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The effects of incorporating spirulina into the production of soft cheese.

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Acknowledgment

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Meriem Assad (Ilyan).

Dedication

Dedication

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Dedication

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List of Abbreviations

List of Abbreviations

HSE: Health; Safety; Environment.

HACCP: Hazard Analysis Critical Control Point.

ISO: International Organization for Standardization.

FAO: Food and Agriculture Organization.

PH: Potential of Hydrogen.

MG (**FC**) : Fat content.

MAT : Total Nitrogenous Matter.

EST : Total dry extract.

MSE : Mean Squared Error

HFD (**MCDC**): Moisture Content of Dehydrated Cheese.

T.SEL (**SC**) : salt content.

DMSO : Dimethyl sulfoxide.

MRS (**SRM**): Selective Culture Medium.

VRBL : Violet Red Bile Lactose Agar.

PCA: Plate Count Agar.

FMAR (**TMAF**): total mesophilic aerobic flora.

LB: Lactic bacteria.

LH: Law heat.

MGLA (**ADF**): anhydrous dairy fat.

IMCU/ML: International Milk Clotting Units per milliliter.

IMCU/L MILK: International Milk Clotting Units per Liter isa measurement used in cheese making.

MGEAG/G: milligrams of Gallic acid equivalents per gram.

NGOs: Non-Governmental Organizations.

AIDS: Acquired Immunodeficiency Syndrome (VIH).

RDAs: Recommended Dietary Allowances.

DGDG: Digalactosyldiacylglycerol.

MGDG: Monogalactosyl diacylglycerol.

SQDG: Sulphoquinovosyldiacylglycerol.

ARDA: Amplified Ribosomal DNA Restriction Analysis.

SOD: Superoxide dismutase.

DNA: Deoxyribonucleic Acid.

List of Abbreviations

RNA: Ribonucleic Acid.

SP-Ca: calcium spirulina.

SP-Na: sodium spirulina.

Asp: Aspartic acid.

Thr: Threonine.

Ser: Serine.

Glu: Glutamic acid.

Pro: proline.

Gly: Glycine.

Ala: Alanine

Val: Valine.

Met:Methionine.

Ile: Isoleucine.

Leu: Leucine.

Tyr: Tyrosine.

Phe: Phenylalanine.

His: Histamine.

Lys: Lysine.

Arg: Arginine.

Trp: Tryptophan.

Cys: Cysteine.

AOC: Controlled Designation of Origin

BEHTAM:BOILEAU Etienne HIRI Abdelkader Tamanrasset.

List of Tables

List of tables

Table 01:The various names of spirulina (Girardin.A;2005). 6
Table 02:Natural geographical distribution of spirulina platensis(Fox.R.D.1999). 7
Table 03:Amino acid composition of spirulina platensis (Babadzhanov A.S.2004), ... 10
Table 04:Fatty acid composition of total lipids and polar lipids in spirulina platensis..... 11
Table 05:Water-soluble vitamins contained in the biomass of spirulina platensis according to season (***mg/100g*** *dry matter*) season (***mg/100g*** *dry matter*) (BabadzhanovA;etal;2004)..... 13
Table 06: Fat-soluble vitamins contained in spirulina platensis biomass (***Mg/100g*** of dry matter) (Babadzhanov A et al 2004)(www.tga.gov.au/docs/html/compguid/platensis.htm)... 13
Table 07:Minerals and trace elements contained in spirulina platensis (Avino p et al;2000). 13
Table 08:Trace element levels in spirulina platensis (Avino p et al;2000) 14
Table 09: Years of origin of noted cheese varieties. 25
Table 10:The type of cheese based on the type of coagulation .(MAJDI, 2009). 27
Table 11:Nutritional and calorific values of cheese per ***100mg*** (CIQUI,2020). 30
Table 12:Nutritional and calorific values of cheese per ***100mg*** (CIQUI,2020). 32
Table 13:Presentation of the Lactalis group in 2022..... 37
Table 14:Effect of breed on the chemical composition of milk.(Panthi et al, 2007) 39
Table 15:The different doses of spirulina added in Camembert production. 47
Table 16:The 07 draining phases. 48
Table 17:Key points for comparison. 60
Table 18:Normal Camembert (***250g; 220g, 145g***). 64
Table 19:Camembert (***250g:220g; 145g***) with spirulina. 64
Table 20:Comparison between the strains studied. 76

List of figures

List of figures

Figure 01:Photo of a kanembou woman skimming the surface of the spirulina 5
Figure 02:Morphologies typical of spirulina (Jarisoa;2005). 7
Figure 03:Distrbution of spirulina on the world 9
Figure 04:The average composition of spirulina. 10
Figure 05: Presentation of secchi disk. 19
Figure 06:*Arthrospira platensis* culture 21
Figure 07:Different strains of *Arthrospira platensis* 21
Figure 08:Average composition of cow's milk (http://www.maison-du-lait.com/fr/laitsliquides) 24
Figure 09:A type of cheese. 26
Figure 10:Major steps in cheese making (actual steps and \or conditions may vary). 29
Figure 11:Spirulina used to make soft cheese. 38
Figure 12 : Diagram of physico-chemical and bacteriological analysis methods for raw cow's milk. 39
Figure 13:Effect of different alcohol concentrations on raw cow's milk. 41
Figure 14:Diagram of camembert production according to the lactalis group. 43
Figure 15:Slicing the curds to make camembert. 46
Figure 16:Incorporation of spirulina in the production of soft cheese. 46
Figure 17:Moulding and draining of camembert enriched with spirulina. 48
Figure 18:Packaging of camembert enriched with spirulina 50
Figure 19:Diagram of experimental procedure for lactic acid bacteria and spirulina. 54
Figure 20:Overview of the antibacterial activity of spirulina 55
Figure 21:Extraction of bioactive compounds by aqueous solvent. 56
Figure 22:Filtration and evaporation of spirulina hydroalcoholic extract. 56
Figure 23:Stages in the revivification and normalisation of microorganisms on agar medium. 58
Figure 24:Camembert withchilli. 59
Figure 25:Camembert with thyme. 60
Figure 26:Results of bacteriological analysis of spirulina. 65
Figure 27:The relationship between spirulina and lactic acid bacteria. 67
Figure 28:Phenolic compound content in fermented and unfermented *A. Platensis* liquid. 68
Figure 29:Changes in the crust of ordinary and enriched soft cheeses. 69
Figure 30:Results of an *Escherichia coli* inhibition test using spirulina. 70
Figure 31:Results of *Staphylococcus aureus* inhibition tests with spirulina. 71
Figure 32:Results of the effect of spirulina on *Pseudomonas aeruginosa* 72
Figure 33:Test results for inhibition of *Bacillus subtilis* bacteria by spirulina extract. 73
Figure 34:Zone of inhibition of proteolytic bacteria by spirulina extract. 73
Figure 35:Antifungal activity of spirulina extract against *Candida albicans*. 74
Figure 36:Tasting sheet for camembert enriched with spirulina. 77
Figure 37:Sensory evaluation of Camembert enriched with spirulina. 78
Figure 38:Sensory evaluation of chilli-spirulina Camembert. 79

List of figures

Figure 39:Sensory evaluation of camembert with thyme and spirulina. 80
Figure 40:Expert opinion on camembert enriched with spirulina. 81
Figure 41:Consumer preferences between traditional camembert and camembert enriched with spirulina. 81
Figure 42:Consumer form. 82
Figure 43:Celia Logo. 93
Figure 44:The Sainte-Cécile factory, owned by the Lactalis Group (Nicolas Barreuro, 2022)94
Figure 45:The Sainte-Cécile factory, owned by the Lactalis Group (Nicolas Barreuro, 2022)94
Figure 46:Analytic balanc SARTORIUS. 95
Figure 47:pH meters HANNA HI2210. 95
Figure 48:Desiccator CIR 04..... 95
Figure 49:Cryostar I FUNKE GERBER. 96
Figure 50: Balanc DILU FLOW 96
Figure 51:Cheese brazer(BAG MIXER) GROSSERON. 96
Figure 52:Camembert mold 97
Figure 53:Vertical slicer , Horizontal slicer andManual stirrer. 97
Figure 54:Shelf holding the Camembert pieces. 97

Table of contents

Tables of contents

Acknowledgment ..... -

Dedication ..... -

List of Abbereviations ..... -

Listes of tabeles: ..... -

List of figures ..... -

Tables of contents ..... -

Introduction **1**

Chapter 1: Spirulina **3**

Introduction 4

I. General about spirulina 4

I.1. History of spirulina 4

I.2. What is spirulina 5

I.3.Taxonomy 6

I.4. Morphology of Spirulina 6

I.5.Natural geographical distribution 7

I.5.Recovery of spirulina 9

I.5.1. Proteins 10

I.5.2. Lipids 11

I.5.3. Carbohydrates 12

I.5.4. Nucleic acids (DNA and RNA) 12

I.5.5. Vitamins 12

- Water-soluble vitamins 12
- Fat-soluble vitamins 13

I.5.6. Minerals and trace elements 13

I.5.7. Metals 14

I.5.8. Pigments 14

II.Biological activities of spirulina 15

II.1.Antioxidant activity 15

II.2.Anti-inflammatory activity 15

II.3.Antifungal activity 15

II.4.Antiviral activity 15

II.5.Anti-cancer activity 15

Table of contents

III. Potential and uses of spirulina 16
IV. Physical and chemical growth conditions of spirulina 17
V. Reproduction of spirulina 17
VI.Different methods of spirulina production 17
VI .1. Artisanal cultivation 18
VI.2. Industrial cultivation 18
VI.3. Spirulina cultivation technique 18
- Inoculation and strain selection 18
- Measurement of spirulina culture concentration 18
- Agitation in spirulina cultivation 19
- Shading 20
- Harvesting 20
- Drying 20

V.II Arthrospira platensis *20*
Chapter 02 :Cheese 22
Introduction 23
I. From milk to cheese 23
I.1. The raw material: milk 23
I.1.1. Definition 23
I.1.2. Milk composition 24
I.2. Generality of cheese 25
I.2.1. History 25
I.2.2. Definition of cheese 25
I.2.3. Cheese varieties 26
Cheese based on coagulation types 26
a. Enzymatic Coagulation (Rennet-Coagulated Cheeses) 26
b. Acid Coagulation (Lactic-Coagulated Cheeses) 27
c. Mixed coagulation 27
Cheeses based on composition 28
a. Cream cheese 28
b. Hard and semi-hard cheeses 28
c. Soft cheeses 28
II. Cheese production 28
III. Nutritional value of cheese 30
IV. Camembert 30

Table of contents

IV.1. History of Camembert 30
IV.2. Definition 31
IV.3. Composition and nutritional value: 31
IV.4. Technological interface of microorganisms in soft cheese production 32
IV.5. Useful micro flora in the production of camembert-type cheese 32
IV.5.2. Yeasts 33
IV.5.3. Molds 34
V. Factors Influencing cheese aging 34
a. Temperature 34
b. Air Composition 34
c. pH 34
d. Water Activity (aw) 34
Experimental Section 35
Material and Methods 36
I. Place and duration of work 37
I.1. Presentation of the Lactalis Group (Célia) 37
II.Preparation of the raw material 38
II.1 Biologicalmaterial: Spirulina 38
II.2 Milk selection 38
III. Control of physico-chemical and bacteriological parameters in milk 39
III.1. Physico-chemical analysis 39
III.1.1. Reception 39
a. Temperature 39
b. Sampling 40
III.1.2 .In the laboratory 40
a. Temperature 40
b. pH: 40
a. Density and acidity 40
a. Alcohol test 40
III.2. Bacteriological analysis 41
 Spirulina 41
 Raw milk 42
 Camembert (Demoulding and after 24 hours) 42
IV. The soft cheese-making process 42
IV.1. Milk preparation 43

Table of contents

IV.2. Maturation of Camembert milk 44
a. Coagulation of Camembert milk 44
b. Slicing 45
c. Addition of spirulina 46
d. Moulding and draining 47
e. Draining chambers 48
f. Demoulding 49
g. Salting 49
h. Penetrant testing 49
i. Refining 49
j. Packaging 50
V. Physico-chemical tests 50
V.1. Determining the fat content of cheeses (MG) 50
V.2. Determination of the total nitrogen content (MAT) 51
V.3. Determination of total dry extract (EST) 52
VI. Characterization of the sensory properties of an enriched soft cheese:Developing the organoleptic properties of cheese 52
a. Texture 52
b. Appearance 52
c. Flavour 52
V.II. The relationship between lactic acid bacteria and spirulina 53
 Spirulina 53
 The lactic acid strain 53
V.II.1. Experimental procedure 53
a. Revivification of the lactic strain 54
b. Purification of the strain 54
V.II.1.1 Preparation of spirulina fermentation solutions with lactic acid bacteria 54
V.II.2. Antimicrobial activity of spirulina 54
 Preparation of the extract 54
 Extraction of bioactive compounds by hydro-methanolic maceration 55
 Equipment 55
 Method 55
 Calculation of dry extract yield 57
V.II.3 Antimicrobial activity of spirulina 57
VII..3.1 Antibacterial activity 57

Table of contents

V.3.2. Antifungal activity 58
VIII. Adjustment of manufacturing parameters to improve texture and taste 59
IX. Comparative analysis between a traditional Camembert and a Camembert enriched with spirulina 60
Results and Discussion 62
I. Physico-chemical parameters and the influence of spirulina on cheese properties. 63
I.1. Analysis of results and comparison with the standard Camembert 63
- Fatcontent (MG) 63
- Total Nitrogen Matter (MAT) 63
- pH and Acidity 63
- Total Dry Extract (EST) 63
- MG/EST ratio 64
- Salt content 64
- Moisture of Dehydrated Cheese (HFD) 64

II. Spirulina bacteriological parameters richi camembert compliance 65
II.1. Spirulina 65
II.2. Raw milk 65
II.3. Demoulding the enriched Camembert 65
III. Effect of spirulina on nutritional composition 66
IV. Microbial activity 66
IV.1. Evaluation of lactic bacteria 66
IV.2. Development of molds: Effect of spirulina on the growth of *Penicillium* and other microorganisms involved in cheese ripening 68
V. Evaluation of the antimicrobial activity of spirulina 70
V.1. Antibacterial activity of spirulina 70
V.2. Results of the antifungal activity of spirulina 73
V.3. Comparative analysis 75
V.4. Comparison of antifungal activity 75
VI. Sensory analysis 76
VI.1. Camembert with spirulina 77
VI.2. Camembert chili-spirulina 79
VI.3. Thyme-spirulina Camembert 79
VII. Consumer preferences between the two types of Camembert 81
VIII. Assessment of the benefits and limitations of adding spirulina in terms of taste and texture 82
IX. Outlook and recommendations 83

Table of contents

Conclusion **85**
Bibliographic References **87**
Annexes **92**
Abstract **102**

INTRODUCTION

Introduction

Introduction

The group of cyanobacteria, formerly known as blue-green algae, is one of the oldest forms of life on Earth and constitutes the bulk of bacteria capable of photosynthesis and oxygen production. They include the genus Spirulina or Arthrospira, filamentous cyanobacteria that include a particularly interesting bacterium called Spirulina platensis (or Arthrospira platensis), better known as Spirulina algae. Consumed for centuries by certain primitive peoples in Africa and America, and known by scientists for several decades for its nutritional value, Spirulina platensis has been rediscovered in recent years. Rich in nutrients such as proteins, carbohydrates, lipids, vitamins and minerals, it is being studied or is already being used on every continent by NGOs to combat malnutrition.

Given its characteristics, growing spirulina could be a solution for improving human health and nutrition, particularly in Third World countries, and also for developing industrial crops.

This cyanobacterium currently appears to be one of the best solutions for the simple production of a high-quality food supplement, and as a result, a number of major companies have embarked on the cultivation of this organism on an industrial scale. Certain studies have highlighted activities on the immune system, cancer and AIDS, as well as effects in the fight against cell ageing, hepatoprotective and anti-inflammatory properties. After a description of Spirulina platensis, a nutritional study will be presented, together with a summary of trials carried out on the use of spirulina in the manufacture of soft cheese.

Cheese serves not only as a nutritional safeguard for adults and a growth-promoting food for children, but also as a versatile carrier for functional ingredients such as Spirulina. Its high protein content, particularly casein, contributes to muscle development and satiety, while its richness in calcium and phosphorus supports bone mineralization and metabolic functions. Vitamins such as B2, B12, and A, naturally present in cheese, further enhance its nutritional profile. Compared to milk, cheese is often better tolerated due to its lower lactose content and the presence of bioactive peptides formed during fermentation and ripening. From a technological standpoint, cheese provides a stable matrix for the incorporation of bioactive compounds like Spirulina, offering protection against oxidation and facilitating controlled release during digestion. Moreover, the fermentation process can enhance the bioavailability of certain micronutrients and modulate the gut microbiota, making cheese a promising vector for nutraceutical innovation. In this context, the integration of Spirulina into soft cheese formulations not only enriches the product with essential nutrients and antioxidants, but also

opens new avenues for developing functional dairy products aimed at improving public health and combating malnutrition.**(SébastienSGUERA ;2008).**

The objectif of this study is:

The objective is to assess and contrast the nutritional, sensory, and functional characteristics of these products. Integrating spirulina into cheese manufacturing aims to boost its nutritional profile by enhancing protein levels, vitamin and mineral content, and antioxidant properties. The research also intends to examine how spirulina affects the flavor, consistency, and visual appeal of cheese, as well as its durability and microbial stability. Furthermore, a financial analysis of both cheese varieties' production enables an evaluation of their market viability and consumer acceptance. This approach combines scientific, technological, and economic aspects to offer a comprehensive view of spirulina's incorporation into cheese production.

Chapter 1: Spirulina

Introduction

Earth is home to approximately 25,000 known algae species. Among the earliest life forms, microscopic blue algae emerged alongside other living organisms about ***3.5 billion*** years ago. This algae, known as Cyanobacteria Arthrospira Platensis or more commonly as Spirulina, is considered the most naturally complete food on our planet **(Cruchot, 2008)**.

Spirulina, an unconventional food resource, can contain up to ***70%*** protein and is abundant in mineral salts, trace elements, and various vitamins (B1, B2, B12, E) **(sall et al, 1999)**.

Extensive research has been conducted on Spirulina, and it is now widely used globally as both a food product and dietary supplement **(Fox, 1996; Paleaz, 2006)**. This has garnered significant attention from researchers over the years, as evidenced by hundreds of publications covering its various aspects. The beneficial potential of Spirulina has been experimentally demonstrated *in vitro* and *in vivo* for treating certain pathologies and preventing high cholesterol, inflammatory diseases, allergies, cancer, drug-induced toxicity, viral infections, cardiovascular diseases, diabetes, and other health conditions **(Khan et al., 2005; Karkos et al., 2008; Kulshreshtha et al. 2008).**

Spirulina cultivation is being developed in its native regions across Africa, Asia, and America, as well as in specialized facilities for commercial production. In Europe, the microalgae are grown in greenhouses or photo bioreactors **(Jourdan, 1999)**. Algeria hosted the largest farm for the production of biological spirulina in Algeria and North Africain El outaya,Biskra, Algeria, bringing together experts and researchers with knowledge i Spirulina cultivation and applications.

I. General about spirulina

I.1. History of spirulina

Before the arrival of the Spanish settlers, the Aztecs were the original inhabitants of Mexico. Their diet, primarily based on maize, was supplemented by a resource from the lake called Tecuitlatl, a puree of spirulina algae rich in protein. After colonization, the rise of agriculture and cattle raising relegated Tecuitlatl to a memory **(Farrar,w,v;1966).**

In 1964, Belgian botanist J. Léonard rediscovered spirulina in Chad, used by the Kanembou people in cakes called "dihé." Analysis revealed these cakes contained mainly Spirulina platensis, an algae rich in protein.

Interest in spirulina grew, especially after the presentation at the 7th Petroleum Congress in 1967 in Mexico City, where researchers isolated and cultivated spirulina strains. Analysis showed a protein content of ***50*** to ***60%***, along with vitamins and other nutritional molecules.

Today, spirulina is considered a valuable protein source with numerous applications, including in the medical field, and is seen as a solution to protein malnutrition in disadvantaged countries **(Leonard;j;1967).**



Figure 1:Photo of a kanembou woman skimming the surface of the spirulina

I.2. What is spirulina

Spirulina is a microscopic spiral-shaped algae. Indeed, it is in the form of a blue-green, mobile, multi-cellular filament (called trichome), unbranched and spirally wound. This filament is helical in shape and observable only in liquid medium under microscope characterizes the genus. Spirulina does not have specialized cells for the fixation of the nitrogen in the air (heterocysts) unlike some other cyanobacteria. The size of spirulina varies depending on strain and growing conditions. However, an average filament length of about ***250 µm*** and with a diameter about ***10 µm*** **(*M. NIANGORAN* 2017).**

Spirulina exhibits a morphology similar to algae, and its content of green and blue pigments led to its classification as blue-green algae **(Jarisoa;2005).**

Indeed, it has long been classified as "blue-green algae" for several reasons **(HèléneCRUCHOT ;2008)**

1/ the presence of an oxygen-producing photosynthesis system.

2/. Its morphology is similar to that of algae.

3/. Its aquatic habitat.

4/. Ability to develop large biomasses.

5/. Its color is attributable to its content of blue (phycocyanin) and green (chlorophyll) pigments.

I.3.Taxonomy

Being part of the cyanobacteria, spirulina is one of the oldest formsof «photosynthetic» life that appeared on earth about three and a half billion years ago. The spirulina is often considered microscopic plankton algae. It is actually abacteria belonging to filamentous cyanobacteria of the genus Arthrospira, most oftencoiled in spirals hence its trade name **(Girardin-Andreani 2005)**The terminology of spirulina is quitethe following table provides details on possible amalgams.

Table 01:The various names of spirulina (Girardin.A;2005).

Spiruline®	Trade name of a cyanobacteria always belonging to the genusArthrospira.
Spirulina®	English trade name of the same cyanobacteria.
Spirulina	Scientific and taxonomic name of other cyanobacteria strongly distanced from Arthrospira; none to date has been studied from the human feeding angle, and none is marketed for this purpose.
Arthrospira	Scientific and taxonomic name of a group of cyanobacteria to which our spirulina food belongs.

I.4. Morphology of spirulina

Spirulina comprises spiral and unbranched mobile filaments, with a diameter of ***10*** to ***12 µm*** and a length of ***250 µm*** when it has 7 spirals **(Jarisoa;2005).**

Three morphologies are distinguished:

- ✓ Straight: pertains to strains with extended filaments.
- ✓ Spiral: pertains to strains with filaments shaped like a pig's tail.
- ✓ Wavy: pertains to strains with filaments in an extended spiral form.

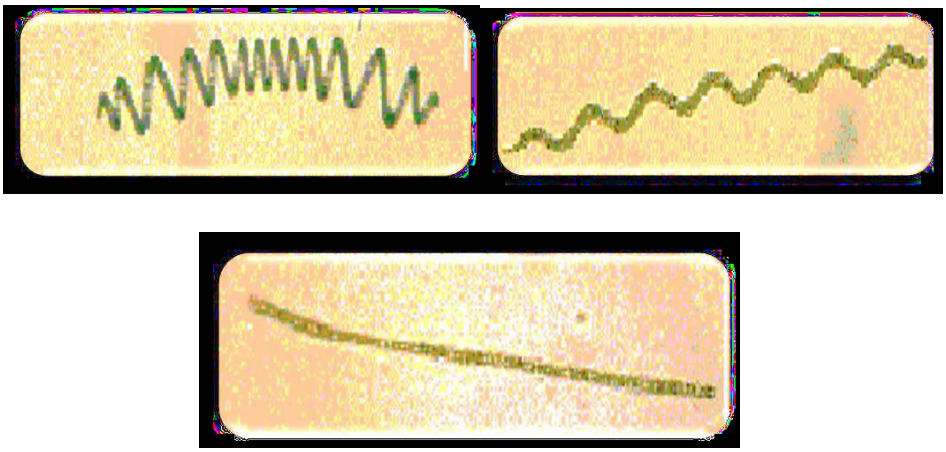


Figure 02:Morphologies typical of SPIRULINA (Jarisoa;2005).

