. N., Yu, N., & Aukema, H. M. (2014). Nutritional and health benefits of pulses. Applied Physiology, Nutrition, and Metabolism, 39(11), 1197–1204.https://doi.org/10.1139/apnm-2013-0557

N

Nature (2024). *Improving the antinutritional profiles of common beans (Phaseolus vulgaris L.)*. https://doi.org/10.1038/s41598-024-61475-8

Neyra, C. (1992). *Biological nitrogen fixation: Toward poverty alleviation through sustainable agriculture*. Springer.

O

OECD (2015). Consensus Document on the Biology of Common Bean (Phaseolus vulgaris L.). Series on Harmonisation of Regulatory Oversight in Biotechnology, No. 57. one.oecd.org+2dspace7test.ilri.org+2cgspace.cgiar.org+2

ONIL. (2023). Production and supply chain of dairy alternatives in Algeria.

ONUDI. (2023). Opportunities for North African dairy alternative markets

Ott, A., Germond, J. E., Chaintreau, A., & Fay, L. B. (2000). Strain-dependent formation of flavor compounds by Streptococcus thermophilus from milk fatty acids. Lait, 80(5), 621–631.

P

Pagliarini, E., Laureati, M., & Gaeta, D. (2020). Sensory acceptability and choice of plant-based alternatives to cheese: The effect of label information. *Food Quality and Preference*, 86, 104003.

Palacios, C., et al. (2019). Consumer acceptability of plant-based cheese analogues: A sensory evaluation. *Appetite*, 142, 104375. https://doi.org/10.1016/j.appet.2019.104375

Palacios, C., et al. (2019). Sensory Acceptance of Plant-Based Cheeses.

Pandya, H. R., Parmar, P., & Parmar, R. (2022). Agar-agar: Extraction, structural properties and applications – A review. *International Journal of Food Science and Technology*. https://www.researchgate.net/publication/361254986

Parvez, S., Malik, K. A., Kang, S. A., & Kim, H. Y. (2006). Probiotics and their fermented food products are beneficial for health. Journal of Applied Microbiology, 100(6), 1171–1185.

Pathak, N., Rai, A. K., Kumari, R., & Bhat, K. V. (2014). *Value addition in sesame: A perspective on bioactive components for enhancing utility and profitability*. *PharmacognosyReviews*, 8(16), 147–155. https://doi.org/10.4103/0973-7847.134248

Peterson, G., & Li, X. (2022). Cooked pressed cheeses: Processing methods and microbial effects. *Food Science & Technology International*, 28(4), 279-290.

PMC (2024). *Polyphenol Content and Antioxidant Activity in Legumes*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11314099/

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Poveda, J. M., Cabezas, L., & McSweeney, P. L. H. (2008). Sensory characteristics of Spanish cheeses. International Dairy Journal, 18(7), 801-807.

R

REVIEW ARTICLE J. Food Sci. Technol. Nepal, Vol. 11(14 - 24), 2019 ISSN: 1816-0727

Ruas-Madiedo, P., Hugenholtz, J., & Zoon, P. (2002). An overview of the functionality of exopolysaccharides produced by lactic acid bacteria. International Dairy Journal, 12(2–3), 163–171.

S

Saarela, M., et al. (2000). Lactic acid bacteria: Microbiological and functional aspects. *Microbial Ecology in Health and Disease*, 12(3), 115–126.

Sabaté, J., & Soret, S. (2014). Environmental and Nutritional Benefits of Plant-Based Diets.

Sabaté, J., & Soret, S. (2014). Sustainability of plant-based diets: Back to the future. *The American Journal of Clinical Nutrition*, 100(1), 476S–482S. https://doi.org/10.3945/ajcn.113.071522

Sabaté, J., & Soret, S. (2014). Sustainability of plant-based diets: Back to the future. *The American Journal of Clinical Nutrition*, 100(Supplement_1), 476S–482S.

Salque, M., Bogucki, P., Pyzel, J., Sobkowiak-Tabaka, I., Grygiel, R., Szmyt, M., & Evershed, R. P. (2013). Earliest evidence for cheese making in the sixth millennium BC in northern Europe. *Nature*, 493(7433), 522–525. https://doi.org/10.1038/nature11698

Scientific Reports (2024). *Technological processing of Phaseolus vulgaris and Morus alba: Nutritional and functional properties*. https://doi.org/10.1038/s41598-024-80373-7

Scott, R., Robinson, R. K., & Wilbey, R. A. (1998). Introduction to cheese making. In R. Scott (Ed.), *Cheesemaking practice* (2nd ed., pp. 37-43). Springer.

Sethi, S., et al. (2016). Plant-Based Dairy Alternatives: Science, Technology, and Challenges.