I.5.Natural geographical distribution

Spirulina occurs naturally in the tropical belt of the globe, between ***35°N*** and ***35°S***. It is predominantly found in brackish water, as well as in salt lakes of tropical and semi-tropical regions **(Castenholz R.W.2001)** with a highly alkaline pH. Depending on its origin, it exhibits several interspecific differences. The following **table (02)** presents some locations where spirulina was identified **(Fox.R.D.1999).**

Table 02:Natural geographical distribution of spirulina platensis(Fox.R.D.1999).

Africa	
Algeria	Tamanrasset
Chad	Kanem Region: Latir, Ouna, Borkou, Katarm, Yoan, Leyla, Bodou, Rombou, Moro, Mombolo, Liwa, Issen, Ounianga Kebir
Sudan	Djebel Marra Crater
Djibouti	Lake Abbe
Ethiopia	Lakes Aranguadi, Lesougouta, Nakourou, Chiltu, Navasha, Rodolphe
Congo	Mougounga
Kenya	Lakes Nakuru, Elmenteita, Crater, Natron
Tanzania	Lake Natron
Tunisia	Lake Tunis; Chott el Jerid
Zambia	Lake Bangweulu
Madagascar	Several small lakes near Toliara
Asia	
India	Lakes Lonar and Nagpur
Myanmar	Lakes Twyn Taung, Twyn Ma, and Taung Pyank
Sri lanka	Lake Beira

Pakistan	Ponds near Lahore
Thailand	Wastewater ponds from tapioca industry, Radburi province, 80 km southwest of Bangkok
Azerbaijan	Not specified
South America	
Peru	Water reservoir near Paracas
Mexico	Near Amantani Island in Lake Titicaca; Lake Texcoco; Crater
Uruguay	Montevideo
Ecuador	Lake Quilotoa – 1 km diameter crater
Europe	
France	Camargue
Hungary	Not specified
North america	
California	Oakland; Del Mar Beach
Haiti	Lake Gonâve
Dominican Republic	Lake Enriquillo
Other Possible Sites Everywhere the Lesser Flamingo (Phoeniconaias minor) (Africa and Asia) and James's Flamingo (Phoenicoparrus jamesi) (South America) inhabit	
Ethiopia	Lake Abijatta
Kenya	Lakes Rodolphe, Hannington
Tanzania	Lakes Manyara, Rukwa
Zambia	Lake Mweru
Botswana	Makgadikgadi Salt Pans
Namibia	Etosha Salt Pan

South Africa	Orange Free State, near Vaaldam
Bolivia	Lakes Colorado, Poopo, Chalviri; Salar de Uyuni
Chile	Aguas Calientes, Laguna Brava, Lake Vilama, Salar de Surire
Mauritania	Coastal zone



Figure 03:Distrbution of spirulina on the world

As demonstrated in the aforementioned table, Spirulina exhibits the capacity to thrive in volcanic lakes, such as Lake Quiliotoa in Ecuador. More broadly, it proliferates in warm aquatic environments characterized by high concentrations of sodium carbonate (Na2CO3) or sodium bicarbonate (NaHCO3), along with other minerals and a source of fixed nitrogen. Consequently, it can also be observed in certain desert regions where water occasionally accumulates from mountainous areas **(Fox.R.D.1999.aezdseza")** . These specific environmental conditions inhibit the growth of most other microorganisms.

The remarkable protein content of Spirulina initially garnered attention from both researchers and industry professionals. Subsequently, through comprehensive analyses of Spirulina, numerous nutritionally significant aspects were elucidated, including its balanced protein composition and the presence of rare essential lipids, as well as an abundance of minerals and vitamins. To elucidate the nutritional properties of *Arthrospira platensis*, it is necessary to examine its composition and then compare it with the Recommended Dietary Allowances (RDAs).

I.5.Recovery of spirulina

It is well established that variations in cultivation conditions easily lead to significant Changes in the biochemical composition of spirulina. However, on average Spirulina contains, on a dry weight basis, up to ***70%*** protein, ***15*** to ***25%*** carbohydrates, up to ***11%*** lipids, as well as vitamins, minerals (mainly trace elements), chlorophyll and phycnia.

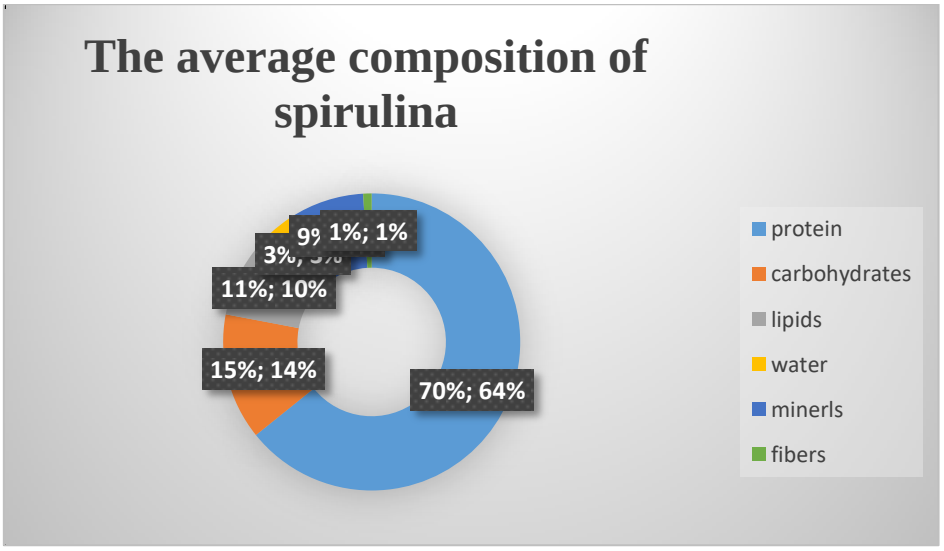


Figure 04:The average composition of spirulina.

Spirulina is used in human food thanks to its high protein, vitamin, mineral and fatty acid content,vitamins, minerals and fatty acids. The combination of all these nutritional factors makes it such a valuable food. The chemical composition of spirulina varies according to the conditions, but the most interesting characteristics are always present **(Clement, 1975)**.and phycobiliproteins.

I.5.1. Proteins

Depending on the strain and cultivation conditions, the protein content of *Arthrospira platensis* varies from ***55*** to ***70%*** of dry weight **(www.tga.gov.au/docs/html/compguid/platensis.htm).**

Table 03:Amino acid composition of spirulina platensis (Babadzhanov A.S.2004).

Acides Aminés	*%*	Acides Aminés	*%*
Asp	***0.9***	Met*	***0.8***
Thr*	***0.5***	Ile *	***1.3***
Ser	***0.6***	Leu*	***0.8***
Glu	***1***	Tyr	***3.8***
Pro	***0.3***	Phe*	***2.5***
Gly	***0.6***	His	***4.7***
Ala	***1***	Lys*	***1.9***
Val*	***1.3***	Arg	***2.1***

Not including Trp* and Cys

Essential amino acid

Spirulina's protein composition makes it a very rich food. As the table above **(Table 03)**,spirulina contains most of the amino acids and in particular all of thein particular all theessential amino acids making up nearly ***60%*** of the total weight of proteins.

I.5.2. Lipids

✓ Total lipids

The dry weight value for total lipids varies from ***5.6*** to ***11%*** by weight **(Ross,E et al ;1990) (XueCet al ;2002) (Harriman G,R et al;1989) (Girardin-Andréani.C et al ;2005)** and even up to ***14.3%*** **(Babadzhanov A.S.2004)**,. These quantitative and qualitative variationsin lipid composition may be due to the extraction method and the means ofanalysis used or simply the variety of *Arthrospira platensis*. This lipid fraction is characterised by a good balance of saturated fatty acids/polyunsaturated fatty acids**(Charpy L, et al 2004)**. The lipids can be separated into a saponifiable fraction (***83%***) and afraction (***17%***) containing mainly paraffin, pigments, terpene alcohols and stele. Alcohols and sterols .

✓ Saponifiable lipids

The saponifiable fraction is mainly composed of monogalactosyldiacylglycerol(MGDG), ***10.3%***, digalactosyldiacylglycerol (DGDG), ***6.44%*** andsulphoquinovosyldiacylglycerol (SQDG), ***11.4%*** **(Xue C. et al;2002)** and phosphatidylglycerol, ***25.9%*** **(Falquet J et al ; 2008).** Weno phosphatidylcholine (lecithin), phosphatidylethanolamine (cephalin) orphosphatidylinositol, membrane lipids, in appreciable quantities.

Unsaponifiable lipids

Sterols appear to represent ***1.5%*** of the non-polar fraction of lipids in Spirulina maxima. species. The sterol fraction is mainly composed of clionasterol (C-24 epimer of β-sitosterol) and low in cholesterol **(Charpy L, et al 2004)**. Spirulina platensis also containssmall amounts of campesterol and stigmasterol**(Falquet J et al ; 2008)** .Paraffins (long-chain saturated hydrocarbons) account for ***25%*** of the unsaponifiable fraction in Spirulina platensis. between ***0.1*** and ***0.3%*** of saturated hydrocarbons in thespirulina dry matter **(Falquet J et al ; 2008)**

Table 04:Fatty acid composition of total lipids and polar lipids in spirulina platensis.

Fatty acids	**Total fats**%	**SQDG**%	**MGDG**%	**DGDG**%
14:0	***0.1+-0.1***	***0.2+-0.2***	***0.2+-0.1***	***0.3+-0.1***
16:0	***45.6+-3.5***	***56.1+-6.5***	***42.0+-5.5***	***40.4+-2.5***
16:1 n-9	***2.6+-0.3***	***0.2+-0.1***	***2.5+-0.1***	***2.4+-0.5***
16:1 n-7	***5.3+-0.3***	***2.3+-0.3***	***5.3+-1.2***	***5.9+-1.3***
16:2 n-9	***3.3+-0.5***	-	***0.3+-0.3***	***0.4+-0.2***
16:3 n-6	***0.4+-0.2***	***0.3+-0.1***	***0.3+-0.2***	***0.6+-0.2***
17:0	***0.1+-0.1***	***0.4+-0.2***	***0.1+-0.1***	***0.2+-0.2***

17:1 n-9	***0.3+-0.1***	***0.6+-0.2***	***0.2+-0.1***	***0.2+-0.2***
Iso 18:0	***0.3+-0.1***	***0.6+-0.3***	***0.2+-0.2***	***0.3+-0.3***
17:3 n-6	***0.2+-0.1***	-	***0.3+-0.2***	***0.3+-0.1***
18:0	***0.7+-0.2***	***1.2+-0.4***	***0.7+-0.2***	***0.8+-0.3***
18:1 n-9	***1.8+-0.3***	***4.3+-0.5***	***1.7+-0.3***	***1.0+-0.2***
18:1 n-7	***0.3+-0.2***	***0.8+-0.5***	***0.7+-0.5***	***0.6+-0.2***
18:2 n-6	***17.6+-2.3***	***28.3+-4.2***	***9.3+-1.5***	***11.0+-2.1***
18:3 n-6	***20.3+-3.0***	***3.6+-0.5***	***30.9+-5.1***	***29.7+-30.6***
20:2 n-6	***0.1+-0.0***	***0.2+-0.1***	***0.3+-0.1***	***0.6+-0.2***
20:3 n-6	***0.6+-0.1***	***0.4+-0.2***	***0.7+-0.2***	***0.7+-0.3***
C30 PUFA	***0.4+-0.1***	***0.2+-0.1***	***1.0+-0.3***	***1.2+-0.5***

Average value of 3 determinations/20:3 n-6 = 20 carbons, 3 double bonds, the 1st starting on carbon n-6

I.5.3. Carbohydrates

Carbohydrates make up ***15*** to ***25%*** of spirulina dry matter**(Fox,R,D;1999) (Falquet J et al ; 2008) .**

These carbohydrates make up the cell membrane in particular. Spirulinacell walls of spirulina are similar to those of Gram-positive bacteria, since they are glucosamine and muramic acid associated with peptides. The primary forms of carbohydrates are rhamnose and glycogen, two polysaccharides easily absorbed by the bodyby the body **(Babadzhanov A.S.2004)**. Other polysaccharides such as calcium-spirulan (Ca-SP) arecomposed of rhamnose, ribose, mannose, fructose, galactose, xylose, glucose, glucuronic acidglucuronic acid, galacturonic acid, sulphate and calcium **(Hayashi T ,et al 1996)**. However, simple carbohydratespresent in very small quantities.

I.5.4. Nucleic acids (DNA and RNA)

Values of ***4.2*** to ***6 %*** total nucleic acids in dry matter have been reported for Spirulina platensis **(AFAA; 1982) (Ross E, et al 1990).**

I.5.5. Vitamins

There are 13 vitamins, 4 fat-soluble (A, D, E, K) and 9 water-soluble (B1, B2, B5, B6, B12, C, PP).

Spirulina contains many of these vitamins, especially B vitamins, in optimal proportions.

✓ Water-soluble vitamins

Vitamins are the main factor involved in the biological properties of spirulina. The main vitamins identified in Spirulina platensis are (per ***100g*** of biomass): vitamin C (***42.0-195.3 mg***), vitamin B3 (***0.6-5.3 mg***), vitamin B1 (***0.8-15.4mg***), vitamin B2 (***0.2-0.9 mg***), vitamin B6 (***0.3-4.0 mg***), vitamin B9 (***0.2-0.6 mg***) andvitamin B12 (***0.3-0.8 mg***).It should be noted that

biomass grown in spring and summer has a higher proportion ofvitamins. This depends essentially on sunshine conditions .

Table 05:Water-soluble vitamins contained in the biomass of Spirulina platensis according to season (*mg/100g* dry matter) season (*mg/100g* dry matter) (BabadzhanovA;etal;2004).

Vitamins	Winter	Autumn	Summer	Spring
Ascorpic acid (c)	42.8	42	106.2	195.3
Nicotinamid (B3) or (pp)	5.3	0.6	0.4	0.9
Pyridoxin(B6)	4	0.6	0.3	0.5
Riboflavin(B2)	0.8	0.7	0.9	0.2
Thiamin(B1)	11.6	15.4	0.8	0.8
Cyanocobalamin(B12)	0.4	0.8	0.3	0.3
Folic acid(B9)	0.6	0.4	0.2	0.2

Fat-soluble vitamins

The three fat-soluble vitamins found in spirulina are β-carotene, the precursor of vitamin Avitamin A, vitamin E and vitamin D.

Table 06: Fat-soluble vitamins contained in Spirulina platensis biomass (*Mg/100g* of dry matter) (Babadzhanov A et al 2004)(www.tga.gov.au/docs/html/compguid/platensis.htm).

Vitamins	Quantitie
β -carotene(vit A)	*64 to 200mg /100mg*
Tocopherol(vitE)	*10 to 19mg/100mg*
Vitamin (D)	*0.3mg/100mg*

I.5.6. Minerals and trace elements

The trace elements present in spirulina are iron, zinc, copper, seleniumiodine, fluorine, chromium, calcium and magnesium, The other elements, in more significant quantities, are considered to be minerals.

Table 07:Minerals and trace elements contained in spirulina platensis (Avino p et al;2000).

Elements	Quantities (***mg/kg*** of biomasse)
Cr	***11.3*** to ***14.2***
Fe	***900*** to ***1176***
Mn	***554*** to ***592***
Zn	***21*** to ***375***
Ca	***4320***

Cl	***4890***
K	***9000***
Mg	***670*** to ***2700***
Na	***4500*** to***235000***
P	***6700*** to ***9000***

1Dosages carried out using 2 analytical methods: INAA = instrumental neutron activation analysis (nondestructive technique) and ICP-AES = inductively coupled plasma-atomic emission spectrometry (destructive technique). The ICP-AES method naturally gives lower values than the INAA method, but the use of 2 different techniques is useful for quantifying a broad spectrum of minerals.(**Avino et al, 2000) ; (Li et al, 2007) (Avino et al. 2000) ; (Falquet and Hurni 2006) (Falquet and Hurni, 2006).**

I.5.7. Metals

The search for metals in spirulina is carried out for the study of potential toxicity morethan for quantitative measurement of functional elements. However, somemetals such as selenium and chromium are required in the diet at low doses.

Although some metals are also listed as trace elements, they have nevertheless beenlisted in the table below **(Table 08).**

Table 08:Trace element levels in Spirulina platensis (Avino p et al;2000) .

Elements	Quantities on spirulina ***mg/kg***
As	***0.002****
Br	***17.9***
Cd	***<1.d***
Co	***0.720***
Cr	***14.2***
Cs	***0.021***
Cu	***375***
Eu	***0.023***
Hg	***0.120***
La	***0.514***
Mn	***27.88**** to ***554***
Ni	***<1.d***
Pb	***12.9***
Sb	***0.064***
Sc	***0.075***
Se	***0.498***
V	***<1.d***
Zn	***210*** to ***375***

<l.d: below detection limit * Al-Homaidan et al, 2006 **(Al-Homaidan A.et al;2006).**

I.5.8. Pigments

Spirulina is rich in the pigments responsible for its color. The main pigments are phycocyanin and chlorophyll.

Phycocyanin is a phycobiliproteins. It is the only natural blue food coloringthe most abundant pigment in spirulina, representing over ***15%*** of the fresh weight and over***20%*** of the dry

weight of the algae **(SallM.G,et al,1999)(Romay C et al;1998).** Chlorophyll is present in proportions of ***9-15 g/kg*** .

II.Biological activities of spirulina

II.1.Antioxidant activity

The main active antioxidants that give spirulina its undisputed status as a powerful antioxidant arepowerful antioxidant status are:phycocyanin, beta-carotene, polyphenols, superoxide dismutase (SOD) and other vitamins and minerals contained in this material. Dismutase (SOD) **(Goulambasse, 2018).**

Numerous in vitro and in vivo studies have identified this potential activity ofspirulina (or its extracts) and have shown that treatment with spirulina significantly reducesoxidative stress **(Goulambasse, 2018)**. It slows downageing and cell destruction **(Barth and Leo, 2019).**

II.2.Anti-inflammatory activity

Spirulina's richness in proteins and fatty acids, particularly omega 3 and 6 that cannot be synthesised by the body, make it of particular biological interestsince this fatty acid is a precursor of prostaglandins, molecules with anti-inflammatory and immunostimulant activityin the body **(Charpy et al., 2008).**

II.3.Antifungal activity

The antifungal activity of Spirulina was demonstrated by the study of Boutalbi S. 2014,she found that Spirulina has good antifungal activity; the diameter of mycelial growthis inversely proportional to the concentrations of spirulina extractedin the culture medium.

II.4.Antiviral activity

Spirulina blocks viral adsorption and penetration of the cell membrane due to its richness in β-carotene and vitamin B12.

Cell membrane due to its high content of β-carotene and vitamin B12 **(Hayashi et al., 1993)**. The mechanism seems to be because the virus, being unable to bind to themembrane of the host cell, it cannot penetrate it or, consequently, replicate **(Andreani, 2012).**

II.5.Anti-cancer activity

Various studies have shown that beta-carotene (one of the antioxidants in spirulina) could reverse the cancerous process and inhibit the spread ofcarcinogenic cells.

One of the studies confirming this result was carried out withpeople with oral leukoplakia (a precancerous condition of the mouth). The latter,after taking ***1g*** of spirulina a day for a year, showed an improvement in their condition and succeeded in halting the development of the disease **(Vidalo, 2015).**

Phycocyanin is also involved in this activity by attacking the free radicals responsible for cancer **(Vidalo, 2015).**

III. Potential and uses of spirulina

Developed countries and in some parts of Africa, spirulina is consumed as a 'health' food supplement.It is sold in theorganic' products. Traders propose various uses, witharguments based on the composition of this organism and studies on the activities of itscomponents. Some of these uses are described below, without being able to judge theireffectiveness.

Spirulina is not a medicine. There fore, it is not subject to the obligation oftherecommended dosage and the quality of the product sold are not necessarily in line with the effects claimed.

Spirulina is sold:

➢For a balanced diet: for its micronutrient content.

➢In slimming diets: for its high levels of protein andPhenylalanine, which regulates appetite.

➢For improving sporting ability: because of its iron, vitaminB12 and ß-carotene, which facilitate recovery.

➢For its antioxidant activity linked to phycocyanine.

➢For its anticoagulant activity linked to calcium spirulina (Sp-Ca) and sodium spirulina (Sp-Na).

Sodium (Sp-Na).

➢To strengthen the immune system thanks to polysaccharides.

➢For its antiviral activity: linked to β-carotene and vitamin B12.

➢For its anti-tumors activity: linked to phycocyanine.

➢For its cholesterol-lowering activity: linked to polyunsaturated fatty acidsomega-3 and omega-6 fatty acids **(Parikh et al., 2001).**

IV. Physical and chemical growth conditions of spirulina

Spirulina requires mineral salts and essential elements such as water, carbon dioxide, oxygen, and sunlight, which serves as its primary energy source. It naturally thrives in warm aquatic environments with temperatures ranging from ***28°C*** to ***40°C***, as well as in brackish and alkaline waters with a pH between 8 and 11,5(**LoïcCharpy et al).**

The agitation of the medium, particularly due to wind, plays a crucial role in ensuring the homogeneous dispersion of cells and optimizing gas exchange necessary for its growth.
The photosynthesis process, which enables the production of organic matter from carbon dioxide and water under the influence of light energy, follows the general reaction **LoïcCharpyet al):**

$$6CO_2+6H_2O+h\nu \rightarrow C_6H_{12}O_6+ 6\ O_2$$

Although Spirulina contains only chlorophyll type A, other algae possess different variants, such as chlorophylls B, C, and D, which contribute to specific photosynthetic mechanisms.

V. Reproduction of spirulina

Spirulina reproduces through binary fission, a simple division process characteristic of asexual reproduction. This mechanism involves the segmentation of filaments, ensuring the continuous propagation of the organism. It is important to note that this process differs from mitosis, which occurs exclusively in eukaryotic cells.

The multiplication rate of Spirulina is remarkably fast, particularly when the temperature exceeds ***30°C*** in shaded conditions. Under optimal environmental conditions, itsgeneration time is exceptionally short, averaging ***7 hours***, allowing for rapid biomass production.

VI.Different methods of spirulina production

Spirulina is cultivated across multiple countries spanning four continents: Africa, Asia, the Americas, and Europe. The production methods and resources vary depending on climatic conditions and available infrastructure, leading to diverse approaches in the design and scale of farms and cultivation ponds. Based on the total surface area of the production basins and the technological means employed, Spirulina cultivation is classified into artisanal and industrial methods **(Jourdan, 2006)**.

VI .1. Artisanal cultivation

This method involves constructing concrete basins and reservoirs near a lake. The reservoir is filled with pumped lake water, which then flows by gravity through a sand filter before reaching the Spirulina cultivation basins. This system ensures the production of high-quality Spirulina for human consumption, with filtration using a ***50 µm*** filter before entering the basins. Additionally, a less pure algae harvest (filtered at ***150 µm***) is obtained, which can be used for poultry farming or aquaculture**(Scheldeman et al., 1999)**.

VI.2. Industrial cultivation

Industrial-scale Spirulina production takes place in large-surface basins (several hectares) with mechanical agitation to optimize growth conditions. The harvested Spirulina undergoes spray drying (*atomization*) to ensure efficient dehydration and preservation. Although this method requires high investment, it enables large-scale production, reaching hundreds of tons annually**(Jourdan, 2006).**

VI.3. Spirulina cultivation technique

✓ Inoculation and strain selection

Spirulina exists in various strains, each sharing common characteristics that distinguish them from other algae. Under microscopic observation or high-magnification lenses (***25x***), Spirulina filaments can be identified as either spiraled or straight. However, determining the exact strain is more complex, as Spirulina exhibits significant variability in size and shape, ranging from tightly coiled spirals to wavy or straight forms.

A high proportion of straight filaments can lead to harvesting difficulties. Therefore, it is preferable to select a ***100%*** spiraled strain, characterized by large filament size, a vibrant blue-green coloration, and efficient filtration properties.

For inoculation, a portion of an existing culture is transferred into a fresh growth medium until the culture reaches a distinct green coloration, indicating successful adaptation and proliferation **(Jourdan, 1999).**

✓ Measurement of spirulina culture concentration

The concentration of a Spirulina culture can be assessed based on its color intensity. To achieve this, a Secchi disk is used—a graduated ruler with a small white disk attached

perpendicularly at one end. This instrument is submerged into the culture until the disk is no longer visible, at which point the depth is recorded from the graduated scale.

- If the Secchi disk remains visible beyond ***5-6 cm***, the culture is considered diluted**.**
- A depth of ***2-3 cm*** indicates that the culture isready for production**.**
- If the visibility is less than ***2 cm***, the culture requires dilution or intensive harvesting to maintain optimal growth conditions.
- The Secchi disk is an optical measurement tool used to assess water transparency in aquatic environments. It consists of a ***30 cm***-long graduated rod, with a white disk attached at its end, having a diameter between ***30*** and ***40 mm***. This instrument is submerged into the water until the disk is no longer visible, allowing for the measurement of light penetration depth and the evaluation of water clarity**(flaquet.1996)**.

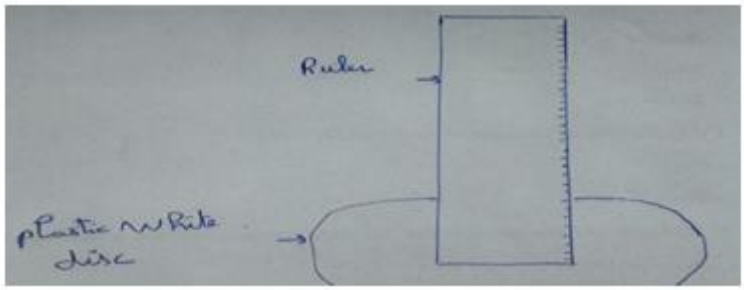


Figure 05: Presentation of secchi disk.

✓ Agitation in spirulina cultivation

Agitation is essential for maintaining optimal growth conditions in Spirulina cultivation. It should be performed2 to 4 times per day, increasing in frequency with higher light intensity. This process ensures:

- Homogenization of the culture, allowing uniform distribution of cells.
- Optimal light exposure, enhancing photosynthesis efficiency.
- Prevention of mineral sludge formation and filament aggregation, ensuring a balanced environment.

Different agitation methods can be employed based on available infrastructure:

- **Manual agitation**: using a broom or similar tool.
- **Mechanical agitation**: utilizing a pump or paddle wheel for continuous and controlled mixing.

Continuous agitation, particularly with a pump, can be implemented safely, provided that parameters are adjusted to protect the delicate Spirulina filaments**(Jordon.1999)**.

- ✓ Shading

Shading is necessary when the culture temperature is very low, below ***10°C***, combined with high light intensity, to prevent Spirulina from being destroyed by photolysis. Additionally, a shaded culture is easier to harvest, and the quality of Spirulina is improved **(Jordan, 1999)**.

- ✓ Harvesting

Harvesting is carried out to maintain the Spirulina concentration between ***0.4*** and ***0.6 g/L***. In the absence of harvesting, and with sufficient nutrients, the concentration increases until it reaches equilibrium between photosynthesis and respiration. However, leaving the culture unharvested for too long at high concentrations can lead to cell mortality**(Jordan, 1999).**

- ✓ Drying

Drying is the only reliable method for preserving and distributing Spirulina without a cold chain. It can be dried in the shade simply by airflow at ambient temperature, under a mosquito net, provided the air temperature is significantly above its dew point**.**
Drying in direct sunlight outdoors is the fastest and most cost-effective method, but it has drawbacks: the product is exposed to dust and animals, requiring at least protection with a mosquito net **(Fox, 1999).**

V.*II Arthrospira platensis*

It is the most widely known and used in research orthe sowing of new crops It consists of trichomes up to ***350 µm***long and between ***6*** and ***12.45µm*** in diameter; they are slightly narrowed at the level ofjoints. The turns have a diameter of ***20*** to ***50µm***, decreasing slightly towards the extremities **(Fox d. ET r 1999).**However, there are undulating spirulina and some times straight.



Figure 06:*Arthrospira platensis* culture

Analysis of the genetic characteristics of the species *Arthrospira platensis* by **(Scheldeman et al in 1999)** based on ARDA (Amplified Ribosomal DNA Restriction Analysis) shows a great morphological plasticity. Someinitially spiraled strains can become wavy or straight **(Cruchot, 2008),** thismay be due to exogenous physicochemical factors such as temperature, orother factors likely to be linked to genetic changes **(Belay, 2007).**

As regards the different strains (or varieties) of Arthrospira platensis, wedistinguishes the "spiral", "wavy" and "straight" strains:

The "spiral" strains: refers to strains whose filaments have the shapeof a pig's tail, such as the "Lonar" (India).

The "wavy" strains: the term "wavy" refers to strains whosefilaments are spiral stretched, such as the "Paracas" (Peru).

The "straight" strains: the term "straight" refers to strains whose filamentsare so stretched that they give the impression of being almost straight.

Whatever the shape of *Arthrospira platensis*, it does not change its composition.

The change in shape is related to its dimensional adaptability relating to the medium Culture. **(Callara, 2008**).

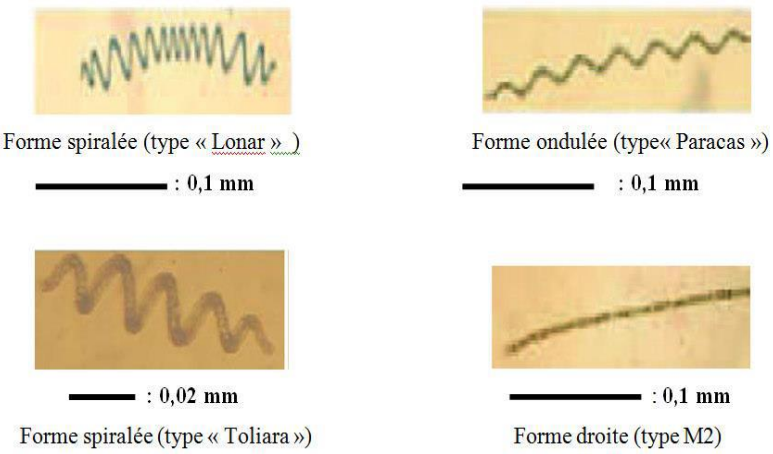


Figure 07:Different strains of *Arthrospira platensis*

Chapter 02 :Cheese

Introduction

Milk and cheese have held a central place in human nutrition for millennia. Milk, a biological secretion produced by the mammary glands of mammals, is considered an ideal and complete food. It is rich in high-quality proteins**,** fats**,** carbohydrates (mainly lactose), as well as vitamins (A, D, B2, B12) and minerals (especially calcium and phosphorus). From a nutritional standpoint, milk is essential, particularly in the diets of infants and young children, but also for adults and the elderly due to its benefits for bone and metabolic health.

The transformation of milk into cheese is one of the oldest methods of food preservation. Cheese is produced through the coagulation of milk proteins, mainly casein, followed by draining**,** aging (ripening)**,** and sometimes-additional treatments such as salting or the addition of molds. This fermented dairy product concentrates the nutritional elements of milk while developing unique sensory characteristics such as aroma, texture, taste, and appearance.

Economically and culturally, milk and cheese play a major role in many societies. In several countries, dairy farming is a cornerstone of agriculture. At the same time, the diversity of cheeses around the world reflects local traditions, artisanal expertise, and food innovation.is renowned for its rich cheese heritage, which is deeply embedded in both its gastronomic culture and economy**.**

However, milk production also raises several contemporary issues, including the environmental impact of livestock farming**,** animal welfare concerns**,** lactose intolerance and allergies, and the shift in dietary habits toward vegetarian or vegan lifestyles. These challenges have prompted the food industry and researchers to develop alternatives, such as plant-based cheesesorfermented dairy products with added health benefits**.**

In short, milk and cheese are not merely food items but complex subjects of study at the intersection of biology, food technology**,** nutrition**,**economics, and sociology. Studying5 them requires a multidisciplinary approach to understand not only their physicochemical properties but also their role in the sustainable food systems of the future.

I. From milk to cheese

I.1. The raw material: milk

I.1.1. Definition

The milk is a matt white, slightly bluish or more or less yellowish, milky fluid, with a faint odour and a sweet taste **(BENSALAH, 2010)**. Milk is the product secreted by the mammary glands of female mammals from the time they give birth **(Vilain, 2010)**. In cows,

lactation, which is maintained by suckling the calf or milking, lasts around 10 months. At the peak of lactation, milk production can reach ***40*** to ***50 litres*** per day.

Milk is mainly made up of water, followed by lactose, fat, protein and minerals, which make up the macronutrients. The minor compounds or micro constituents are mainly trace elements, vitamins, pigments and somatic cells.It is obtained by the complete milking of one or more healthy cows, which contains at least ***8.25%***, milk solids and not less than ***3.25%*** milk fat **(HASHIM SHEET, 2024)**.

I.1.2. Milk composition

Milk is mainly composed of the following elements: ***87%*** water, ***4.8%*** lactose, ***3.5%*** protein (mainly casein and whey, which are easily digestible and balanced in essential amino acids), as well as minerals and trace elements (***0.5%*** including ***120mg*** of calcium for every ***100mg*** of milk), vitamins and lipids. The composition of milk lipids is extremely diverse and specific, including around ***65%*** fatty acids **(NOBLET, 2012).**

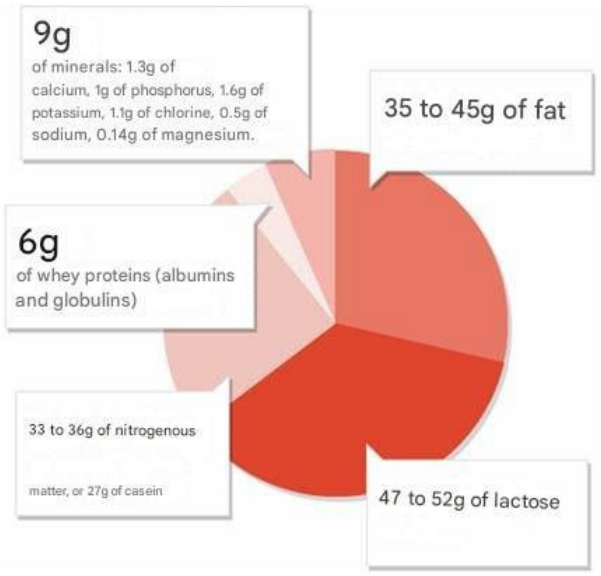


Figure 08:Average composition of cow's milk (http://www.maison-du-lait.com/fr/laitsliquides)

I.2. Generality ofCheese

I.2.1. History

The first evidence of the storage and processing of milk into cheese, dating from around ***6000 BC***, has recently been found in pottery in Poland **(Salque et al. 2013)** and Dalmatia **(Gross 2018).** From then on, cheese-making skills began to spread throughout the world, taking advantage of the rise of civilisations**(Fox and McSweeney 2017).** Today, cheese is produced and consumed on all 5 continents, with a strong focus on Europe **(Delfosse 2012).**

Table 09: Years of origin of noted cheese varieties.

Cheese variety	Yr of first documentation
Gorgonzola	879
Roquefort	1070
Grana	1200
Cheddar	1500
Parmesan	1579
Gouda	1697
Gloucester	1697
Stilton	1785
Camembert	1791

I.2.2. Definition of cheese

Each country has its own definition of cheese **(Hickey 2017).**A more international definition is given by the **Codex Alimentarius**: 'Cheese is the product, ripened or not, soft, semi-hard, hard or extra hard, which may be coated, and in which the protein/casein ratio of the whey does not exceed that of the milk, obtained by: (a) total or partial coagulation of the protein of milk, skimmed milk, partly skimmed milk, cream, whey cream, buttermilk, or any combination of these materials, through the action of rennet or other coagulating agents, and partial draining of the whey resulting from the coagulation, while respecting the principle of

cheese making or (b) processing techniques resulting in the coagulation of milk proteins and/or products obtained from milk and which give a finished product with similar physical, chemical and organoleptic characteristics to the product defined in (a).**(Codex Alimentarius Commission 2007). Figure (09)**



Figure 09:A type of cheese.

I.2.3. Cheese varieties

Cheeses can be categorized in various ways, including the type of animal milk used, their country of production, manufacturing techniques, compositional characteristics, or intended usage. One method of classification based on composition (specifically moisture content, results in a concise list of categories: soft, semi-soft, semi-hard, hard, and extra hard cheeses) also on type of coagulation (lactic-type cheese, rennet-type cheese and mixed cheese) (**MAJDI, 2009**).

Cheese based on coagulation types

Cheeses can be classified based on the type of coagulation used during their production, which directly influences their texture, flavor, and microbiological profile:

a. Enzymatic coagulation (Rennet-Coagulated Cheeses)

This is the most common method, using rennet (animal, microbial, or fermentation-derived chymosin) to cleave κ-casein and form a firm curd. Examples: Cheddar, Gouda, Camembert, Emmental, Parmigiano Reggiano.

b. Acid coagulation (Lactic-Coagulated Cheeses)

Here, acid (either directly added or produced by lactic acid bacteria) lowers the pH to the isoelectric point of casein (~4.6), causing curd formation. Exemples : Cottage cheese, Quark, Cream cheese, Chèvre

c. Mixed coagulation

Mixed coagulation refers to the use of both enzymatic (rennet) and acid-induced mechanisms to coagulate milk during cheese production. This hybrid approach allows cheese makers to fine-tune texture, moisture, and flavor development by leveraging the strengths of each method.Exmples;Neufchatel;Crescenza.

Table 10:The type of cheese based on the type of coagulation .(MAJDI, 2009).

Type of cheese	Lactic-type cheese	Rennet-type cheese	Mixed cheese
Characteristics	_Obtained essentially by biological coagulation, also known as lactic coagulation or coagulation by acidification. _These are fresh cheeses. _They are made at a temperature ranging from ***16*** to ***23°c***. _This type of cheese requires ***3*** to ***10ML*** of rennet per ***100L*** of milk.	_Obtained essentially by chemical coagulation also called coagulation by the action of enzymes (rennet). _These are pressed cheeses, firm cooked cheeses and firm uncooked cheeses. _They are made at a temperature ranging from ***34*** to ***40°C***. _This type of cheese requires ***25*** to ***35ml*** of rennet per ***100l*** of milk	_Obtained by chemical coagulation and biological coagulation. _These are soft cheeses. _They are made at a temperature ranging from ***28*** to ***37°c***. _This type of cheese requires ***15*** to ***25ml*** of rennet per ***100l*** of milk

Cheeses based on composition

a. Cream cheese

Cream cheese is a creamy white, slightly sour tasting product with a diacetyl flavor and is a soft, mild, rich, unripened cheese.

b. Hard and semi-hard cheeses

Hard and semi-hard cheeses are versatile, nutrient-rich dairy products. Although they are highly valued from a health perspective, there is considerable controversy among consumers and the scientific community.

c. Soft cheeses

Soft cheeses with surface flora are classified as bloomy rind and washed rind cheeses. In the case of bloomy rind cheeses (e.g. Camembert, Brie) and washed rind cheeses (e.g. Pont l'Évêque, Munster).

II. Cheese production

Although there are many different types of cheese, most manufacturing processes involve several shared steps. The creation of cheeses with varying textures and flavors results from modifications in one or more stages during production. (**Figure 3)** provides a schematic representation of the fundamental steps in cheese production, along with some variations for specific cheese types.

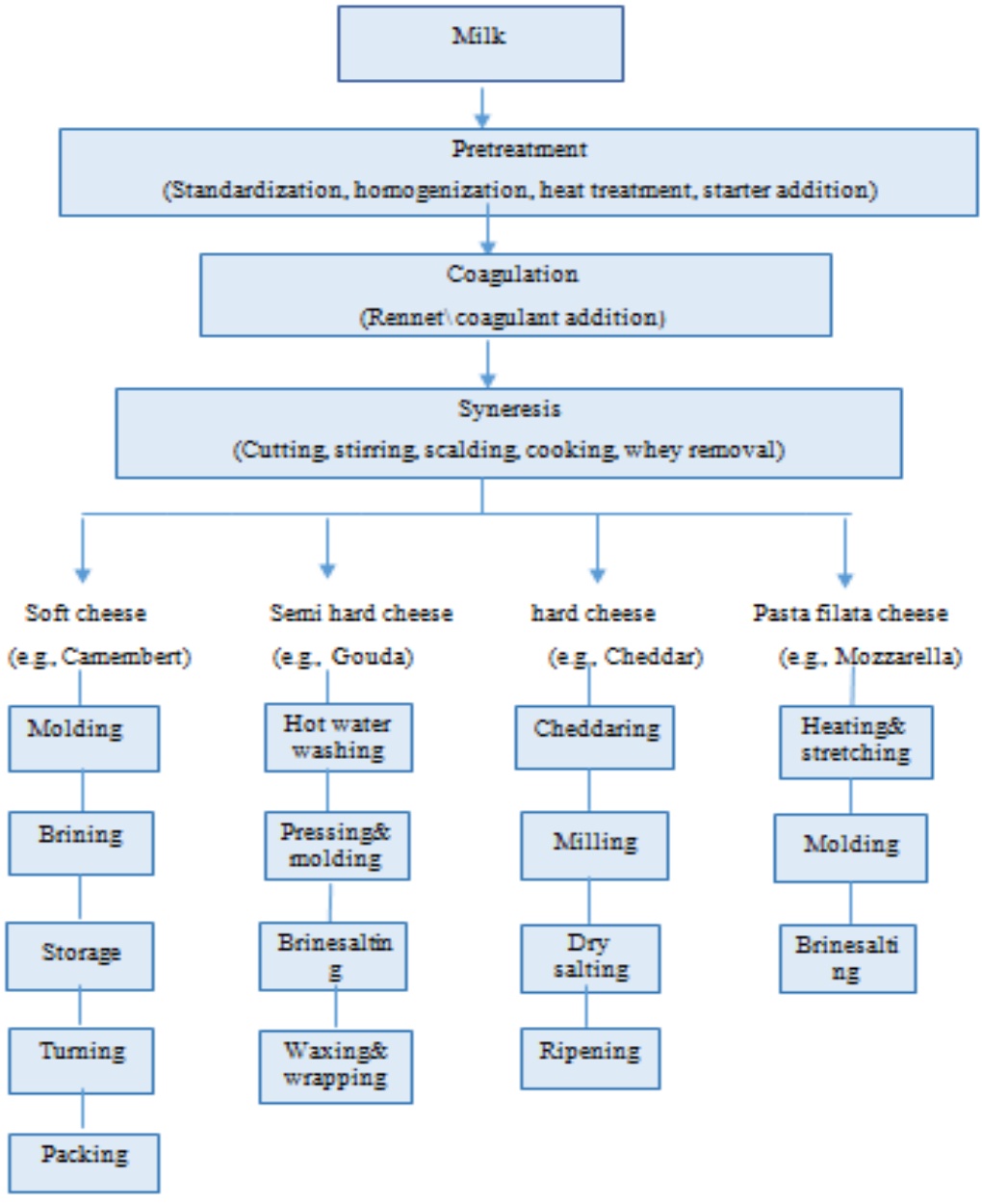


Figure 10:Major steps in cheese making (actual steps and \or conditions may vary).

III. Nutritional value of cheese

Cheese serves as both a nutritional safeguard for adults and a growth-promoting food for children, owing to its high-quality protein content and combination of phosphorus, calcium, and vitamins. It typically enjoys greater popularity than milk and is more easily digestible **(TREMOLIERE ET AL. 1984).**

Table 11:Nutritional and calorific values of cheese per *100mg* (CIQUI,2020).

Nutrients/***100mg***	Average content
Energy	***388Kcal***
Water	***46.2g***
Proteins	***21.8g***
Carbohydrates	***0.56g***
lipids	***27.4g***
Saturated fatty acids	***18.2g***
cholesterol	***89.8mg***
Calcium	***626mg***
phosphorus	***454mg***
Magnesium	***29.2mg***
Zinc	***2.87mg***
Vitamin B12	***1.36ug***
Salt	***1.28g***
Vitamin B 2	***0.41mg***
Retinol	***226ug***

IV. Camembert

IV.1. History of camembert

Camembert owes its name to a small Norman village located near Vimoutiers in the region of Argentan. Today, the largest Camembert factories are found in the area. The Camembert may have originated in monasteries that produced refined cheeses to preserve them. It was a great success. Then, many monks went into hiding, for example in Münster or Saint-Nectaire, under the French Revolution.

The tradition claims that a refractory priest took refuge with Marie and Jacques Harel in the manor of Beaumoncel in Camembert. The priest then taught Marie Harel how to make cheeses using the Brie cheese technique he had previously used in Livarot. This cheese resembled Brie in appearance: a small round cheese surrounded by straw. Marie Harel passed on this new cheese tradition to her daughter and her son-in-law, Thomas Paynel, who developed its commercialization. they sold it at the markets of Argentan and Caen.

From local product, Camembert gained a national reputation during the inauguration of the Paris-Granville railway line in 1853. Marie Harel's grandson, Victor Paynel, offered one of the Camembert cheeses to Emperor Napoleon III, who greatly enjoyed it and served it at the Tuileries Palace, thus promoting it nationally and even internationally. From there, the exchange extended from Ohio to the United States **(VITAUX, 2009).**

Since 1983, Camembert from Normandy, its region, and its production processes have benefited from an AOC (Controlled Designation of Origin). In 1993, it was recognized at the European level through AOP certification (Protected Designation of Origin).

IV.2. Definition

Camembert is a soft cheese, surface-ripened, mainly by molds, in accordance with the General Standard for Cheese **(CXS 283-1978)**. It is presented in the form of a flat cylinder or pieces of said cylinder. The paste has a color ranging from off-white to pale yellow and a soft texture (when pressed with the thumb) but is not crumbly, ripened from the surface to the center of the cheese. Gas holes are generally absent, but the presence of some openings and cracks is acceptable. A soft rind, entirely covered with white molds but sometimes showing spots of red, brownish, or orange color, develops. The whole cheese may be cut or formed into pieces before or after mold development **(CODEX ALIMENTARIUS, 2022).**

IV.3. Composition and nutritional value

Depending on how camembert made, the nitrogen content is between ***30*** and ***50% nitrogen/dry matter***. Camembert is considered one of the best food sources of highly digestible proteins. These proteins have a high biological value, characterised on the one hand by their balanced amino acid composition and on the other by their ability to form a cheese paste that is highly prized by consumers **(BOUTERFA, 2020).**

The fat in camembert (***25 to 40%***) ensures the smoothness of the paste and also helps to create the particular flavor of the finished product. as far as lactose is concerned , it should be noted that mature cheeses contain no carbohydrates. only a small quantity remains in the curd after draining, and this is then transformed into lactic acid during the maturing process.

Only a small quantity remains in the curd after draining, and this is sub -sequently transformed into lactic acid during the ripening process. as for other nutrients, camembert is an important source of calcium (***200*** to ***700mg/100g***), phosphorus, sodium and vitamins (particularly from group B) **(table 06)**.

In addition, the small Camembert of reduced diameter (***80_85mm***) having a dry extract higher than ***60g***.knowing that the denomination true Camembert of Normandy is protected by a quality label which defines in particular an area of production **(BOUTERFA , 2020)**.

Table 12 :Nutritional and calorific values of cheese per *100mg* (CIQUI,2020).

Constituent	Average Content
Energy	***359Kcal***
Water	***46.7g***
Proteins	***17.5g***
Carbohydrates	***Traces***
Lipids	***32.2g***
Calcium	***523mg***
Phosphorus	***354mg***
Sodium	***470mg***
Retinol (vitamin A)	***470ug***
Vitamin D	***0.4ug***
Sodium chloride	***1.18g***

IV.4. Technological interface of microorganisms in soft cheese production

Soft cheese forms a true ecosystem, containing microorganisms essential to its production. These microorganisms contribute either directly through their metabolic activity or indirectly by releasing enzymes that influence the composition of the cheese.