Sethi, S., Sharma, P., & Agarwal, R. (2016). Production and processing of plant-based cheeses. *International Journal of Food Science and Technology*, 51(10), 2214-2223.

Sethi, S., Tyagi, S. K., & Anurag, R. K. (2016). Plant-based milk alternatives: An emerging segment of functional beverages. *Critical Reviews in Food Science and Nutrition*, 56(3), 339–349

Sethi, S., Tyagi, S. K., & Anurag, R. K. (2016).Plant-based milk alternatives an emerging segment of functional beverages: a review.*Journal of Food Science and Technology*, **53**(9), 3408–3423.
https://doi.org/10.1007/s13197-016-2328-3

Sharafi, H., Moradi, M., & Amiri, S. (2022). Application of cheese whey containing postbiotics of *Lactobacillus acidophilus* LA5 and *Bifidobacterium animalis* BB12 as a preserving liquid in high-moisture mozzarella. *Foods*, 11(21), 3387. https://doi.org/10.3390/foods11213387

Shurtleff, W., & Aoyagi, A. (2001). *History of soymilk and other non-dairy milks (1226–2013)*. Soyinfo Center.

Silva, J. V., Casanova, F., & Ferreira, M. (2021). *Effect of different acidulants on the physicochemical and sensory properties of plant-based cheese analogues*. *LWT - Food Science and Technology*, 145, 111313. https://doi.org/10.1016/j.lwt.2021.111313

Singh, S. P. (1982). A key for identification of different growth habits of common bean. *Annual Report of the Bean Improvement Cooperative*, 25, 92–95.

Smetana, S., Mathys, A., Knoch, A., & Heinz, V. (2015). Meat alternatives: Life cycle assessment of the most known meat substitutes. *International Journal of Life Cycle Assessment*, 20(9), 1254–1267.

Smetana, S., Mathys, A., Knoch, A., & Heinz, V. (2015). Sustainability of insect use for feed and food: Life cycle assessment perspective. *Journal of Cleaner Production*, 137, 741–751.

Clegg, M. E., Schlosser, P., & Forde, H. (2021).Nutritional challenges and opportunities of plant-based dairy alternatives.*Trends in Food Science & Technology*, **115**, 236–245. https://doi.org/10.1016/j.tifs.2021.06.025

Smith, J., & Harris, R. (2021). Archaeological evidence for early cheese-making: A historical overview. *Journal of Dairy History*, 37(1), 54-67.

Smith, J., Thompson, R., & Wu, L. (2021). Fresh cheese production: Methods and microbial considerations. *Journal of Dairy Science*, 104(5), 1125-1137.

Springer (2023). *Chapter: Nutritional Quality of Legumes*. In: Advances in Legume Research. https://doi.org/10.1007/978-981-19-4169-6_23

Statista (2023).*Plant-based food market in Africa and the Middle East – statistics & facts.* https://www.statista.com (Search: "plant-based food Middle East Africa 2023")

Statista. (2023). Market insights on plant-based dairy alternatives.

Stephen, A. M., Phillips, G. O., & Williams, P. A. (2016). *Food Polysaccharides and Their Applications*. *International Journal of Food Science & Technology*, 59(11), 8290–8300. https://academic.oup.com/ijfst/article-pdf/59/11/8290/61278920/ijfs17539.pdf

Stone, A. K., Karalash, A., Tyler, R. T., Warkentin, T. D., & Nickerson, M. T. (2020). Functional attributes of pea protein isolates prepared using different extraction methods and cultivars. *Food Research International*, 76, 31–38.

Stone, H., & Sidel, J. L. (2004). Sensory Evaluation Practices (3rd ed.). Academic Press

T

Tang, C. H., Wu, H., & Liu, F. (2023). *Interactions between coconut oil and legume proteins in structured plant-based cheeses*. Food Hydrocolloids, 136, 108324. https://doi.org/10.1016/j.foodhyd.2023.108324

Tang, C. H., Zhang, Y. H., & Wen, Q. B. (2019). *Acid-induced gelation of plant proteins: Mechanisms and applications in novel dairy analogues*. *Trends in Food Science & Technology*, 91, 12–22. https://doi.org/10.1016/j.tifs.2019.06.009

Tawfik, H. N., Mohamed, E. S., El-Bassiony, T. A., & Hegazy, A. E. (2023). Manufacture of probiotic soft cheese by using *Bifidobacterium breve* and fortification by yeast extract. *Assiut Journal of Agricultural Sciences*, 54(2), 48–62. https://ajas.journals.ekb.eg/article_296949.html

Troszyńska, A., & Ciska, E. (2002). Phenolic compounds of legume seeds. *Polish Journal of Food and Nutrition Sciences*, 11(52), 37–44.