IV.5. Useful micro flora in the production of camembert-type cheese

In the Camembert production process, various microorganisms play a role, including naturally occurring or intentionally added bacteria and molds. These introduced microorganisms, which may be freeze-dried, frozen, or added to milk via spraying or direct mixing, are crucial for developing the analytical and sensory characteristics of the final product.

IV.5.1. Bacteria

The bacteria required for Camembert-type cheese production fall into two main categories: lactic acid bacteria and ripening bacteria

- ✓ **Lactic Acid Bacteria**

Lactic acid bacteria are Gram-positive bacteria that produce lactic acid from glucose and galactose **(AXELSSON, 2004).**They generally develop under anaerobic or even facultative anaerobic conditions, and play a major role in the acidification of milk and quail. They are also agents in the ripening of cheese, through their proteolytic and lipolytic abilities (development of taste, aroma and texture) **(SINGLETON, 2002)**

- ✓ **Ripening Bacteria**

Lactic acid bacteria are not the only microorganisms involved in the production of Camembert-type cheese. Ripening bacteria, also known as surface bacteria, colonize the cheese surface either naturally or through directed inoculation.

These bacteria are generally aerobic, requiring oxygen to grow, mesophilic, and halophilic (able to thrive in salty environments but sensitive to acidic conditions). The surface pH must be above 5.5 to allow their development. Surface bacteria play a major role in cheese ripening by performing proteolytic, lipolytic, and esterasic activities, leading to the formation of various aromatic compounds and the characteristic color of the cheese rind (**Mahout et al., 2000).**

The main groups include *Micrococcaceae* and coryneform bacteria. Among the coryneform bacteria, the most frequently found species on cheese surfaces is *Brevibacterium linens***(Mounier et al., 2005).**

IV.5.2. Yeasts

These microorganisms adapt to diverse substrates such as air, soil, plants, water, silage, and milk. The classification of *Geotrichum candidum* within the yeast group is now widely accepted. Yeasts are commonly found on cheese surfaces, contributing to:

- De-acidification by consuming lactic acid.

- Ethanol production and secondary metabolites through lactose fermentation.

- Esterification, proteolytic, and lipolytic activities.

Like propionic acid bacteria, yeasts can be introduced directly into milk **(Dahou, 2017).**

IV.5.3. Molds

Molds are mainly represented by two Penicillium species, introduced via fungal cultures:

- *Penicillium camemberti*: A surface mold specific to soft cheeses like Camembert, responsible for de-acidification (lactic acid consumption and protein degradation), triglyceride hydrolysis, and fatty acid oxidation.

-*Penicillium roqueforti:* This mold, present in blue-veined cheeses, exhibits proteolytic and lipolytic activities and has the ability to oxidatively degrade fatty acids **(Dahou, 2017).**

V. Factors influencing cheese aging

a. Temperature

Temperature is a critical factor to control during aging, as microbial and enzymatic activity varies accordingly. For most microorganisms used in cheese production and for the majority of enzymes involved in ripening, optimal temperatures exceed ***20°C*** **(Mietton, 1995).**

b. Air Composition

Confined environments should be avoided when aging cheese with strictly aerobic microorganisms, as they hinder the growth of desired micro-flora and promote the development of undesirable microbes. Therefore, fresh air renewal is essential. Additionally, humidifying the air reduces the risk of contamination in aging rooms and cheese products **(Chekireb, 2021).**

c. pH

pH affects microbial development and enzymatic activity. Among microorganisms, only lactic acid bacteria, yeasts, and molds can thrive at pH levels below 5 . Enzymatic activity is also highly sensitive to pH variations **(Mietton, 1995).**

d. Water Activity (aw)

Water activity refers to the free water in a product, which makes it vulnerable to bacterial proliferation. Humidity levels should be adjusted based on the targeted microbial categories: ***90–95%*** relative humidity for bacterial surface flora, ***85–90%*** relative humidity for fungal surface flora, ***80–85%*** relative humidity for dry-rind cheeses, to limit contaminant growth. **(Chekireb, 2021).**

Experimental Section

Material and Methods

Material and methods

I. Place and duration of work

The experimental approach of this study was carried out over a period from January to June 2025. It was carried out at :

The Céliacompany, belonging to the Lactalis group, located in BeniTamou, Blida.

The microbiology laboratory of the Faculty of Natural and Life Sciences at YahiaFarès University, Médéa.

I.1. Presentation of the Lactalis Group (Célia)

Célia is an international company specialising in the processing of milk and its derivatives. Founded in 1933, it is located in the wilaya of Blida, at BeniTamou, rue des Frères Zardi.

Its main objective is to ensure optimum production quality to guarantee consumer satisfaction **(table 13)**. To achieve this, the plant applies ISO standards (22000, 45000, 9001) and implements HACCP and HSE systems to ensure product safety and conformity.

Table 13:Presentation of the Lactalis group in 2022.

Presentation of place	Lactalis Group in Algeria
Group criteria	_The world's leading dairy group. _The world's leading cheese group.
Rawmaterialcriteria	_The world's 3rd largest group in the drinking milk market. _90 years of expertise. _8,5500 employees. _10th largest food group in the world.
Breakdown of employees by geographical area	_266 production sites in 51 countries. ***_50%*** in Europe. ***_17%*** in Asia and Oceania. ***_33%*** in the Americas.
Quantity of milk collected	***_22.6 BILLION*** litres of milk collected worldwide .
Breakdown of sales by category	***_40%*** cheese. ***_17%*** drinking milk.

	_14% ultra-fresh. ***_12%*** butter and cream. ***_9%*** ingredients and nutrition. ***_06%*** other.

II.Preparation of the raw material

II.1 Biological material: Spirulina

The spirulina used, *Arthrospira platensis* FOX BEHATAM, was supplied by the Alkiram organic farm in Biskra, Algeria. It was grown by DrAbd El RrazakKiram. Algae samples were taken on 22 January 2025 and 22 April 2025. **Figure(11)**.



Figure 11:Spirulina used to make soft cheese.

II.2 Milk selection

1. The raw material, milk, is an essential element in obtaining a rich, high-quality product. According to the Lactalis group (Célia), the collection service is supplied exclusively with cow's milk for the manufacture of derived products.

2. Milk is collected in several geographical areas nationwide, including :AïnTémouchent, Sidi Bel Abbès, Mostaganem, Relizane, Algiers, Blida, Tipaza, Médéa, M'sila, Boussaâda, Oum El Bouaghi and Constantine. The aim of this geographical distribution is to guarantee a supply of milk of optimum quality and in sufficient quantity.

3. Animal factors: Cattle breeds influence the chemical composition of milk. It depends, of course, on the genotype of the dairy cow, but also on several other factors, such as: age, season, stage of lactation and diet **(MULONDA KAKUMBWA ,2016)**. According to the Lactalis group (Célia), certain specific breeds are preferred in order to guarantee optimal characteristics of the milk used in production. **Table (14).**

Table 14:Effect of breed on the chemical composition of milk.(Panthi et al, 2007) .

Breed	Butyrous rate (%)	Protein rate (%)	Casein rate (%)	Lactose rate (%)
Montbéliarde	3,67+0,22	3,26+0,04	2,63+0,02	4,81+0,13
Holstein	3,77+0,32	3,28+0,21	2,57+0,23	4,78+0,19
Normande	3,81	3,49	2,77	4,73

III. Control of physico-chemical and bacteriological parameters in milk

The figure below summarises the working methodology used by the Célia Group in this research. **Figure(12).**

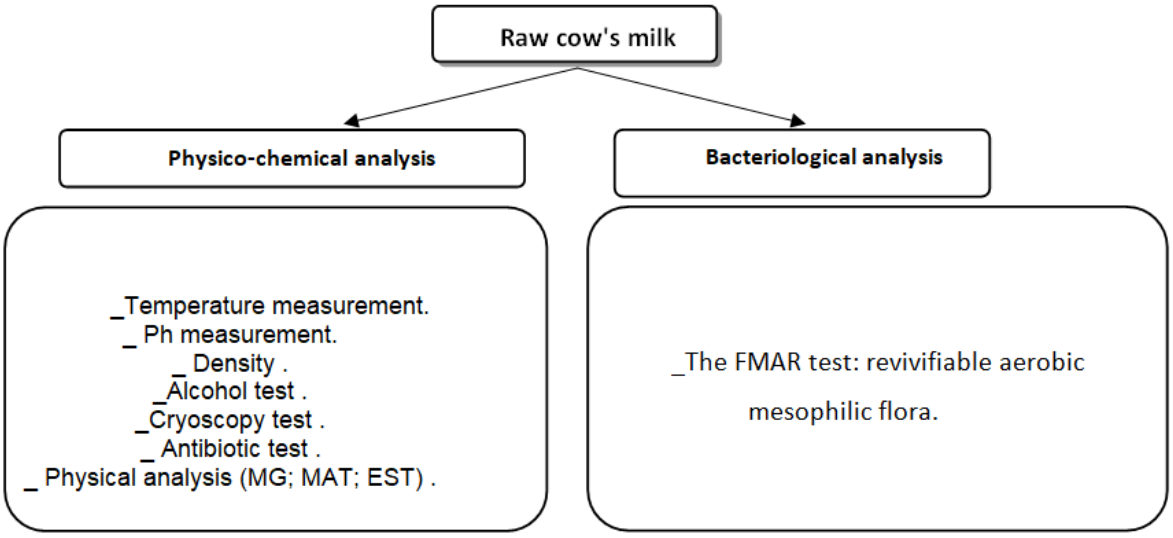


Figure 12 : Diagram of physico-chemical and bacteriological analysis methods for raw cow's milk.

III.1. Physico-chemical analysis

III.1.1. Reception

a. Temperature

The temperature of the raw milk is measured before it is emptied using a food-grade thermometer. This is immersed in the tank containing the milk, and the temperature is read directly on the thermometer scale, which must be below ***10°C***.

b. Sampling

More than one litreis collected in a sterile container (one litre for the density test and another for the following parameters).

III.1.2 .In the laboratory

a. Temperature: Between ***17*** and ***23°C***, the parameters to check are :

b. pH:

To determine the pH of the milk, the pH meter electrode is immersed directly into a beaker containing the raw milk sample. The pH value appears immediately on the meter's display, providing a quick and reliable measurement. It should be in the range [6.60 to 6.80].

a. Density and acidity

Density is expressed in ***g/L***, and acidity in degrees Dornic **(°*D*)**. The quality of the milk on delivery can be assessed on the basis of its acidity, which enables the volume of lactic acid generated by the bacteria to be estimated. According to the Lactalis Group, these two parameters are determined by the Lactoscope.

a. Alcohol test

The alcohol test is a quick way of assessing the quality of milk when it is received. When alcohol is added to acidic milk, it turns into curds and is rejected. On the other hand, if no coagulation occurs, the milk is accepted.

How to operate

In five Petri dishes, add ***2 ml*** of raw cow's milk and ***2 ml*** of alcohol at different concentrations and temperatures. Shake for ***30 seconds***, **Figure (13).**

1. Box 01=***2ml*** at ***65 %*** .
2. Box 02=***2ml*** at ***68 %*** .
3. Box 03=***2ml*** at ***72 %*** .
4. Box 04=***2ml*** at ***72.5 %*** .
5. Box 05=***2ml*** at ***75 %*** .

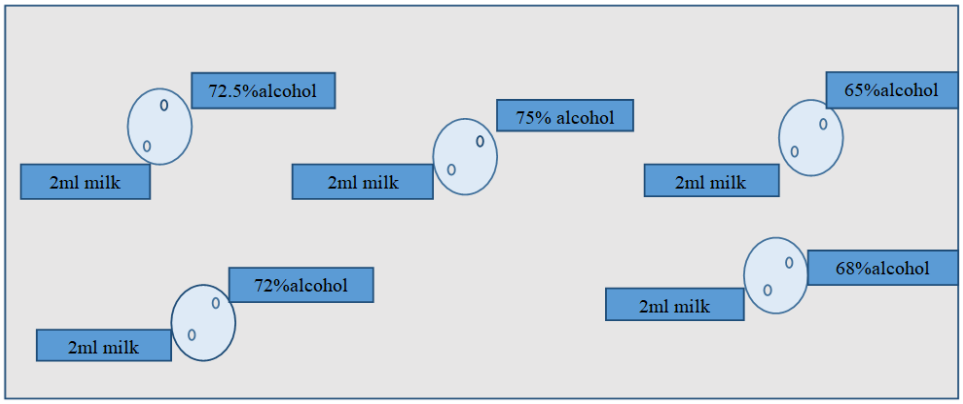


Figure 13:Effect of different alcohol concentrations on raw cow's milk.

Cryoscopy test

The freezing point is the temperature at which milk changes from a liquid to a solid when cooled. For cow's milk, this point varies on average between ***-0.53*** and ***-0.61°C***. The result is displayed on the cryoscope screen in degrees Celsius ***(°C)***.

- **Antibiotic test**

Testing for antibiotics in raw milk is essential to guarantee food safety and avoid the presence of residues that could harm human health.

- **Antibiotic test strips**

Test strips are practical tools for rapidly detecting the presence of antibiotic residues. They are essential for guaranteeing milk quality and preventing health risks to consumers.

These tests identify the presence of β-lactams and tetracyclines in raw cow's, goat's or sheep's milk. The test is quick and easy, with results obtained in just ***10 minutes***.

III.2. Bacteriological analysis

✓ Spirulina

The assessment of the microbiological quality of spirulina is based on the use of the selective medium VRBL, allowing the isolation and counting of indicator bacteria. For this analysis:

1 gram of spirulina is dissolved in ***10 ml*** of distilled water, then subjected to a decimal dilution using factors 10^{-3} and 10^{-4} in order to obtain concentrations suitable for inoculation. Inoculation is carried out in depth, using a two-layer technique, guaranteeing even distribution of the micro-organisms and better visibility of the colonies formed. Incubation takes place at

25°C for ***24 hours***, enabling bacterial growth to be assessed and ensuring rigorous analysis of the health quality of the spirulina.

✓ Raw milk

Analysis of the revivifiable aerobic mesophilic flora is based on a series of methodical steps aimed at quantifying the microbial load present in raw cow's milk. In this context:

A decimal dilution is carried out using K2, with dilution levels ranging from 10^{-4} to 10^{-7}. The culture medium used for this analysis is PCA agar, recognised for its ability to promote the growth of aerobic mesophilic bacteria. After inoculation, the samples are subjected to a prolonged incubation period of ***72 hours*** at ***30°C***, the optimum condition for the development of the targeted microorganisms.

This method provides a reliable estimate of the revivifiable aerobic mesophilic flora, which is essential for assessing the microbiological quality of raw milk.

✓ Camembert (Demoulding and after *24 hours*)

Analysis of faecal and total coliforms is based on the use of VRBL selective medium, enabling isolation and counting of these bacteria, which are indicative of faecal contamination.

Inoculation, carried out in depth using a two-layer technique, guaranteeing even distribution of the micro-organisms and better visibility of the colonies formed. Incubation, at specific temperatures of ***44°C*** for faecal coliforms and ***30°C*** for total coliforms, for ***24 hours***.

This methodological approach makes it possible to assess the microbiological quality of food products and detect any contamination, thereby contributing to health control and food safety.

IV. The soft cheese-making process

Diagram of camembert production according to the lactalis group (Célia)

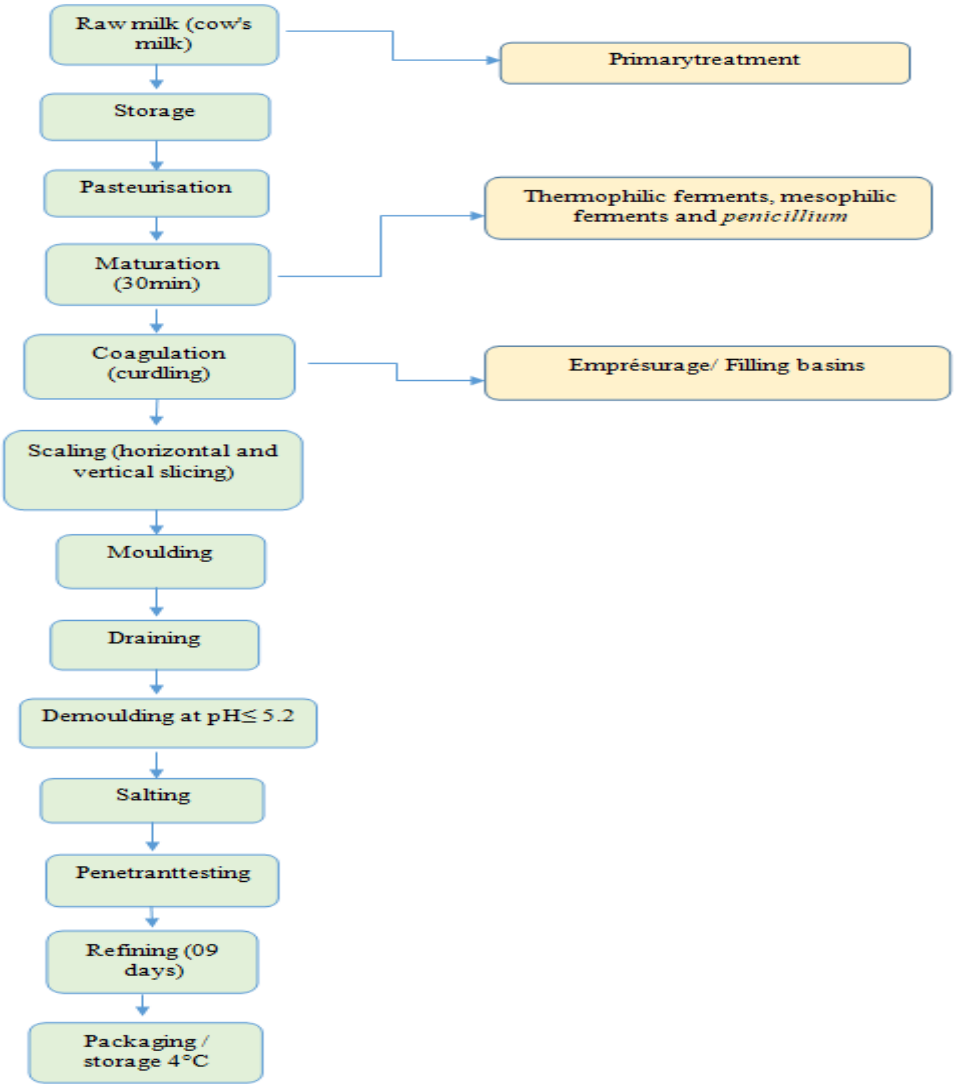


Figure 14:Diagram of Camembert production according to the lactalis group.

IV.1. Milk preparation

Before being used to make Camembert, the raw milk must undergo rigorous control and appropriate treatment to guarantee its microbiological and physico-chemical quality. A number of parameters must be respected, including a pH of 6.70, acidity of 17, density of 1037, fat content of 41 and total nitrogen content of 40.

The milk pasteurisation process is carried out in several stages to eliminate pathogenic micro-organisms while preserving the essential characteristics of the product. During the first pasteurisation, the raw milk is heated to an inlet temperature of ***78°C*** before being rapidly cooled to ***6°C***, this heat treatment being applied for a few seconds. A second pasteurisationis then carried out using the same protocol, with an inlet temperature of ***78°C*** and an outlet temperature of ***6°C***, this guaranteeing greater microbiological stability and optimum quality of the milk used to make the cheese.

At this stage, Camembert milk is formed after a succession of operations. Firstly, powdering consists of adding Löw Heat (LH) milk powder to increase the protein content (MAT), and pure water, treated according to the utility service, to the raw cow's milk. This mixture is homogenised for ***30 minutes*** at ***11°C***, with a hydration time of ***4 hours*** at ***12°C***. The mixture is then melted by adding anhydrous dairy fat (sman - MGLA) to increase the fat content.

Degassing is then carried out by passing the mixture through a degasser to eliminate the odours of the anhydrous dairy fat (ADF) and raw milk. After this stage, the mixture is subjected to a homogeniser to ensure uniform distribution of the components. Finally, a third pasteurisation stage is carried out, with an inlet temperature of ***78°C*** and an outlet temperature of ***37°C***, guaranteeing better quality milk for Camembert production.

IV.2. Maturation of Camembert milk

In the Camembert production process, the milk is left to rest in secondary vats for ***18 hours***, with regular stirring for ***15 minutes*** every ***15 minutes***. This stage is essential to prevent the dispersion of the casein micelles present in raw cow's milk and to guarantee optimum homogeneity of the mixture.

Milk enrichment is based on the addition of various elements that contribute to the final quality of the cheese. These include lactic ferments, which play a key role in fermentation and ripening. Thermophilic bacteria, which develop at an optimum temperature of ***37°C***, favour warm fermentation, while mesophilic bacteria, which are active at temperatures below ***25°C***, are involved in cold ripening.

In addition, specific ingredients are incorporated to enhance the cheese's flavour profile. The addition of yeast enhances the development of flavours, while calcium in the form of calcium chloride ($CaCl_2$) helps to structure the cheese. Finally, Penicilliumis introduced to ensure the formation of Camembert's characteristic rind.

The mixture is then homogenised for ***35 minutes*** to ensure an even distribution of the components. During the maturing phase, a number of parameters change, including a gradual decrease in pH, leading to an increase in acidity, which is essential for transforming the milk into cheese. The ferments used in this process are of French origin, guaranteeing quality and typicality in line with traditional manufacturing standards.

a. Coagulation of Camembert milk

In the soft cheese-making process, the matured milk is poured into a ***150 L*** tank, the volume of which is determined by a specific equation.

MG + (MAT ×Density) / MSE

MSE = 122 after qualification, according to the CéliaAlgérie group.

MG=fat content.

MAT=protein content.

Addition of rennet: Incorporation of ***35 ml*** of rennet to initiate coagulation.

Activity: ***200IMCU/ml***.

Dosage: ***30_60IMCU/L Milk***.

To prepare the rennet:

715g of rennet in ***5L*** of distilled water.

- The rennet remains ***24 hours***.
- The rennet is of bacterial and French origin.

Checking that the milk has set is based on a timed test, which enables the rennet's action time to be checked and the start of coagulation to be determined. The ideal time for this phase is ***5 minutes***. Before carrying out the test, it is essential to disinfect the finger to avoid contamination.

If the setting time observed is less than ***4 minutes*** or more than ***5 minutes***, the quantity of rennet needs to be adjusted, either by decreasing or increasing it, to ensure optimum coagulation and consistent cheese quality.

The total coagulation time is ***45 minutes***, confirmed by the concrete test, which verifies that the coagulation dispersion follows a single path, guaranteeing uniform structuring of the product.

b. Slicing

Slicing the curds is an essential stage in making Camembert. It is done using a slicer, in two directions: vertical and horizontal, to obtain a cubic shape. This cutfacilitates draining. **Figure(15).**



Figure 15:Slicing the curds to make Camembert.

c. Addition of spirulina

In this stage, a suitable quantity of freeze-dried spirulina (in powder form) is added to a calculated quantity of curd containing serum. These experiments enabled us to identify the optimum formula, guaranteeing the desired final characteristics of the product.

The ingredients are added to a decontaminated basin. Using a ladle, the mixture is carefully homogenised to achieve perfect harmony. **Figure(16)**. The spirulina used complies with bacteriological analysis standards.