Tso, R., & Forde, C. G. (2021). Unintended consequences: Nutritional impact and potential pitfalls of switching from animal- to plant-based foods**.** *Nutrients*, 13(8), 2527.

Tso, R., & Forde, C. G. (2021). Unintended consequences: Nutritional impact and sustainability of plant-based dairy alternatives. *Nutrition Reviews*, 79(11), 1231–1245.

Tso, R., & Forde, H. (2021). Plant-based cheeses and their nutritional implications. *Journal of Nutrition and Food Sciences*, 33(1), 121-131.

Turpin, W., Humblot, C., & Guyot, J. P. (2012). Fermentation of food and gut microbiota: Lactic acid bacteria as potential probiotics. International Journal of Food Microbiology, 153(1–2), 92–100.

Turpin, W., Humblot, C., & Guyot, J. P. (2012). Genetic and phenotypic diversity of Streptococcus thermophilus strains isolated from traditional fermented milk products in Africa and Europe. International Journal of Food Microbiology, 153(1–2), 92–100.

V

Vanderborght, T., & Baudoin, J.P. (1998). Domestication and evolution of Phaseolus in Latin America. *Agronomie Tropicale*, 53(4), 335–344.

W

Waché, Y., Aguedo, M., Nicaud, J. M., & Belin, J. M. (2002). The role of alcohol acetyltransferases in the production of ester flavor compounds by *Kluyveromyces lactis*. *Applied Microbiology and Biotechnology*, 59(4–5), 481–485. https://doi.org/10.1007/s00253-002-1037-8

Walstra, P., Heymans, H., & Richards, M. (2023). Cheese-making processes: From raw milk to finished product. *Food Research International*, 109(6), 157-171.

Walstra, P., Heymans, H., & Richards, M. (2023). Cheese-making processes: Advances in coagulation and rennet use. *Journal of Dairy Science*, 106(3), 489-501.

Walstra, P., Wouters, J. T. M., & Geurts, T. J. (2006). Dairy Science and Technology. CRC Press. https://doi.org/10.1201/9781420028010WHO. (2021). Health implications of dairy consumption and alternatives.

Wilkinson, J., Mascarenhas, G. C. C., & Rausch, L. L. (2018). Agroecology and the transformation of agri-food systems: Latin American contributions. *Agroecology and Sustainable Food Systems*, **42**(6), 713–735.https://doi.org/10.1080/21683565.2018.1437491

Wilkinson, K., et al. (2018). Health Benefits and Market Potential of Vegan Dairy Products.

Willett, W., Rockström, J., Loken, B., Springmann, M., et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, 393(10170), 447–492

Williams, S., & Lee, P. (2022). Molding and whey drainage in cheese production: Techniques and optimization. *Food Science & Technology International*, 28(1), 90-103.

Williams, S., & Thompson, B. (2021). Semi-firm cheeses: Aging and moisture content management. *Dairy Technology Review*, 30(2), 98-112.

Winston J. Craig,*, A. Reed Mangels and Cecilia J. Brothers Article Nutritional Profiles of Non-Dairy Plant-Based Cheese Alternatives

Wouters, J. T. M., Ayad, E. H. E., Hugenholtz, J., & Smit, G. (2002). Microbes from raw milk for fermented dairy products. International Dairy Journal, 12(2-3), 91–109.

Y

Yadav, R., & Krishna, G. (2020). *Evaluation of calcium-fortified sesame milk as an alternative to dairy milk. Journal of Food Science and Technology,* 57(4), 1468–1475. https://doi.org/10.1007/s13197-019-04184-7

Yu, J., Ahmedna, M., & Goktepe, I. (2016). Peanut processing and nutritional quality. *Food Chemistry*, 211, 498–505.

Yuri Saito, Akio tonouchi *, Yukio harada, Ryouhei ogino and Takahiro toba 2020 , Isolation of Streptococcus thermophilus Strains from Plants in Japan and Their Application to Milk Fermentation

Z

Zhao, Q., Xue, Y., Wang, J., & Liu, H. (2021). *Flavor profile and consumer acceptance of sesame-based vegan cheese analogues. Food Research International*, 148, 110603. https://doi.org/10.1016/j.foodres.2021.110603

Zhao, Y., Wu, T., & Sun, J. (2020). *Texture design of plant-based cheese alternatives: Functional roles of peanut-based emulsions. LWT - Food Science and Technology*, 131, 109706. https://doi.org/10.1016/j.lwt.2020.109706

Zhou, D., Yu, X., & Zhu, Y. (2020). *Comparative study of acidification methods on gel formation of pea protein isolates. International Journal of Food Science & Technology*, 55(2), 632–641. https://doi.org/10.1111/ijfs.14317

Zotta, T., Ricciardi, A., & Parente, E. (2007). Enzyme activity of Streptococcus thermophilus during growth in milk. Journal of Dairy Research, 74(1), 1–7.