After several tests, the ideal quantity of spirulina added to a litre of Camembert milk is ***0.75g*** **(Table 15).**

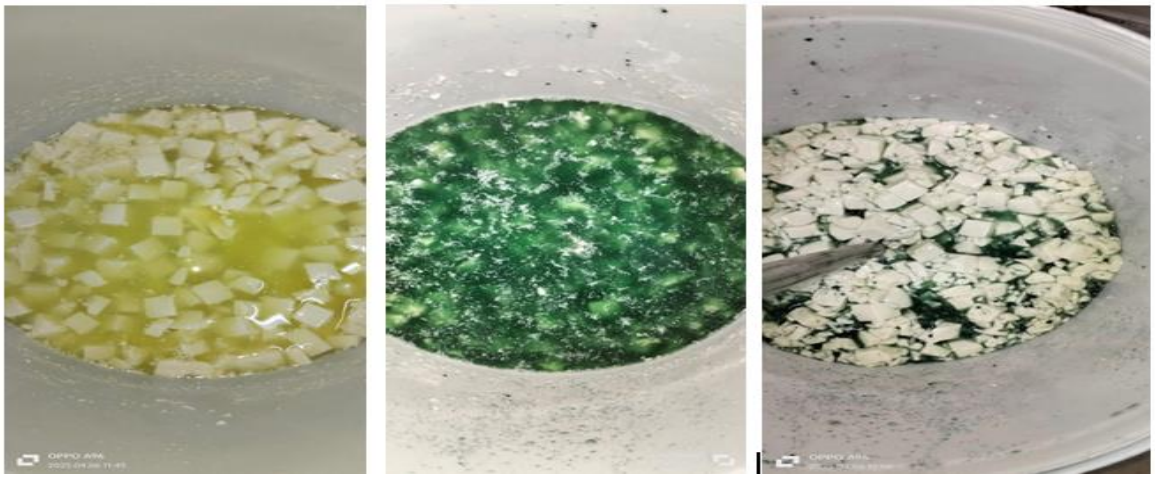
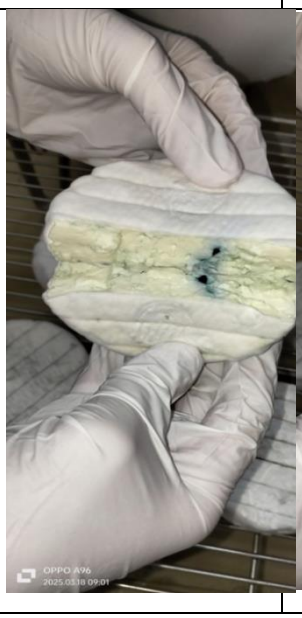
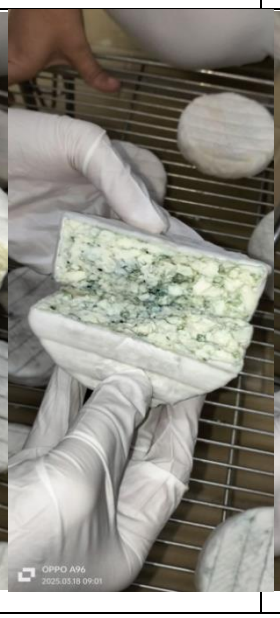


Figure 16:Incorporation of spirulina in the production of soft cheese.

Table15:The different doses of spirulina added in Camembert production.

The quantities	***0.25g/L***	***0.5g/L***	***0.75g/L***	***1g/L***
The colour	light	medium	excellent	dark
The example				

Assessing the colour of Camembert according to light, medium, excellent and dark categories enables the product to be standardised according to market standards and consumer expectations. Soft cheese experts use precise criteria to judge the visual quality of the cheese, in particular the colour of the rind and the paste.

d. Moulding and draining

At this stage, the curd is passed through a puiseur to reduce the whey, then through a parseur. The special Camembert mouldsare then filled with the prepared mixture. **Figure (17).** The cheese is left to drain for a set time before being transferred to the draining chambers.

The size of the moulds (diameter) varies according to the type of Camembert: small Camembert, large Camembert, etc.



Figure 17:Moulding and draining of Camembert enriched with spirulina.

e. Draining chambers

The draining of soft cheese takes place in seven phases, each lasting one hour, with a gradual reduction in temperature from ***29°C*** to ***18°C***. **Table(16)**.

Table16:The 07 draining phases.

Phases	P1	P2	P3	P4	P5	P6	P7
Temperature	***29°c***	***28°c***	***27°c***	***25°c***	***23°c***	***19°c***	***18°c***
Time	***1h***	***1h***	***1h***	***1h***	***1h***	***1h***	***1h***

This drop in temperature plays an essential role in the development of lactic bacteria and the ripening of the cheese.

Initially, the temperature is maintained at ***29°C***, then gradually reduced to ***18°C*** in the final phase. Each phase lasts one hour, allowing controlled adjustment of the fermentation conditions. This variation directly influences the activity of the lactic acid bacteria. Thermophilic bacteria, which require high temperatures for optimal growth, do not develop at this stage of production. On the other hand, mesophilic bacteria, which thrive at moderate temperatures, start to grow thanks to the favourable conditions created by this draining phase. These bacteria play a key role in acidifying the cheese, helping to shape its texture and organoleptic characteristics.

Before being removed from the mould, the product is left to rest for ***16 hours*** to reach a dry extract of 42 (EST 42), guaranteeing optimum structure and good cohesion of the cheese. This process is crucial to the final quality of the product and to the development of Camembert's characteristic flavours. The pH gradually decreases to 4.90.

Optimisation of draining :

An essential stage in ensuring good draining is the turning of the Camembert pieces, carried out at ***1 hour***, ***5 hours*** and ***8 hours*** after the start of the process.

f. Demoulding

Demoulding is a key stage in the manufacture of Camembert. Once the cheese has drained sufficiently, it is gently removed from its moulds on specialised lines, ensuring precise and uniform handling. This operation prepares the cheese for salting.

g. Salting

The process of salting Camembert is carried out using a specialised device, which distributes the salt evenly over each piece of cheese. The amount applied varies according to the surface: ***1.80 g*** on the top and ***3.20 g*** on the bottom.

Salt plays a fundamental role in cheese-making. It helps to improve flavour, while ensuring effective decontamination, thereby limiting the proliferation of undesirable micro-organisms. What's more, it promotes optimal draining, giving the cheese better structure during the maturing process. It also plays a part in the flocculation process, influencing the texture and cohesion of the final product.

The salt used at this stage is an Algerian product, selected for its cheese-making properties. Before being applied, it undergoes a sieving phase to ensure a homogenous granulometry and an even distribution on the Camembert pieces.

h. Penetrant testing

Penetration is an essential stage in the Camembert ripening process, and it is essential to incline the support to prevent the serum flowing onto the other parts, thus avoiding the formation of defects such as toad skin. This arrangement ensures that the moisture is evenly distributed and that the cheese matures to perfection.

After ***24 hours***, several parameters must be respected to maintain favourable conditions for ripening. Humidity must be stabilised at ***85%***, to ensure adequate hydration of the rind and proper development of surface micro-organisms. Ventilation, set at ***50 m^3/h***, plays a key role in controlling humidity and preventing unwanted contamination. Finally, the temperature must be maintained at ***18°C***, allowing the cheese to mature gradually and express its organoleptic characteristics.

i. Refining

Ripening Camembert is an essential stage that allows the cheese to develop its characteristic flavours and texture. Pieces of Camembert are left for 9 days in hâloirs, where

the ripening agents begin to grow and encourage the formation of a bloomy rind. They are then placed in conservation chambers for 20 days, where the ripening process continues under controlled conditions.

This process is crucial in guaranteeing the final quality of the cheese, giving it a melting texture and a balanced taste.

j. Packaging

The packaging has been produced by the same company, using the same materials, but with a new look that reflects the product. This new packaging describes the appearance of the cheese and contains all the new information about it. **Figure(18).**



Figure 18:Packaging of Camembert enriched with spirulina

V. Physico-chemical tests

Physicochemical analyses are carried out using reference methods as well as the rapid methods of the Célia Lactalis group.

Parameters to be monitored during production

According to our study, the essential parameters to be monitored are :

- Fat content (FG).
- Total nitrogenous matter (TNM).
- Dry extract (DE).

V.1. Determining the fat content of cheeses (MG)

Fat is a major parameter in cheese production. It is determined using the Van Gulik acid-butyrometric method, in the following stages:

1. Weighing the sample: Take approximately ***3 g*** of spirulina-based Camembert and place it in a well using a precision balance.

2. Insert into the butyrometer : Place the cup containing the sample in the butyrometer.

3. Adding the acid: Add ***10 ml*** of sulphuric acid, then close the neck of the butyrometer with a stopper.

4. Heating in a water bath: Place the butyrometer in a water bath at ***65°C***.

5. Stirring: Stir every ***10 minutes*** for ***5 seconds*** using a vortex to ensure complete dissolution of the Camembert. This process takes approximately ***1 hour***. After dissolution, leave the butyrometer to stand for ***15 minutes*** in the water bath.

6. Addition of isoamyl alcohol: Add ***1 ml*** of isoamyl alcohol, then shake immediately for at least ***3 seconds***.

7. Completion with sulphuric acid: Fill the butyrometer up to mark 35 with sulphuric acid.

8. Rotate the butyrometer: Turn the butyrometer over 6 times.

9. Heating in the water bath: Return the butyrometer to the water bath at ***65°C*** for ***5 minutes***.

10. Centrifugation: Place the butyrometer in a centrifuge for ***10 minutes***.

11. New heating phase: Return the butyrometer to the water bath at ***65°C*** for ***10 minutes***.

12. Reading the results: Read the results obtained.

V.2. Determination of the total nitrogen content (MAT)

The total nitrogen content, which corresponds to the protein content, is an essential parameter for cheese production. It is determined using the Kjeldahl reference method, which involves the following steps:

1. Weighing: Take ***1 g*** of Camembert and place it in nitrogen-free weighing shoes (Whatman paper).

2. Transfer: Place the sample, with the weighing basket, in a mineralisation tube (MATRA).

3. Add catalyst: Add two tablets of Kjeltabs catalyst (potassium sulphate + copper sulphate) to the tube.

4. Addition of acid: Add ***20 ml*** of sulphuric acid, then gently mix the tube.

5. Mineralisation: Place the tube in the mineraliser, which is connected to a scrubber.

6. Dilution: After cooling, dilute the contents of the tube with ***80 ml*** of distilled water, rinsing the sides thoroughly. Shake by rotation to ensure complete dissolution of the crystals.

7. Distillation: Connect the digestion tube to the distiller, thenprogramme the addition of ***70 ml*** of ***40%*** sodium hydroxide to release the ammonia.

8. Separation of the ammonia: Carry out steam distillation and trap the condensed ammonia-water solution in ***50 ml*** of boric acid.

9. Titration: Titrate with ***0.1 N*** hydrochloric acid using a pH meter. The final titration point is reached at pH = 4.6, then note the volume of acid delivered.

10. Calculating the results: Perform the calculation to determine the total nitrogen content.

V.3. Determination of total dry extract (EST)

Dry matter is a fundamental parameter in the manufacture of cheeses, particularly Camembert. It is determined using a rapid method which involves the following steps:

1. Grinding: The piece of Camembert is ground in a grinder for ***5 seconds***.

2. Measuring the pH: The ground Camembert is spread out in a Petri dish so that its pH can be measured using a pH meter. The pH value is displayed on the instrument screen after stabilisation.

3. Desiccant dryer: A desiccant equipped with a precision balance (including a heating system and a resistor) is used. An aluminium dish is placed in the apparatus, on which the Camembert cheese is placed and spread out. The results are obtained after ***20 minutes*** of treatment.

VI. Characterization of the sensory properties of an enriched Camembert cheese:Developing the organoleptic properties of cheese

a. Texture

The texture of soft cheese depends not only on the type of feed the cows receive, but also on the addition of spirulina, which plays a positive role in improving and strengthening the structure of the cheese. In fact, the combination of spirulina with LAB (lactic acid bacteria) contributes to a supple, pleasant texture.

b. Appearance

Our spirulina-based Camembert has the same appearance as standard Camembert.

- On the outside: The Camembert rind is well developed thanks to the combination of spirulina and ripening agents, mainly *Penicillium camemberti*.
- Inside: Visually, it is similar to Roquefort cheese, thanks to the green spots left by the spirulina.

c. Flavour

Our product has a flavour similar to that of traditional Camembert, but with a slight marine note in the aftertaste.

V.II. The relationship between lactic acid bacteria and spirulina

✓ Spirulina

A local spirulina in powder form was used in this study: spirulina BEHATAM, grown in a small production unit located ***80 km*** from Tamanrasset.

✓ The lactic acid strain

The lactic acid strain used in this study belongs to the genus *Pediococcus ssp*.

V.II.1. Experimental procedure

The experimental procedure used in this study is illustrated in the diagram below **(Figure 19).**

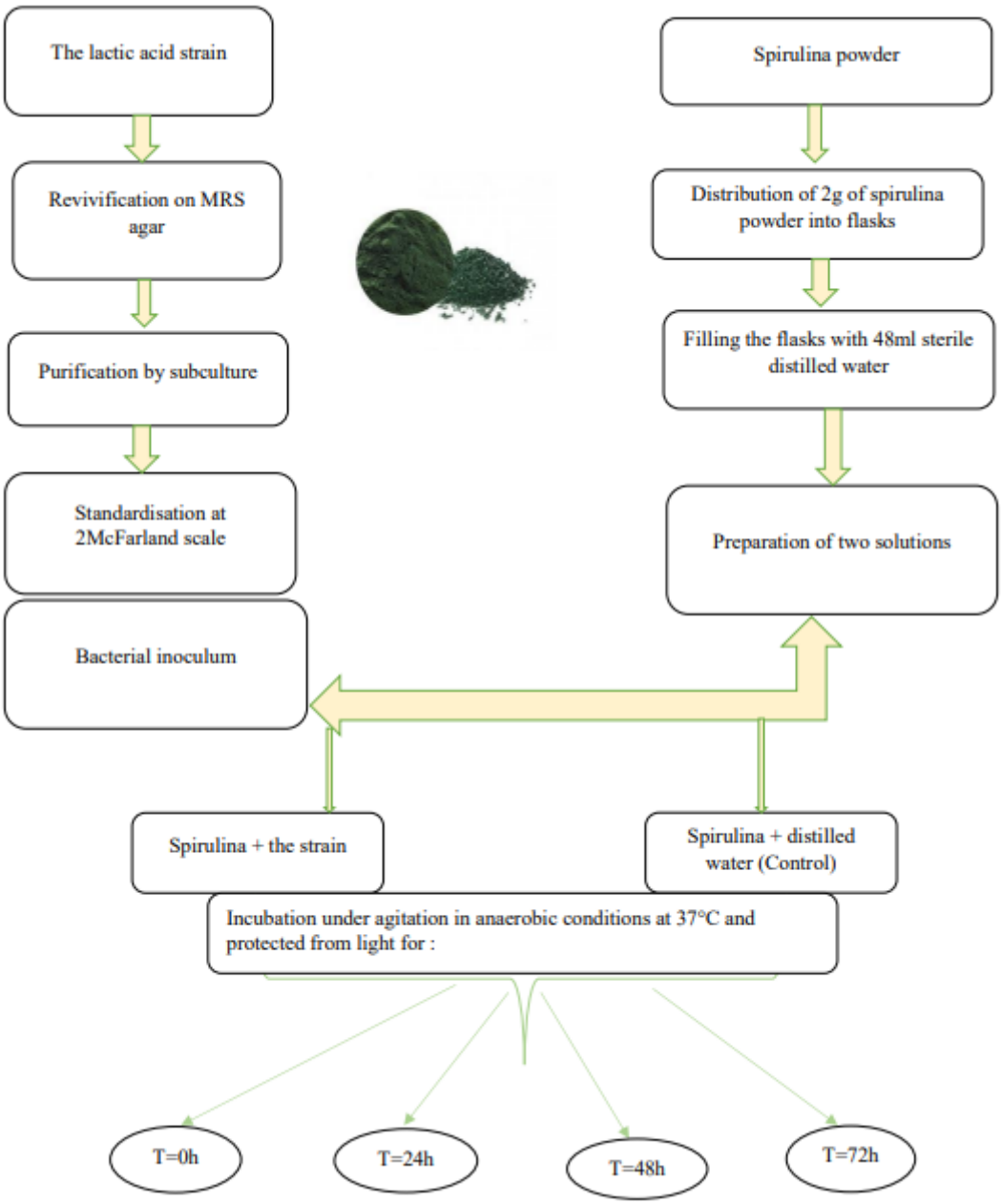


Figure 19:Diagram of experimental procedure for lactic acid bacteria and spirulina.

Revivification of the lactic strain

A pure culture isolate, previously stored at ***-20°C***, was introduced into MRS broth. After inoculation, the strain was incubated at ***37°C*** for ***24 hours*** under anaerobic conditions.

a. Purification of the strain

This strain was purified by several replicates in liquid MRS medium, followed by streak isolation on MRS agar. Macroscopic and microscopic observations confirmed the purity of the bacteria.

V.II.1.1 Preparation of spirulina fermentation solutions with lactic acid bacteria

Evaluation of freeze-dried spirulina biomass as a medium for the proliferation and fermentation of the *Pediococcus ssp*. strain was carried out according to the procedure established by **(Nicolaï et al. 2019).**

Under aseptic conditions, we introduced ***2 g*** of spirulina powder into a ***100 ml*** Erlenmeyer flask. We added ***48 ml*** of sterile distilled water to this powder, then inoculated the suspension with ***2 ml*** of *Pediococcus* strain culture. The final solution was brought to a total volume of ***50 ml***. This preparation is designed for fermentation in the presence of lactic acid bacteria.

For the control group, another container was prepared by combining ***2 g*** of spirulina powder with ***50 ml*** of distilled water, without the inclusion of bacterial culture. This unfermented solution was used as a reference to assess the impact of fermentation.

The flasks were then placed in a shaking water bath at ***37°C*** to guarantee the fermentation process. A microbiological assessment was carried out at four different times: ***0, 24, 48*** and ***72 hours*** of fermentation, for both processes: using spirulina with distilled water and using spirulina with lactic acid bacteria. It is important to mention that the lactic acid fermentation of spirulina was carried out under identical experimental conditions.

V.II.2. Antimicrobial activity of spirulina

✓ Preparation of the extract

The study of these activities was carried out in the microbiology laboratory of the Faculty of Science at the UniversitéYahiafarés in Médéa.

This work was carried out according to the plan illustrated below. **Figure (20)**.

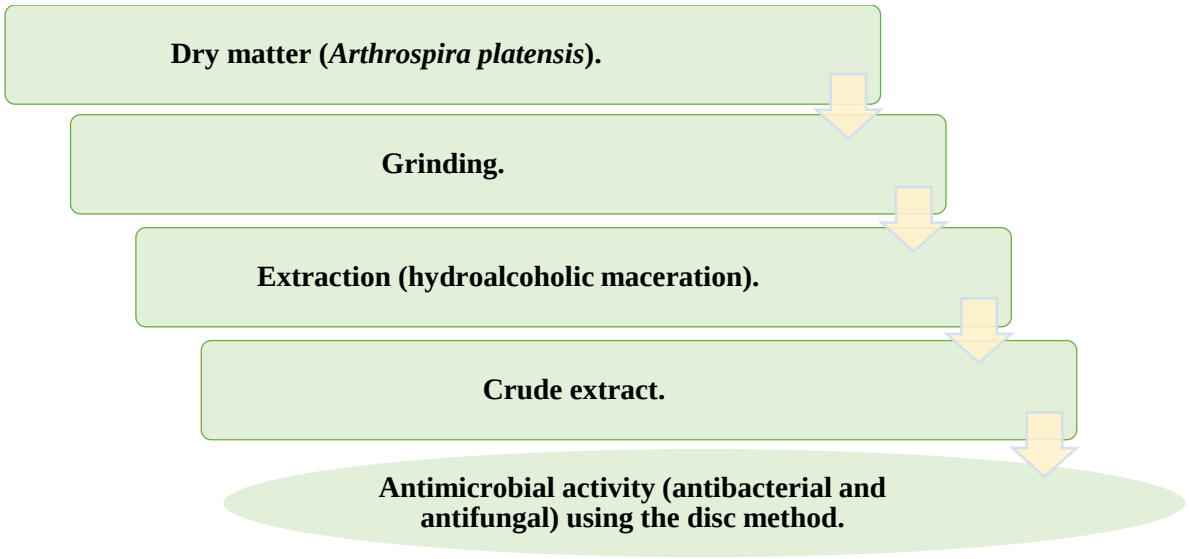


Figure 20:Overview of the antibacterial activity of spirulina .

✓ Extraction of bioactive compounds by hydro-methanolic maceration

The extraction of bioactive compounds, in particular the polyphenols present in algae, is based on a method described by **(Sultana et al. 2009)**. This discontinuous solid-liquid maceration extraction process involves immersing the solid material in a solvent at room temperature for a set period of time, allowing the soluble constituents to be released. The solvent is then evaporated under vacuum to recover the extracted compounds, guaranteeing optimum concentration of the bioactive substances while minimising their degradation.

✓ Equipment

Spirulina (dry matter), methanol, distilled water, balance, crucible, filter paper, rotavapourer, hot air oven, flasks, beakers.

✓ Method

1. Take a sample of ***10 g*** of spirulina in the form of ground material.

2. The ground material is mixed with ***100 ml*** of aqueous solvent (***70 ml*** methanol / ***30 ml*** distilled water).**Figure (21)**.



Figure 21:Extraction of bioactive compounds by aqueous solvent.

The mixture is left for ***24 hours*** at room temperature and in the dark, this process being repeated three times.

N.B=The duration of the extraction process promotes the depolymerization of the main structural compounds of the algae, such as lignin and pectic substances, and allows for better solubilization of the main bioactive compounds **(Ali and Doumandji, 2017)**.

3. The hydroalcoholic extract is filtered using filter paper, then the solvent is removed by vacuum evaporation using a rotavapor at ***45°C***.**Figure(22).**



Figure 22:Filtration and evaporation of spirulina hydroalcoholic extract.

4. The extract is transferred to a hot air oven at ***40°C*** and stored in dark bottles at ***4°C***.

✓ Calculation of dry extract yield

This is the ratio between the mass of extract and the dry powdered seaweed (as a percentage).

Rdt = (Pb/Pa°*100)

PB= Raw extract.

PA=Weight of dry powdered seaweed.

V.II.3 Antimicrobial activity of spirulina

VII..3.1 Antibacterial activity

✓ Principle of the antibacterial evaluation method

The method used in this study is disc diffusion on agar medium, which enables the impact of a substance (spirulina extract) on bacterial growth to be rapidly evaluated. It's a reliable technique that's simple to perform and the results can be quickly interpreted **(Audrey MANET page11).**

✓ Bacterial strains used

We used five strains:

_ *Escherichia coli*

_ *Staphylococcus aureus.*

_*Pseudomonas aeruginosa.*

_*Bacillus subtilis.*

_ Proteolytic bacteria.

These strains were subcultured by re-isolating a few colonies in new nutrient agar Petri dishes, then incubated for ***18*** to ***24 hours***.

✓ Disk diffusion antibiotic susceptibility testing protocol

Inoculation

Miller Hinton medium is used, which must be poured into Petri dishes to a thickness of ***4 mm.*** They must then be left to dry before use.

Using a densitometer, a quantity of ***0.5 MC*** Ferland of each colony of the strains studied is taken from the re-isolated strains in test tubes containing ***9 ml*** of sterile ***0.9%*** physiological water.

A clean swab is inserted into the solution and rubbed over the entire surface of the agar from top to bottom in close lines. Repeat this process several times, turning the dish ***60 degrees*** each time. Finally, the swab is passed over the edge of the agar. **Figure (23).**

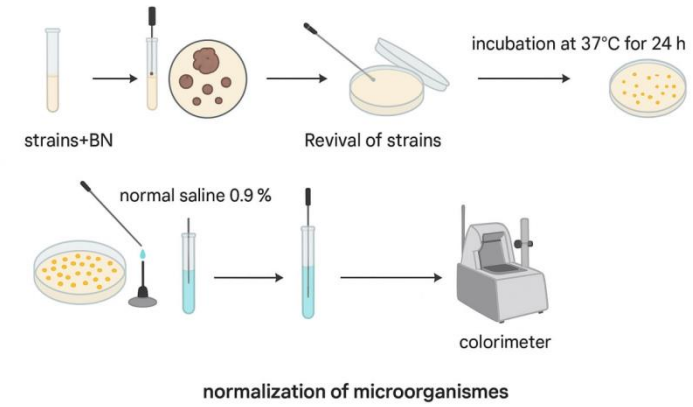


Figure 23:Stages in the revivification and normalisation of microorganisms on agar medium.