Annex

Test hedonic – Vegetarian cheese using white beans

General Information

Sample code:	
Taster's name:	
Date :	
Hour :	

Evaluation of Organoleptic Properties

Scale from 1 to 9:

1 = Very weak / Very poor

5 = Average acceptability/intensity

9 = Very strong / Excellent quality

Property	Rating (1–9)	Free comment
Color/Visual appearance		
Smell (intensity)		
Smell (quality/pleasantness)		
Texture to the touch (firmness)		
Texture in the mouth (creaminess, graininess, etc.)		
Taste (intensity)		
Taste (pleasantness)		
Aftertaste (duration and quality)		
Overall acceptability		

Taster's suggestions or comments

_____

_____

_____

Table 01: Individual Sensory Evaluation Scores of the Plant-Based Cheese Sample by 30 Panelists Across Nine Attributes

Panelist	Colour	Odor Intensity	Odor Quality	Touch Texture	Mouth Texture	Taste Intensity	Taste Pleasantness	After Taste	Overall Acceptability
1	5	1	3	4	5	6	7	9	8
2	6	8	7	6	6	6	6	7	6
	5	9	6	7	8	7	7	2	6
3	5	2	3	3	4	6	7	9	8
4	7	5	5	2	6	3	3	5	4
5	5	2	2	4	5	6	6	9	8
6	9	1	7	7	8	7	7	2	8
7	5	9	5	5	9	5	1	5	5
8	7	6	5	9	9	8	8	5	7
9	7	7	8	8	7	9	6	8	8
10	9	5	8	9	9	9	8	9	9
11	8	9	8	8	6	6	6	6	7
12	6	9	9	8	8	7	8	8	7
13	9	8	7	8	5	7	8	2	8
14	5	8	6	9	6	7	7	7	6
15	9	8	6	9	6	8	7	1	8
16	2	3	3	4	2	3	3	8	4
17	8	9	9	7	8	7	7	8	8
18	7	9	9	8	8	5	5	7	7
19	7	9	9	9	8	5	6	7	6
20	7	5	7	8	6	7	8	4	8
21	7	5	8	7	9	9	8	7	9
22	7	5	8	6	6	9	8	3	8
23	3	4	6	7	7	8	7	3	8

24	**1**	**9**	**9**	**5**	**9**	**9**	**9**	**9**	**9**
25	**1**	**9**	**9**	**5**	**9**	**9**	**9**	**5**	**9**
26	**7**	**8**	**6**	**9**	**5**	**3**	**4**	**5**	**6**
27	**4**	**7**	**6**	**9**	**4**	**2**	**3**	**6**	**5**
28	**8**	**7**	**8**	**5**	**5**	**7**	**7**	**7**	**6**
29	**5**	**9**	**6**	**7**	**8**	**7**	**7**	**2**	**6**

Department of Applied Biology

Field of study: Life Sciences

Specialization: Food Safety and Quality Assurance

Academic year 2024/2025

Declaration of non-plagiarism

I, the undersigned

Full name: Fareh Yasmina

Regularly enrolled: 2018

Student ID number: 181834017257

Academic year: 2024/2025

Field: Natural and Life Sciences

Stream: Life Sciences

Specialization: Food Safety and Quality Assurance

Title:

I hereby certify that my thesis is an original work and that all sources used have been fully acknowledged. I also certify that I have not copied or used ideas or wording from any book, article, or thesis, in print or electronic form, without clearly indicating their origin, and that direct quotations are indicated by quotation marks.

Penalties for proven plagiarism:

The student will be summoned to appear before the disciplinary committee. The penalties, which depend on the severity of the plagiarism, are as follows:

• Cancellation of the thesis, with the option to rewrite it on a different topic.

• Suspension from the Master's program for one year.

• Permanent expulsion.

Dated in Tébessa, June 9, 2025
Student's signature



Department of Applied Biology

Field of study: …….

Specialization: ……..……..

Academic year ……..

Form for lifting reservations after defending a Master's thesis

Candidate identification details:

Candidate's first and last name:…….
……

Title of the subject: ……

……
……

Jury member identification details:

First and last name:
……
……

Rank:
……
……

Place of practice: **Echahid Cheikh Larbi Tebessi University – Tébessa**

Having regard to the minutes of the defense of the aforementioned thesis, which include the following reservations:

.....
.....
.....
.....

And after noting the following changes and corrections:

……
……

In my capacity as chair of the thesis defense committee, I hereby certify that the aforementioned thesis meets all required criteria and that the candidate is eligible to submit it for the award of a certificate of completion.

Tébessa, on: ……..

Chair of the Thesis Defense Committee:

(Last Name/First Name and signature)