- ✓ **Applying the discs and reading**

Under aseptic conditions, using sterile forceps, place the sterile (blank) ***6 mm*** Whatman paper discs on the agar surface (2 discs per plate).

One disc contains ***10 µl*** of extract diluted in dimethyl sulphoxide (DMSO) at different concentrations (***50*** and ***100 mg/ml***) and the other contains ***10 µl*** of extract diluted in distilled water (***50*** and ***100 mg/ml***), incubated at ***37°C*** for ***18*** to ***24 hours***.

The diameters of the zones of inhibition were measured precisely in order to assess the effect of our extract, according to the reference values, bactericidal action: no microbial growth around the discs and bacteriostatic action: presence of zones of inhibition around the discs arranged on the surface of the culture medium.

V.3.2. Antifungal activity

- ✓ **Fungal strains used**

We used two fungal strains:

_ *Candida albicans.*

_ *Fusariumsolani* .

These strains were transferred to new Petri dishes on PDA medium and incubated for 7 to 10 days. The protocol was identical to that used to test antibacterial activity.

VIII. Adjustment of manufacturing parameters to improve texture and taste

With the aim of improving taste, diversifying our range and satisfying consumers, we have developed several flavours by incorporating additives such as Indian chilli **Figure (24)**, for a spicy note, and French thyme, for a traditional aromatic touch in our Camembert. **Figure (25).**

In addition, in order to enhance and reinforce its antimicrobial activity, the combination of thyme and spirulina gives our product a visual distinction compared with a Camembert flavoured only with thyme. The lower molecular weight of the thyme helps to homogenise the Camembert and make it more supple. These additives are added at the same stage as the spirulina.



Figure 24:Camembert with chilli.



Figure 25:Camembert with thyme.

IX. Comparative analysis between a traditional camembert and a camembert enriched with spirulina

Table 17:Key points for comparison.

Appearance	Camembert ordinaire	Camembert withspirulina
Composition	Cow's milk + lactic ferments and *penicillium*.	Cow's milk + lactic ferments + spirulina as a biological material + *penicillium*.
Nutritional value	Source of calcium and protein	Richer in protein, iron, B vitamins, antioxidants (thanks to spirulina)
Taste and texture	Creamy, slightlyspicy	Vegetable notes, slightly modified texture
Colour	White.	Slightly green tint
Microbiologicalproperties	Classic ripening	Spirulina influences microbialflora
Impact on health	Provides calcium and protein	Antioxidants, iron, nutritional boost (thanks to spirulina)
Manufacturing process	Traditional fermentation	Adjustmentsrequired for balance
Sensoryacceptability	Taste appreciated by consumers	Modified flavour may influence acceptability
Effect on preservation	Standard shelf life	May influence shelf life

Innovation potential	Traditional product	Integrationintodietary trends
Effect on digestion	Classic digestion	Facilitate digestion
Influence onmicrobiota	Little impact	Encourage certain beneficialbacteria
Marketdemand	Strong demand, well-established product	Innovative product, needs to be developed
Economic impact	Stable market	Niche product with growth potential
Manufacturing process price	Standardised, well-mastered	Requiresadjustments and testing

Results and Discussion

Results and discussion

I. Physico-chemical parameters and the influence of spirulina on cheese properties.

The addition of spirulina to soft cheese results in significant changes to the physico-chemical parameters compared with traditional Camembert. These variations influence the texture, composition and organoleptic properties of the cheese, offering a distinct product that could appeal to fans of new flavours.

I.1. Analysis of results and comparison with the standard Camembert

✓ Fatcontent (MG)

The high fat values observed during the primary and secondary ripening stages (***41.03%***) indicate good lipid retention in the cheese matrix. However, the significant decrease at the demoulding stage (***22.74%***) suggests a loss of fat due to draining and redistribution of the components. In comparison, a standard Camembert generally has a more stable fat content, with primary and secondary ripening at ***41%*** and demoulding at ***19.5%.***

✓ Total nitrogen matter (MAT)

The high TNM values (***40.29%***) reflect a high protein concentration, essential for the structure of the cheese thanks to the addition of spirulina, which is rich in essential proteins (the 08 essential amino acids). This content is high compared to that of a classic Camembert (MAT ***39%***), which has a basic protein concentration, contributing to the creamy texture and firmness of the product.

✓ pH and acidity

The progressive decrease in pH, from 6.70 to 5.00, reflects a gradual acidification due to the activity of lactic bacteria and fermentation in the presence of phenolic compounds released by spirulina into the lactic environment. This evolution is rapid compared to that of traditional Camembert, where the pH gradually decreases to around 5.50. The increase in acidity (from 19 to 26) confirms this biochemical transformation, influencing texture and the development of aromas.

✓ Total dry extract (EST)

The values obtained (***35.80%*** after draining and ***38.46%*** after demoulding) indicate a progressive concentration of solids. A standard Camembert generally has a EST of over ***40%***, which suggests that the dry extract content is a key factor to monitor, as spirulina modifies the structure of the curd and can influence the elimination of whey. In fact, it has an impact on the draining of Camembert pieces, leading to variations in dry extract concentration.

✓ MG/EST ratio

The value obtained (0.543) is lower than that of a conventional Camembert, which is generally around 0.55 to 0.59. This difference could be attributed to a redistribution of lipids and a change in texture induced by spirulina.

✓ Salt content

The levels measured (***1.45%*** and ***1.50%***) are in line with the standards for classic Camembert, which generally has a salt content of between ***1.3%*** and ***1.6%.*** Salt plays a key role in the preservation and development of flavours.

✓ Moisture of dehydrated cheese (HFD)

The value obtained (***0.72%***) at the demoulding stage is relatively similar to standard Camembert (***0.76%***), contributing to its melt-in-the-mouth texture.

Table18:Normal Camembert (*250g; 220g, 145g*).

Workshop	Stages	MG	EST	MG/EST	MAT	PH	Acidity	HFD	T.SEL
J0	Primary ripening	41	/	/	39.5	6.72	19	/	/
J+1	Secondary ripening	41	/	/	39.5	6.26	24	/	/
J+1	Emprésurage	/	/	/	/	6.24	/	/	/
J+1	5h draining	/	37	/	/	5.2	/	/	/
J+2	Demoulding	25	46	0.544	/	5.1	/	0.721	/
J+2	Demoulding	/	/	/	/	5.1	/	/	1.40
J+8	Packaging	27.5	50	0.555	/	5.1	/	0.687	1.52

Table 19:Camembert (*250g:220g; 145g*) with spirulina.

Workshop	Stages	MG	EST	MG/EST	MAT	PH	Acidity	HFD	T.SEL
J0	Primary ripening	41.03	/	/	40.29	6.70	19	/	/
J+1	Secondary ripening	41.03	/	/	40.29	6.23	24	/	/
J+1	Emprésurage	/	/	/	/	6.17	26	/	/

J+1	5h draining	/	35.80	/	/	5.35	/	/	/
J+2	Demoulding	22.748	38.46	0.593	/	5	/	0.79	/
J+2	Demoulding	/	/	/	/	5	/	/	1.45
J+8	Packaging	/	/	/	/	5	/	/	1.5

In both cases the density is 1037.

II. Spirulina bacteriological parameters richi camembert compliance

II.1. Spirulina

Bacteriological analysis of spirulina results in a conformity of the latter which testifies to a total absence of contaminating agents (total and faecal coliforms), **(figure26)** .Thanks to its ability to inhibit microbial activity through its antioxidants h cases the density is 1037.

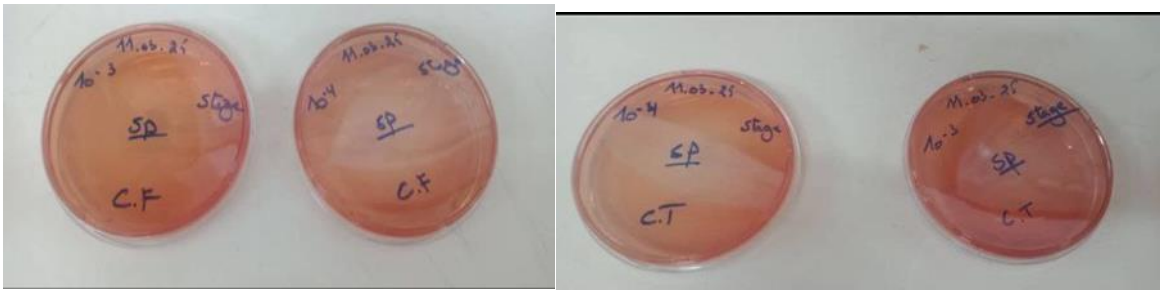


Figure 26:Results of bacteriological analysis of spirulina.

II.2. Raw milk

Bacteriological analysis of raw milk shows that the limited presence of pathogenic bacteria and microbial contaminants is evidence of effective control of milking and storage conditions.

Microbiological parameters in compliance include: a low concentration of total aerobic flora,

an absence or reduced presence of thermotolerant coliforms, and a controlled bacterial load, guaranteeing the safety of the raw milk. These results underline the importance of rigorously applying good agricultural practices and implementing preventive measures to limit the risks of contamination.

II.3. Demoulding the enriched Camembert

The bacteriological analysis carried out when the spirulina-enriched Camembert was removed from the mould confirms that the product complies with current microbiological

standards. The results show that there is no contamination by pathogenic bacteria, attesting to rigorous control of hygiene and manufacturing conditions, and that the beneficial bacterial flora, particularly lactic bacteria, is well developed, contributing to the ripening and organoleptic quality of the cheese. What's more, count tests reveal values that comply with regulatory thresholds, guaranteeing the safety of the product.

These results validate the effectiveness of the manufacturing process and confirm that the incorporation of spirulina does not alter the microbiological balance of Camembert, while preserving its traditional characteristics.

III. Effect of spirulina on nutritional composition

Adding spirulina to soft cheese considerably improves its nutritional value. Firstly, spirulina is an exceptional source of protein, accounting for up to ***70%*** of its composition, which boosts the protein content of the cheese. Secondly, it enriches Camembert with essential vitamins such as B1, B2, B3, B5, B6, B9, E and K, complementing those naturally present in the cheese.

What's more, spirulina contains a wide range of minerals such as iron, calcium, magnesium, zinc, potassium and selenium, all of which contribute to greater nutritional density. Its antioxidant content, including phycocyanin, chlorophyll and beta-carotene, boosts its health benefits by protecting cells from oxidative stress.

Finally, the presence of essential fatty acids, such as gamma-linolenic acid, improves the lipid profile of Camembert. In addition to these benefits, the addition of spirulina influences the texture and colour, giving it a slightly green tinge inside and a more pronounced flavour, while optimising its nutritional quality.

Incorporating spirulina into Camembert production offers a cheese with improved properties, both nutritionally and sensorially, and could appeal to consumers looking for innovative, healthier alternatives.

IV. Microbial activity

IV.1. Evaluation of lactic bacteria

Incorporating spirulina into Camembert production, in association with lactic bacteria, has enabled the development of a cheese with enhanced functional properties **(figure 27)**. Spirulina, which is rich in protein (up to ***70%*** of its dry matter), phycocyanin (a powerful

antioxidant), iron, beta-carotene and B vitamins, acts as a bioactive ingredient that enriches the cheese matrix.

When spirulina is added to soft cheese dough or rind, it can stimulate the activity of lactic acid bacteria and ripening cultures (*Lactococcuslactis, Penicilliumcamemberti*, etc.) by providing them with additional nutrients, thereby encouraging more dynamic and homogenous microbial development. In return, the lactic acid bacteria produce metabolites, notably organic acids, which lower the pH and facilitate the release of certain bioactive compounds from the spirulina, thereby improving the bioavailability of its nutrients. In addition, this interaction can have a positive effect on texture (smoother) and flavour, reducing spirulina's natural bitterness through fermentation. Camembert has an original colour (shades of green), a higher nutritional value, and can be positioned as a functional food, suitable for vegetarian diets or health-conscious consumers, without altering the typical organoleptic qualities of traditional Camembert.

Technological adjustments (dose of spirulina, time of incorporation, maturing conditions) are however necessary to guarantee a balance between sensory quality and functional benefits.

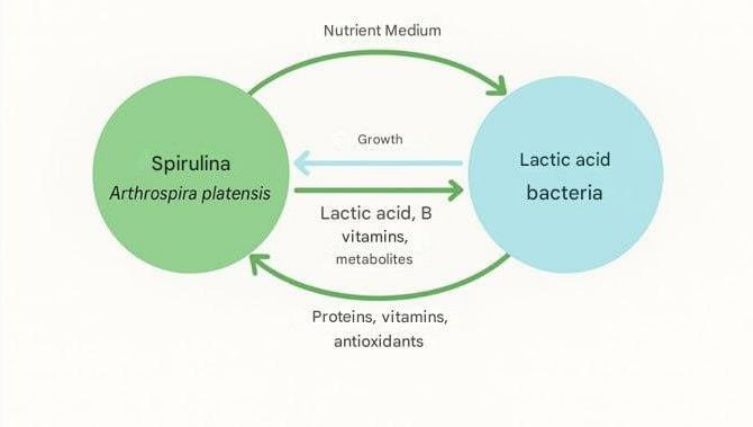


Figure 27:The relationship between spirulina and lactic acid bacteria.

The results of the determination of phenolic compound levels from spirulina solutions fermented or not fermented by lactic acid bacteria at different fermentation times are presented in **(figure 28)**.

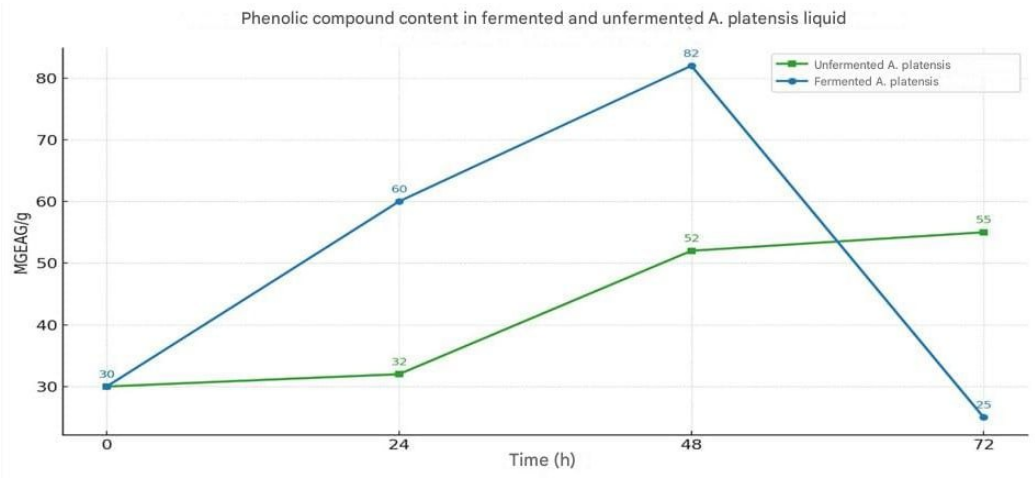


Figure 28:Phenolic compound content in fermented and unfermented *A. Platensis* liquid.

The evolution of phenolic compound content in *Arthrospira platensis* liquid was evaluated over a ***72-hour*** period, under fermented and non-fermented conditions. At ***0 h***, both samples had an equivalent concentration of ***30 mg EAG/g***. In the unfermented condition, a progressive increase was observed, reaching ***32 mg EAG/g*** at ***24 h***, ***52 mg EAG/g*** at ***48 h***, then ***55 mg EAG/g*** at ***72 h***. On the other hand, in fermented conditions, a much more marked increase was noted: ***60 mg EAG/g*** at ***24 h*** and a peak of ***82 mg EAG/g*** at ***48 h***. However, at ***72 h***, a significant drop was recorded, with the concentration falling to ***25 mg EAG/g***.

The results obtained indicate that fermentation significantly stimulates the release or transformation of phenolic compounds in the short term, most probably via the enzymatic action of the micro-organisms involved. The peak reached at ***48 hours*** suggests an optimal phenolic enrichment phase. However, the sharp drop observed at ***72 hours*** could be due to the degradation or metabolisation of these compounds by the micro-organisms themselves, or to oxidation or precipitation phenomena. In contrast, the unfermented condition shows a slow but continuous release of phenolic compounds, indicating better long-term stability. Fermentation is therefore effective for rapid extraction, but excessive duration can compromise the stability of the final product. It is therefore crucial to optimise fermentation time to maximise the yield of bioactive compounds without causing their degradation.

IV.2. Development of molds: Effect of spirulina on the growth of *Penicillium* and other microorganisms involved in cheese ripening

Results and discussion

The association between spirulina and *Penicillium camemberti* in Camembert production is not a common practice. *Penicillium camemberti* is a fungus essential to the ripening of soft cheese, contributing to its creamy texture and distinctive flavour. In contrast, spirulina is a nutrient-rich cyanobacterium, widely used as a dietary supplement.

Although spirulina is well known for its antioxidant and nutritional properties, its integration into a fermentation process involving *Penicilliumcamemberti* has not been documented in the literature to date. However, ongoing research into the biotechnological valorisation of spirulina could offer promising new directions.

The results of the interaction between spirulina and *Penicillium camemberti* (particularly the formation of the rind) in both standard Camembert and Camembert enriched with spirulina at various stages during ripening in maturing chambers are presented in .**Figure (29)**.

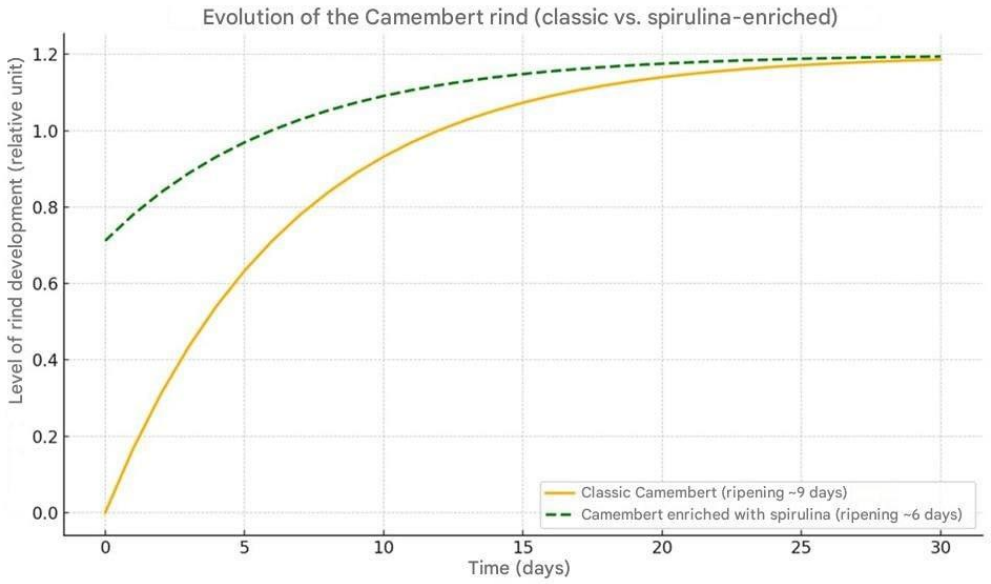


Figure 29:Changes in the crust of ordinary and enriched Camembert cheeses.

Enriched Camembert reaches a given level of development six days earlier than conventional Camembert. This acceleration could be due to several factors: a strengthening of the beneficial microflora by the spirulina, an antioxidant or enzymatic effect favouring the activity of *Penicillium*, as well as a better distribution of humidity or pH on the surface

V. Evaluation of the antimicrobial activity of spirulina

V.1. Antibacterial activity of spirulina

a. Escherichia coli

The absence of a halo around *Escherichia coli* during an inhibition test with spirulina **(figure 30)**can be attributed to several biological and chemical factors. Firstly, *E. coli* is a Gram-negative bacterium, which means that it has an outer membrane rich in lipopolysaccharides, acting as a protective barrier against many antimicrobial agents. This structure limits the penetration of bioactive compounds present in spirulina, such as phycocyanin, polysaccharides and antimicrobial peptides**.**

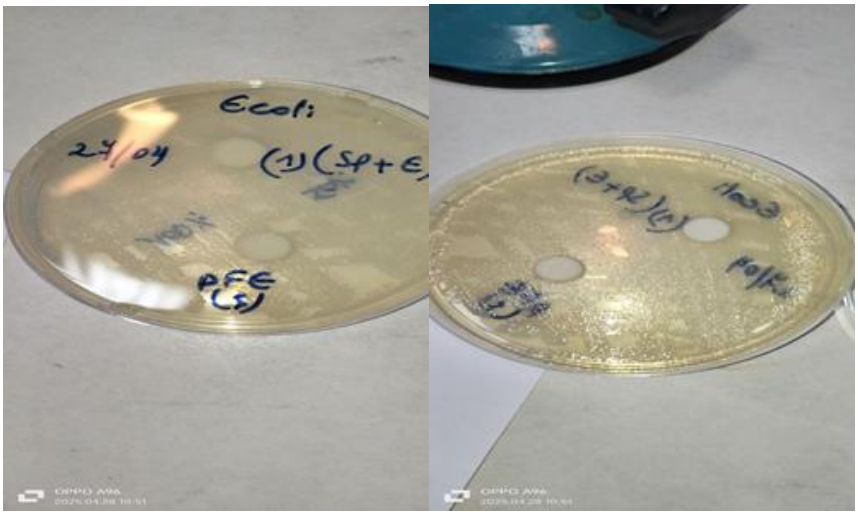


Figure 30:Results of an *Escherichia coli* inhibition test using spirulina.

b. Staphylococcus aureus

The absence of a halo of inhibition of the antimicrobial activity of spirulina (*Arthrospira platensis*) against *Staphylococcus aureus***(figure 31)**can be explained by several biological and biochemical factors, despite the fact that this bacterium is Gram-positive.

Firstly, although Gram-positive bacteria are generally more sensitive to natural antimicrobial agents due to their less complex cell wall (absence of an outer membrane), *S. aureus* has particularly effective defence mechanisms. This species is capable of producing enzymes that inactivate antimicrobial compounds, such as hydrolases or catalases, and expresses efflux pump systems that reduce the intracellular concentration of active substances.

Secondly, the bioactive compounds present in spirulina extract (such as phycocyanin, antimicrobial peptides or fatty acids) may not be effective or present in sufficient concentration to specifically targetthe structures or metabolic pathways of *S. aureus*. Some strains of this bacterium may also have natural or acquired resistance to antimicrobial agents, including those of natural origin.

Finally, technical factors can also influence the absence of a zone of inhibition: the type of extract (aqueous, alcoholic, etc.), its concentration, the stability of the active compounds or even their diffusion in the culture medium can limit the visible action on the agar.

Thus, the absence of a halo of inhibition does not necessarily mean a total absence of activity, but rather ineffectiveness under the conditions tested, which calls for methodological adjustments or further characterisation of spirulina's active compounds.

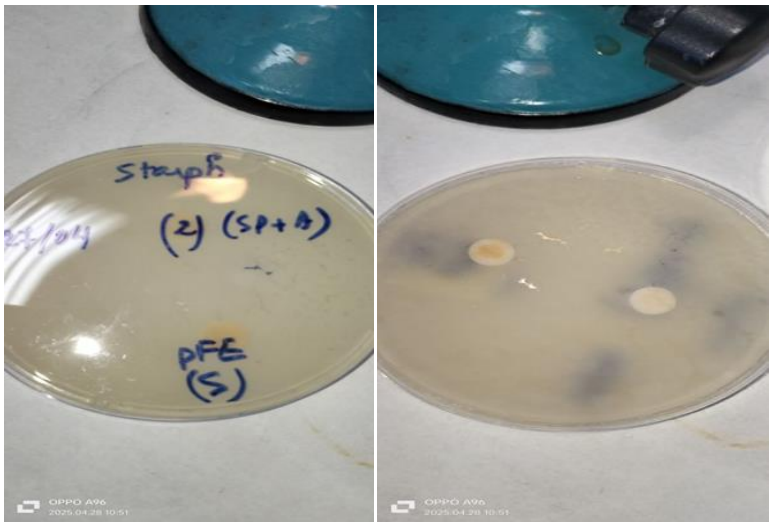


Figure 31:Results of *Staphylococcus aureus* inhibition tests with spirulina.

c. Pseudomonas aeruginosa

The absence of a halo of inhibition, illustrated in **figure (32)**, explains the ineffectiveness of spirulina against *Pseudomonas aeruginosa*. This Gram-negative bacterium has an outer membrane rich in lipopolysaccharides, which limits the penetration of antimicrobial compounds. Although spirulina contains bioactive molecules such as phycocyanins, polysaccharides and certain antimicrobial peptides, their effectiveness varies according to the nature and resistance of the bacteria targeted. What's more, *P. aeruginosa* is renowned for its natural resistance, thanks to efflux pumps that expel toxic substances and the formation of biofilms that provide additional protection.

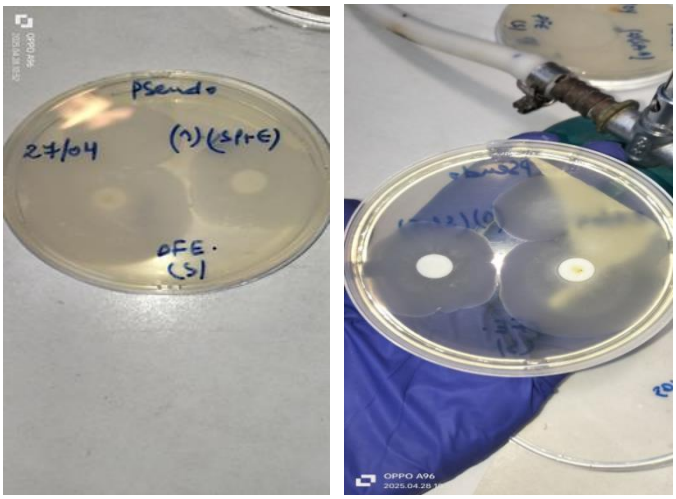


Figure 32:Results of the effect of spirulina on *Pseudomonas aeruginosa.*

d. Bcillus subtilis

The ***19mm*** zone of inhibition observed for spirulina extract against *Bacillus subtilis***(Figure 33)** indicates significant antimicrobial activity. This inhibition of bacterial growth is due to the presence of bioactive compounds in spirulina, such as phycocyanin, polysaccharides and certain antimicrobial peptides, which disrupt the structure of the cell membrane and the metabolic processes essential for bacterial survival. Such a zone of inhibition means that spirulina's antimicrobial effect is relatively powerful and could be compared with that of other natural or synthetic antimicrobial agents. Generally speaking, the greater the zone of inhibition, the more effective the antibacterial action. *Bacillus subtilis*, although non-pathogenic in most cases, may be involved in certain food contamination processes, making these results interesting for potential applications in the agri-food or pharmaceutical industries.



Figure 33:Test results for inhibition of *Bacillus subtilis* bacteria by spirulina extract.

e. Proteolytic bacteria

As part of the evaluation of the antimicrobial potential of spirulina (*Arthrospira platensis*) against proteolytic bacteria **(figure 34)**, known for their ability to hydrolyse proteins and cause degradation in food or biological products, a ***32 mm*** diameter zone of inhibition was observed around the discs, indicating strong antibacterial activity.

Such inhibition suggests that spirulina extract contains bioactive compounds with high antimicrobial potential, such as phycocyanin, sulphated polysaccharides, antimicrobial peptides or certain fatty acids. These compounds can act by disrupting the bacteria's cell membranes, inhibiting enzymes essential to their metabolism or interfering with the synthesis of their proteins. The sensitivity of proteolytic bacteria to spirulina extract opens up promising prospects for its use as a natural biocontrol agent.

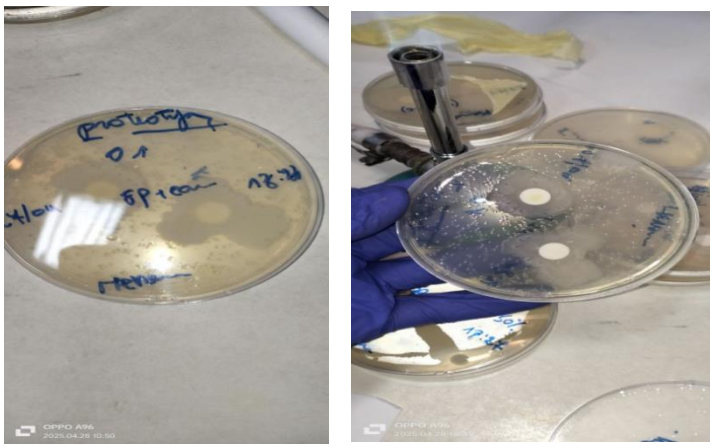


Figure 34:Zone of inhibition of proteolytic bacteria by spirulina extract.

V.2. Results of the antifungal activity of spirulina

a. Candida albicans

Spirulina extract (*Arthrospira platensis*) showed significant antifungal activity against the fungus *Candida albicans*, with a zone of inhibition reaching ***39 mm*** in diameter **(figure35)**. This marked inhibition testifies to strong biological efficacy, suggesting the presence of active compounds capable of interfering with fungal growth.

Among the molecules potentially responsible for this effect are phycocyanin, sulphated polysaccharides, certain polyunsaturated fatty acids and antimicrobial peptides. These compounds are known to disrupt the integrity of the fungal cell membrane, inhibit ergosterol synthesis and induce intracellular oxidative stress.

The efficacy of spirulina against *C. albicans*, a common opportunistic pathogen, reinforces its interest as a natural alternative to conventional antifungals. This result, combined with the activity observed against proteolytic bacteria, highlights the versatile potential of *Arthrospira platensis* as a natural antimicrobial agent, with possible applications in the fields of health, cosmetics and food preservation.

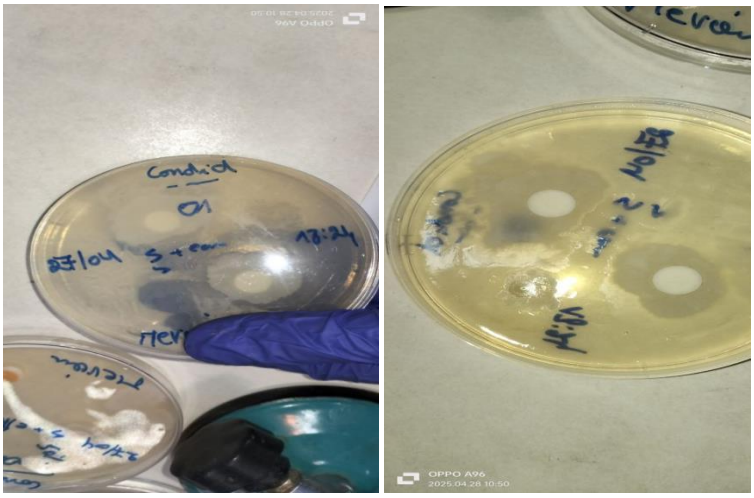


Figure 35:Antifungal activity of spirulina extract against *Candida albicans*.

b. Fusarium solani

Arthrospira platensis extract showed moderate antifungal activity against fungi of the genus *Fusarium solani,* characterised by a zone of inhibition ***13mm*** in diameter. Although this inhibition is relatively weak compared to that observed against other micro-organisms, it remains significant given the intrinsic resistance of these phytopathogenic fungi.

This inhibitory action could be attributed to the presence of bioactive compounds such as phycocyanin, polyunsaturated fatty acids, sulphated polysaccharides and various antimicrobial peptides, known to disrupt fungal membrane structures or inhibit metabolic pathways essential to their development.

Thus, despite a less marked activity, these results suggest the potential interest of spirulina as a natural antifungal agent, particularly in an integrated approach to the fight against fungal pathogens in agriculture or for the preservation of foodstuffs. Taken together,

these data underline the biological versatility of *A. platensis* and justify further investigations to optimise its efficacy and broaden its areas of application.

V.3. Comparative analysis

_ Gram-negative bacteria (*E. coli* and *P. aeruginosa*) show low sensitivity to spirulina, probably due to their lipopolysaccharide-rich outer membrane, which limits the penetration of antimicrobial compounds.

_ Gram-positive bacteria (*B. subtilis* and *S. aureus*) are more sensitive to spirulina, with greater zones of inhibition.

_Proteolytic bacteria are highly sensitive to spirulina, suggesting an effective interaction between spirulina's bioactive compounds and proteolytic enzymes.

Pseudomonas aeruginosa and proteolytic bacteria have high proteolytic activity, enabling them to break down proteins and adapt to different environments.

V.4. Comparison of antifungal activity

Comparative evaluation of the antifungal activity of *Arthrospira platensis* extract revealed a marked difference in sensitivity between *Candida albicans* and *Fusarium solani*.

C. albicans showed a zone of inhibition of ***39 mm***, indicating a high susceptibility to spirulina extract. This response could be explained by the unicellular nature of this fungus, which has a plasma membrane that is more exposed and potentially more vulnerable to active compounds such as phycocyanin, fatty acids or antimicrobial peptides present in spirulina. Conversely, *Fusarium solani* only displayed a ***13 mm*** zone of inhibition, indicating more moderate antifungal activity. This low sensitivity may be linked to its filamentous structure, the more robust composition of its cell wall, and its ability to produce spores and protective secondary metabolites, limiting the direct action of bioactive substances.

Pathogenically, *C. albicans* is a common opportunistic agent in humans, while *Fusarium solani* is primarily a plant pathogen. However, some *Fusarium* species can also cause severe human infections, particularly in immunocompromised individuals. These biological and physiological distinctions directly influence their response to natural antifungal agents.

In conclusion, this analysis highlights the superior efficacy of spirulina extract against *C. albicans* compared with *Fusarium solani*. It underlines the importance of targeting fungi

with a simple structure in order to make better use of natural extracts, while recognising the potential limitations when dealing with more resistant fungal species. **Table(20).**

Table 20:Comparison between the strains studied.

Bacterialstrains	Gram	Spirulinasensitivity
Escherichia coli	Gram negative	Weak or absent
Pseudomonas aeruginosa	Gram negative	Absent
Bacillus subtilis	Gram positive	Strong (***20mm*** inhibition zone)
Staphylococcus aureus	Gram positive	Moderate
Proteoleticbacteria	variable	Strong (***32mm*** inhibition zone)
/	/	/
Fungalstrains	Gram	
Candida albicans	/	Spirulinasensitivity
Fusariumsolani	/	High (***39mm*** inhibition zone)

VI. Sensory analysis

Sensory analysis of spirulina-enriched Camembert revealed significant differences from traditional Camembert, particularly in terms of colour, texture and flavour.

The incorporation of spirulina led to a perceptible change in the colour of the cheese, giving it a slightly greenish hue, which could influence consumer acceptability. In terms of texture, the analyses showed a slight change in firmness, probably due to interactions between the protein compounds in the spirulina and the cheese matrix. In terms of taste, the addition of spirulina seems to have brought subtle notes of seaweed as well as a slight intensification of the umami taste, perceived in varying degrees by the tasters. These analyses were carried out using tasting sheets supplied by the Céliacompany, providing a detailed assessment of the product's sensory characteristics.

These analyses were carried out using tasting sheets supplied by the Céliacompany. **Figure(36)**.

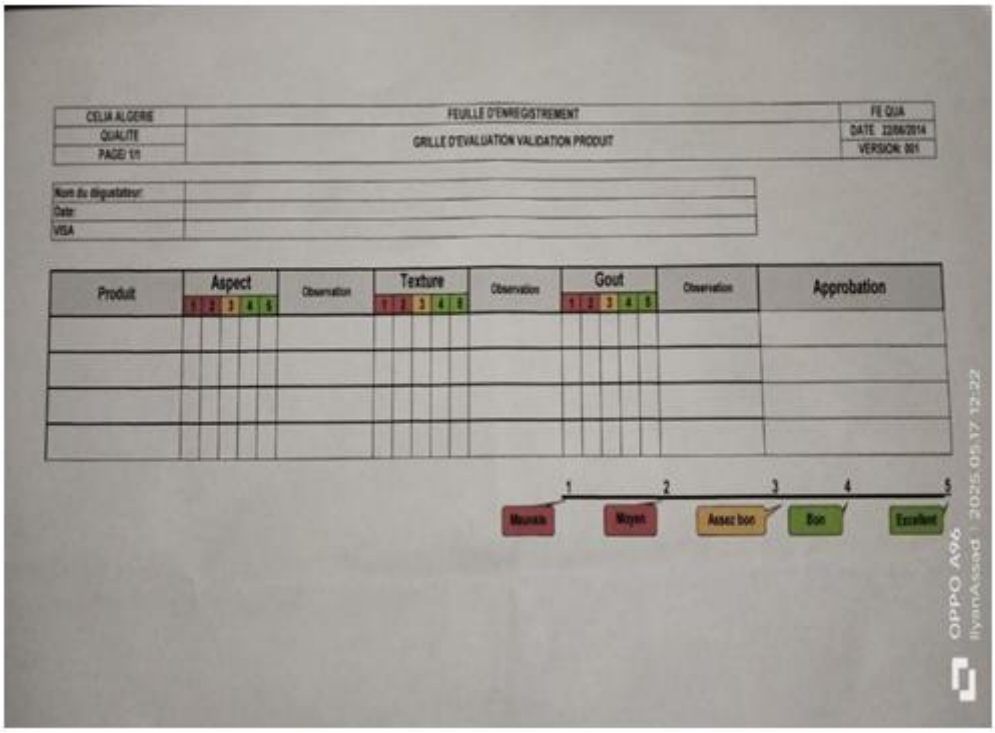


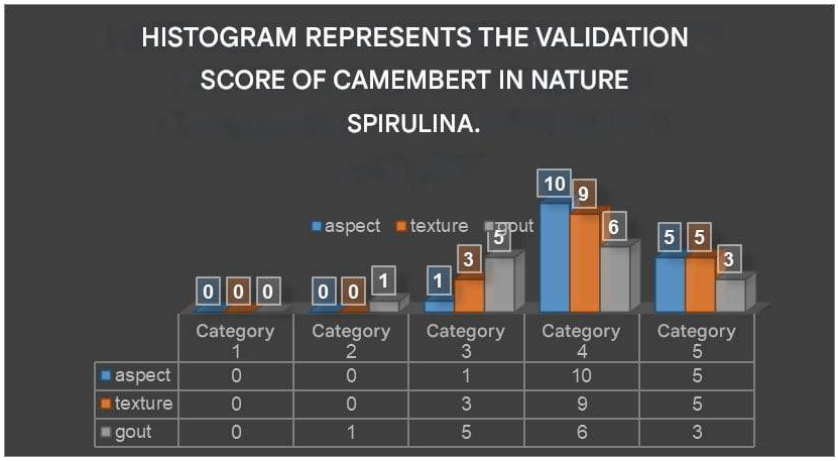
Figure 36:Tasting sheet for camembert enriched with spirulina.

VI.1. Camembert with spirulina

The graph **(figure37)** shows the results of a sensory evaluation of Camembert in natural spirulina, graded according to three essential criteria for marketing: appearance, texture and taste. These assessments are grouped into five rating categories, ranging from 1 (very poor) to 5 (excellent).

According to Lactalis Group standards, only grades 4 and 5 are considered valid for marketing, reflecting a level of satisfaction deemed sufficient to accept the product for commercial production and distribution.

Analysis of the results shows that the Camembert evaluated obtained an overwhelming majority of scores in categories 4 and 5, which means that the product is generally perceived as complying with Lactalis' quality requirements.



	Category 1	Category 2	Category 3	Category 4	Category 5
aspect	0	0	1	10	5
texture	0	0	3	9	5
gout	0	1	5	6	3

Figure 37:Sensory evaluation of Camembert enriched with spirulina.

The sensory analysis of Camembert enriched with spirulina revealed a positive assessment by testers on several key criteria.

The visual aspect of the product was particularly appreciated, with 10 evaluations in category 4 and 5 in category 5, giving a total of 15 positive ratings. These results indicate that Camembert is perceived as very visually pleasing, an essential factor in its acceptance by consumers.

The results for texture were also very favourable. The texture of the cheese scored 9 marks in category 4 and 5 in category 5, representing 14 positive evaluations. This shows that the product's consistency and mouthfeel are in line with consumer expectations.

The taste, although a little more variable, is still well rated. There were 6 evaluations in category 4 and 3 in category 5, giving a total of 9 positive ratings. A few tasters awarded a mark of 3 (5 assessments), which suggests that there is a slight margin for improvement on this criterion, without compromising the overall acceptability of the product.

Finally, none of the criteria were rated in category 1, and only very marginal values appeared in categories 2 and 3, mainly for taste. These results confirm that the incorporation of spirulina in Camembert is generally well perceived and could be optimised to further improve the sensory experience for consumers.

To improve the taste quality of Camembert enriched with spirulina, a new range of flavourshas been proposed, including a Camembert with thyme and a Camembert with chilli. These two variants were subjected to tasting by experts from the Lactalis group, as well as by other tasters.

VI.2. Camembert chili-spirulina

The graph **(figure 38)** shows the results of the sensory evaluation of Camembert chili-spirulina according to three criteria: appearance, texture and taste. In accordance with Lactalis Group validation standards, only scores 4 and 5 are considered acceptable for marketing.

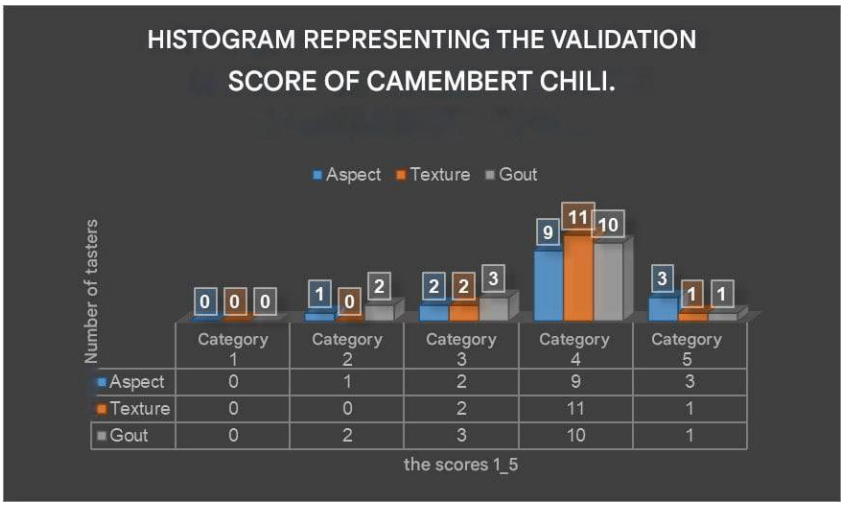


Figure 38:Sensory evaluation of chilli-spirulina Camembert.

The appearance of the chilli-spirulina Camembert was well rated, with 9 assessments in category 4 and 3 in category 5, giving a total of 12 positive ratings. Texture was the most highly rated criterion, with 11 ratings in category 4 and 1 in category 5, showing an excellent perception of the product's consistency.

Taste was also appreciated, with 10 scores in category 4 and 1 in category 5, for a total of 11 positive evaluations. The other, lower scores were marginal, with a few category 2 and 3 ratings, mainly for taste.

In conclusion, Camembert chili-spirulina meets the sensory quality criteria defined by the Lactalis group. The results confirm that the product is well perceived by tasters, particularly for its texture and appearance. With a large majority of scores between 4 and 5, the Camembert chili-spirulina is therefore considered suitable for marketing.

VI.3. Thyme-spirulina Camembert

The graph **(figure 39)** illustrates the results of the sensory evaluation of the Thyme-spirulina Camembert according to three criteria: appearance, texture and taste. According to the Lactalis Group's standards, a product is considered to conform to the market if it obtains a majority of scores of 4 or 5.

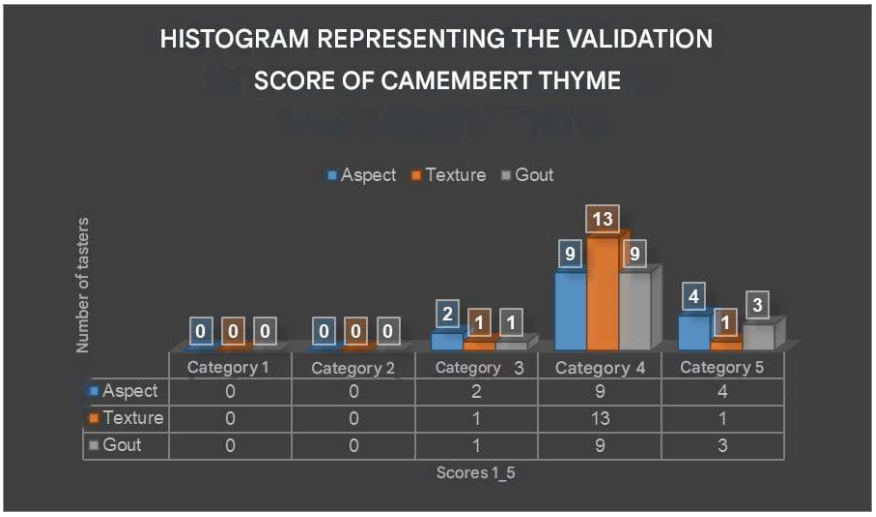


Figure 39:Sensory evaluation of Camembert with thyme and spirulina

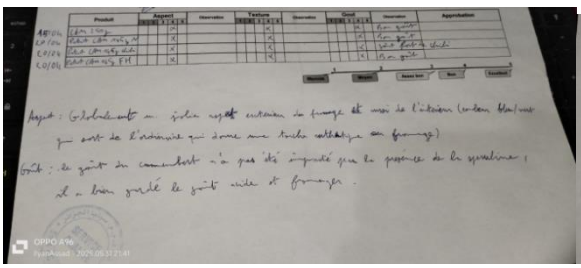
The data collected shows that Camembert with thyme-spirulina is well perceived overall by the tasters, with a high concentration of evaluations in these two categories. The product's appearance was judged to be satisfactory, with 9 tasters giving it a mark of 4 and 4 a mark of 5, giving a total of 13 positive assessments out of 15.

Texture was particularly valued, receiving 13 marks in category 4 and 1 in category 5, making it the most appreciated criterion. Taste also scored well, with 9 scores of 4 and 3 of 5, representing 12 favourable reviews.

No scores below 3 were recorded for any of the criteria, underlining a uniformly positive assessment of the product.

In short, Camembert with thyme-spirulina fully meets the validation criteria set by the Lactalis Group. Thanks to a majority of high scores, it is considered suitable for marketing, with a special mention for its texture, which was particularly appreciated by the tasters.

The experts shared their opinions on Camembert enriched with spirulina. **Figure(40)**.



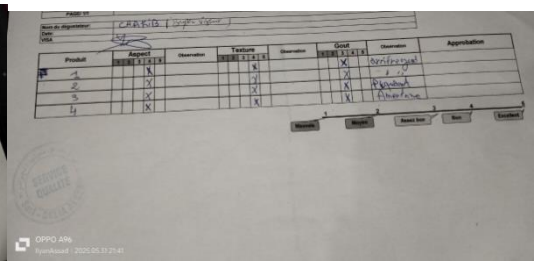


Figure 40:Expert opinion on camembert enriched with spirulina.

VII. Consumer preferences between the two types of Camembert

Out of a sample of 20 people, 15 said they were prepared to try the Camembert enriched with spirulina, and the majority ultimately preferred this innovative Camembert to the ordinary Camembert.

This preference **(Figure 41)** highlights a marked interest in new products, perceived as healthier and more original thanks to the presence of spirulina, recognised for its nutritional benefits. Despite the familiarity and tradition associated with the classic Camembert, the taste and innovative aspect of Camembert with spirulina appealed to a large proportion of consumers, particularly those who are sensitive to current food trends and concerned about their well-being.

This result suggests that innovation in dairy products can find a real audience, especially with consumers who are curious and open to new taste experiences. **Figure(42)**.

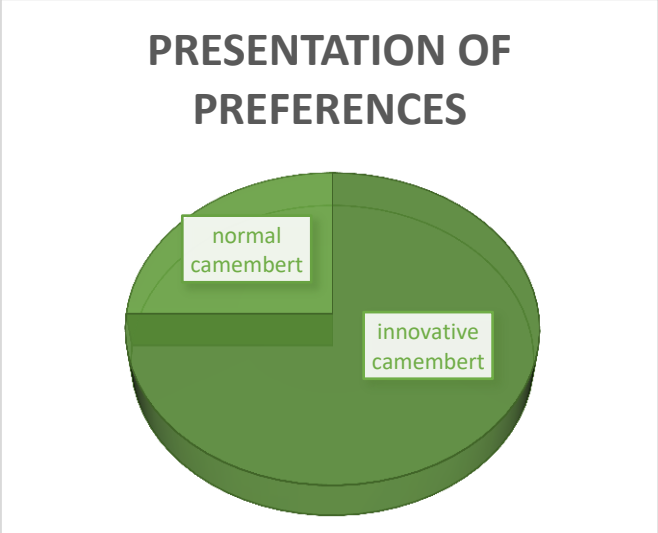
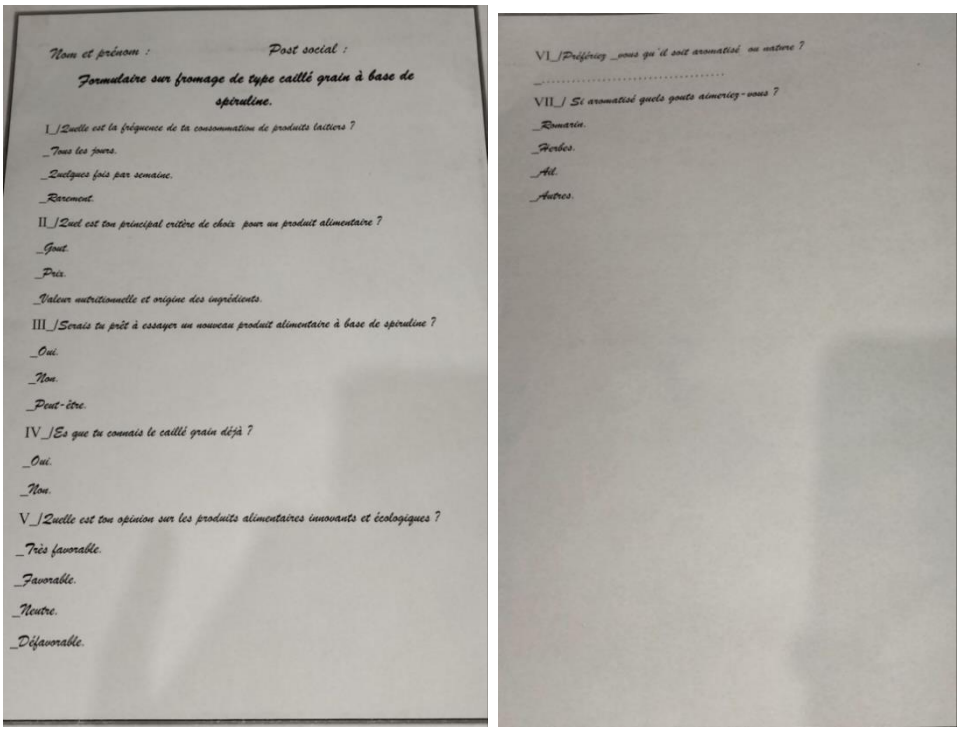


Figure 41:Consumer preferences between traditional Camembert and Camembert enriched with spirulina.



Nom et prénom : Post social :

Formulaire sur fromage de type caillé grain à base de spiruline.

I_/Quelle est la fréquence de ta consommation de produits laitiers ?
_Tous les jours.
_Quelques fois par semaine.
_Rarement.

II_/Quel est ton principal critère de choix pour un produit alimentaire ?
_Goût.
_Prix.
_Valeur nutritionnelle et origine des ingrédients.

III_/Serais tu prêt à essayer un nouveau produit alimentaire à base de spiruline ?
_Oui.
_Non.
_Peut-être.

IV_/Es que tu connais le caillé grain déjà ?
_Oui.
_Non.

V_/Quelle est ton opinion sur les produits alimentaires innovants et écologiques ?
_Très favorable.
_Favorable.
_Neutre.
_Défavorable.

VI_/Préférez _vous qu'il soit aromatisé ou nature ?
_.....

VII_/ Si aromatisé quels goûts aimeriez-vous ?
_Romarin.
_Herbes.
_Ail.
_Autres.

Figure 42:Consumer form.

VIII. Assessment of the benefits and limitations of adding spirulina in terms of taste and texture

- ✓ **Benefits**

_ Original and innovative taste : Spirulina adds a slightly herbaceous or marine flavour that can enrich the taste profile of Camembert, offering a new experience to consumers looking for something new.

_ Added nutritional value: Even if it doesn't directly affect taste, the perception of a healthier product can have a positive influence on acceptance.

Texture sometimes firmer: Depending on the quantity added, spirulina can contribute to a denser texture, which may appeal to some consumers who prefer a less creamy cheese.

- ✓ **Limits**

_ Taste that may not be to one's liking: The herbaceous or marine note of spirulina may be too strong or unusual for consumers used to the mild, traditional taste of Camembert, thus reducing its acceptance.

_ Changes in texture: The addition of spirulina may make the paste drier or grainy, which may be less appreciated by those who prefer the melting, creamy texture typical of Camembert.

_ Risks of imbalance: Too high a dose of spirulina can mask the other flavours in the cheese and upset the expected taste balance.

To sum up, the addition of spirulina adds an interesting innovative and nutritional dimension, but requires a precise balance to preserve the taste and textural characteristics that make classic Camembert so appealing.

IX. Outlook and recommendations

- ✓ **Outlook**

The introduction of Spirulina-enriched Camembert represents a real opportunity for innovation in the dairy products sector, which is traditionally anchored in classic flavours. As consumers become more and more health-conscious about the quality of ingredients and the naturalness of products, spirulina, as a superfood rich in proteins, vitamins and antioxidants, represents a strong argument for differentiation.

This innovation is also helping to broaden Camembert's target market, particularly by attracting young urbanites, organic consumers and followers of new food trends. In addition, the search for foods with a low environmental impact is boosting interest in products enriched with spirulina, a fast-growing micro-algae that requires few resources.

Finally, this product can be part of a drive to diversify cheeses, encouraging the emergence of a more varied offering on the national and international markets.

- ✓ **Recommendations**

To ensure the commercial success and taste of Camembert with spirulina, we need to focus on a number of areas:

_ Work on the formulation: It is essential to precisely adjust the quantity of spirulina to balance the flavours and avoid it dominating the traditional taste. Repeated sensory tests will help to find the best balance between innovation and consumer expectations.

_ Consumer awareness and education: highlighting the nutritional and environmental benefits of spirulina through information campaigns, tasting events and targeted marketing will help to overcome any reluctance linked to taste or appearance.

_ Attractive, self-explanatory packaging: The design of the product should reflect both the natural, healthy aspect of spirulina and the authentic character of Camembert, with clear labels (organic, local, nutritional) to reassure and attract consumers.

_Diversification of the offer: Offering several versions, with different concentrations of spirulina or combinations with other natural ingredients (herbs, spices) will make it possible to cater for a variety of tastes and test market preferences.

_ Partnerships and distribution: Working with specialist networks (organic shops, short distribution channels, delicatessens) will enable us to reach the customers who are most receptive to this type of product.

_ Monitoring and continuous innovation: Regularly gathering feedback from consumers to improve the recipe and adapt the sales strategy in line with market trends.

The addition of spirulina to Camembert represents a significant step forward in agri-food innovation. A well-defined strategy, combining flavour adjustment, consumer awareness and diversification of the offer, will be essential to ensure the product's commercial success and acceptability.

Conclusion

Conclusion

Conclusion

Spirulina, a filamentous cyanobacterium classified among microalgae, is globally acknowledged for its exceptional nutritional and functional attributes. Characterized by an impressive profile rich in complete proteins, essential amino acids, B-group vitamins (particularly B12), polyunsaturated fatty acids, minerals (such as iron, magnesium, and calcium), and antioxidant compounds like phycocyanin, Spirulina has earned recognition as a potent functional ingredient.

Within the framework of innovative dairy transformation, the incorporation of Spirulina into soft cheese production represents a novel and promising approach. This integration aims not only to enhance the nutritional density of the final product but also to align with emerging consumer trends that emphasize health, sustainability, and transparency of ingredients.The strategic introduction of spirulina during the slicing (or post-coagulation) phase ensures optimal retention of its bioactive compounds while minimizing potential disruption to microbial ecosystems critical to the cheese ripening process. The core microbiota principally lactic acid bacteria and *Penicillium camemberti* remains unaffected in terms of growth dynamics and enzymatic activity, thereby preserving Camembert's hallmark organoleptic qualities, including its creamy texture, edible bloomy rind, and subtly matured flavor profile.

Nutritionally, the presence of spirulina contributes to an enriched matrix, notably elevating levels of proteins, unsaturated lipids, pigments, and trace elements. This not only augments the functional value of the cheese but also positions it as a potential vehicle for dietary supplementation, particularly in contexts addressing malnutrition or demanding nutrient-dense options.From a sensory standpoint, Spirulina imparts a mild marine undertone and enhances umami perception effects that may either intrigue or challenge consumers depending on familiarity and cultural preferences. Its chlorophyll and phycocyanin content introduce a natural greenish hue, lending a distinctive visual identity to the cheese. While this aesthetic shift might affect product acceptability among traditional consumers, it simultaneously opens a niche for adventurous or health-oriented markets.In sum, spirulina-enriched Camembert exemplifies a successful fusion of artisanal tradition and modern nutritional science. Its development underscores the importance of multidimensional optimization encompassing formulation calibration, microbial compatibility, sensory refinement, and consumer education. Such innovation holds significant promise not only for diversifying functional dairy portfolios but also for contributing to a more sustainable, nutritious, and forward-thinking food system.

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Annexes

Annexes

Annex 1: Company Presentation

"Celia Algeria"

The dairy known under the name ONALAIT, located in Béni-Tamou, was a vast industrial complex established on an area of seven hectares, serving as a source of pride for the city of Blida. It ensured the supply of milk and high-quality dairy products throughout the region. As a multi-category site, it produced soft cheeses (camembert, brie) and processed cheese under the "Président" brand, as well as ultra-fresh dairy products under the "Lactel" brand.



Figure 43:Celia Logo.

In 2007, it was privatized and acquired by the Lactalis Group, founded in 1933 by André Besnier in France. Present in 94 countries and employing 80,000 people, it has 250 production sites in 50 countries. In 2017, Lactalis was the 3rd largest dairy processing company in the world and the 2nd in terms of turnover.

In Algeria, Lactalis also markets powdered milk under the Celia brand and specialty cheese, butter, and cream products under the "Président" brand, mainly imported from France.

"Président", an international brand present in over 150 countries worldwide, was created in 1968 by Michel Besnier, son of André, the company's founder. Originating from Normandy, the brand was launched sixty years ago by the Lactalis Group, which pioneered the industrialization of soft cheeses. The company has since extended its expertise to all aspects of dairy: from cheese to butter, and from cream to yogurt. This development was made

possible thanks to the dedication of its employees, all driven by a shared passion for the exceptional raw material that is milk.

Figure 44:The Sainte-Cécile factory, owned by the Lactalis Group (Nicolas Barreuro, 2022).



Figure 45:The Sainte-Cécile factory, owned by the Lactalis Group (Nicolas Barreuro, 2022).

Annexes

Annex 02 : Equipment used in the laboratory.

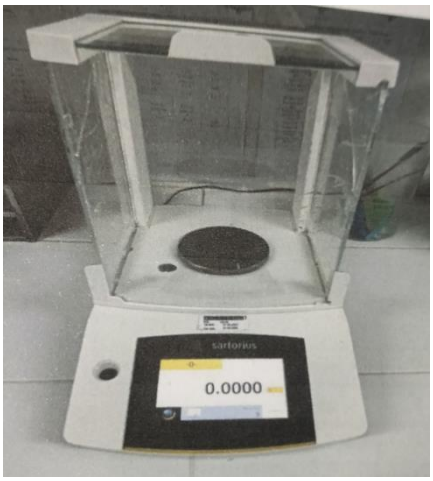


Figure 46:Analytic balanc SARTORIUS.



Figure 47:pH meters HANNA HI2210.



Figure 48:Desiccator CIR 04.



Figure 49:Cryostar I FUNKE GERBER.



Figure 50: Balanc DILU FLOW .



Figure 51:Cheese brazer(BAG MIXER) GROSSERON.

Annexes

Annex 03 :: Equipment used in thesoft cheese factory



Figure 52:Camembert mold .



Figure 53:Vertical slicer , Horizontal slicer andManual stirrer.



Figure 54:Shelf holding the Camembert pieces.

Annexes

Annex 04:Ingredients added to the milk for the fermentation and coagulation in Camembert production.

Liquids:

Calcium : 20000012432.

Rennet

starter cultures :

* G700

* LB12

* GCA

* GCD

* KL71

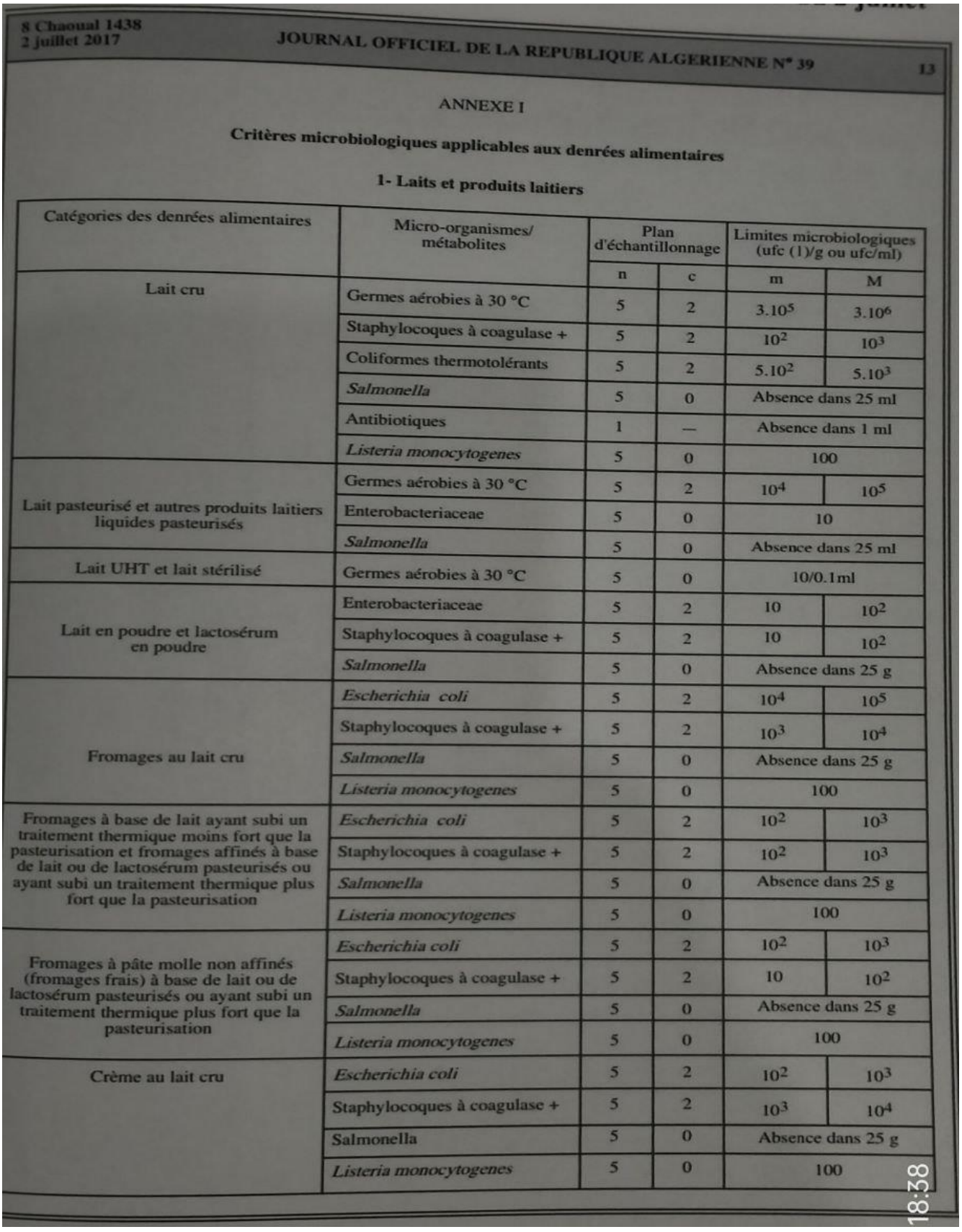
* PC12

Other ingredient

Lysozyms.

Annexes

Annex 05 :Official Journal of the Algerian Republic No. 39 of July 2nd



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13

ANNEXE I

Critères microbiologiques applicables aux denrées alimentaires

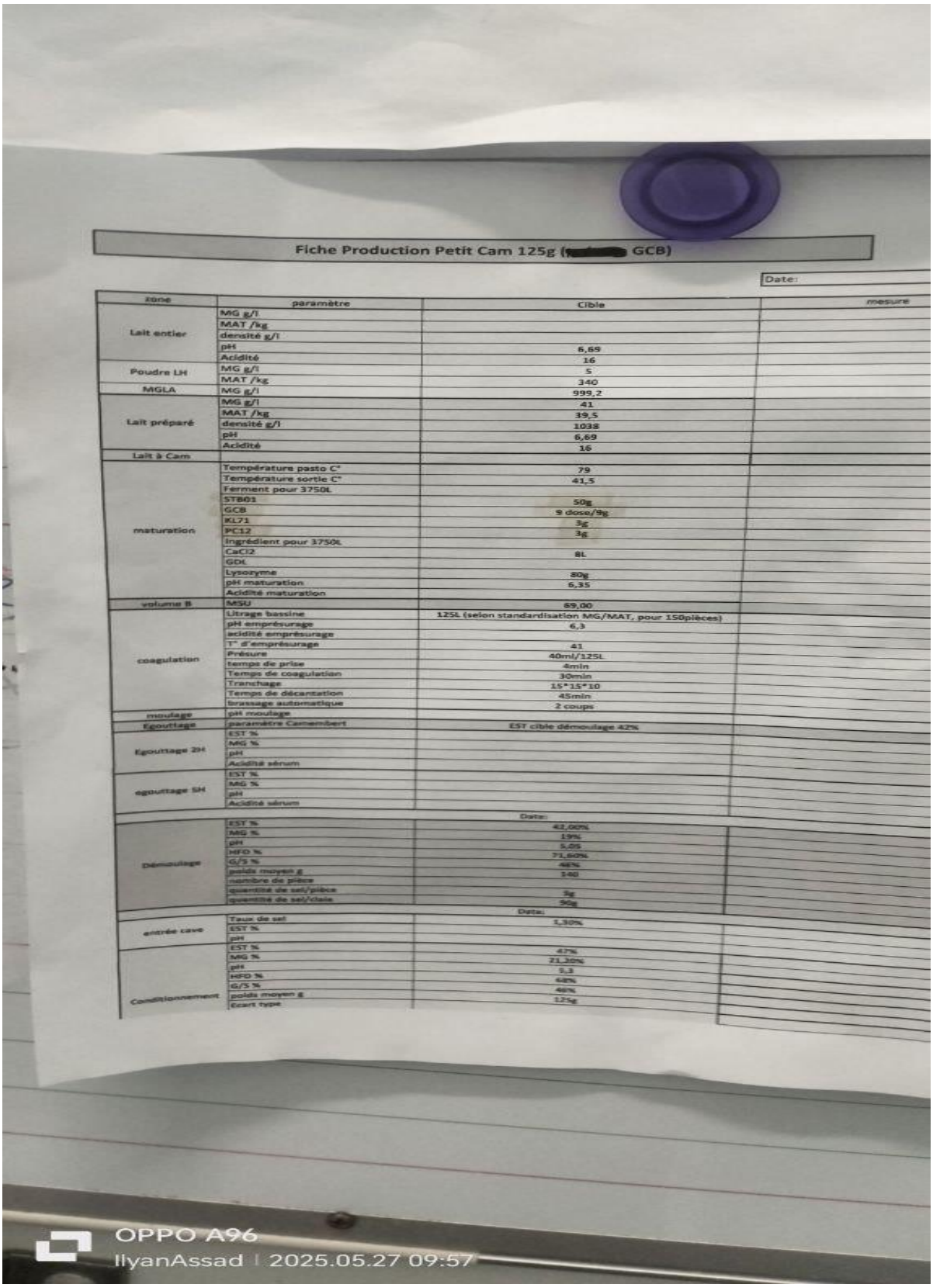
1- Laits et produits laitiers

Catégories des denrées alimentaires	Micro-organismes/ métabolites	Plan d'échantillonnage		Limites microbiologiques (ufc (1)/g ou ufc/ml)	
		n	c	m	M
Lait cru	Germes aérobies à 30 °C	5	2	3.10^5	3.10^6
	Staphylocoques à coagulase +	5	2	10^2	10^3
	Coliformes thermotolérants	5	2	5.10^2	5.10^3
	Salmonella	5	0	Absence dans 25 ml	
	Antibiotiques	1	—	Absence dans 1 ml	
	Listeria monocytogenes	5	0	100	
Lait pasteurisé et autres produits laitiers liquides pasteurisés	Germes aérobies à 30 °C	5	2	10^4	10^5
	Enterobacteriaceae	5	0	10	
	Salmonella	5	0	Absence dans 25 ml	
Lait UHT et lait stérilisé	Germes aérobies à 30 °C	5	0	10/0.1ml	
Lait en poudre et lactosérum en poudre	Enterobacteriaceae	5	2	10	10^2
	Staphylocoques à coagulase +	5	2	10	10^2
	Salmonella	5	0	Absence dans 25 g	
Fromages au lait cru	*Escherichia coli*	5	2	10^4	10^5
	Staphylocoques à coagulase +	5	2	10^3	10^4
	Salmonella	5	0	Absence dans 25 g	
	Listeria monocytogenes	5	0	100	
Fromages à base de lait ayant subi un traitement thermique moins fort que la pasteurisation et fromages affinés à base de lait ou de lactosérum pasteurisés ou ayant subi un traitement thermique plus fort que la pasteurisation	*Escherichia coli*	5	2	10^2	10^3
	Staphylocoques à coagulase +	5	2	10^2	10^3
	Salmonella	5	0	Absence dans 25 g	
	Listeria monocytogenes	5	0	100	
Fromages à pâte molle non affinés (fromages frais) à base de lait ou de lactosérum pasteurisés ou ayant subi un traitement thermique plus fort que la pasteurisation	*Escherichia coli*	5	2	10^2	10^3
	Staphylocoques à coagulase +	5	2	10	10^2
	Salmonella	5	0	Absence dans 25 g	
	Listeria monocytogenes	5	0	100	
Crème au lait cru	*Escherichia coli*	5	2	10^2	10^3
	Staphylocoques à coagulase +	5	2	10^3	10^4
	Salmonella	5	0	Absence dans 25 g	
	Listeria monocytogenes	5	0	100	

18:38

Annexes

Annex 06 :Production sheet for small Camembert 125g.



Fiche Production Petit Cam 125g ([redacted] GCB)

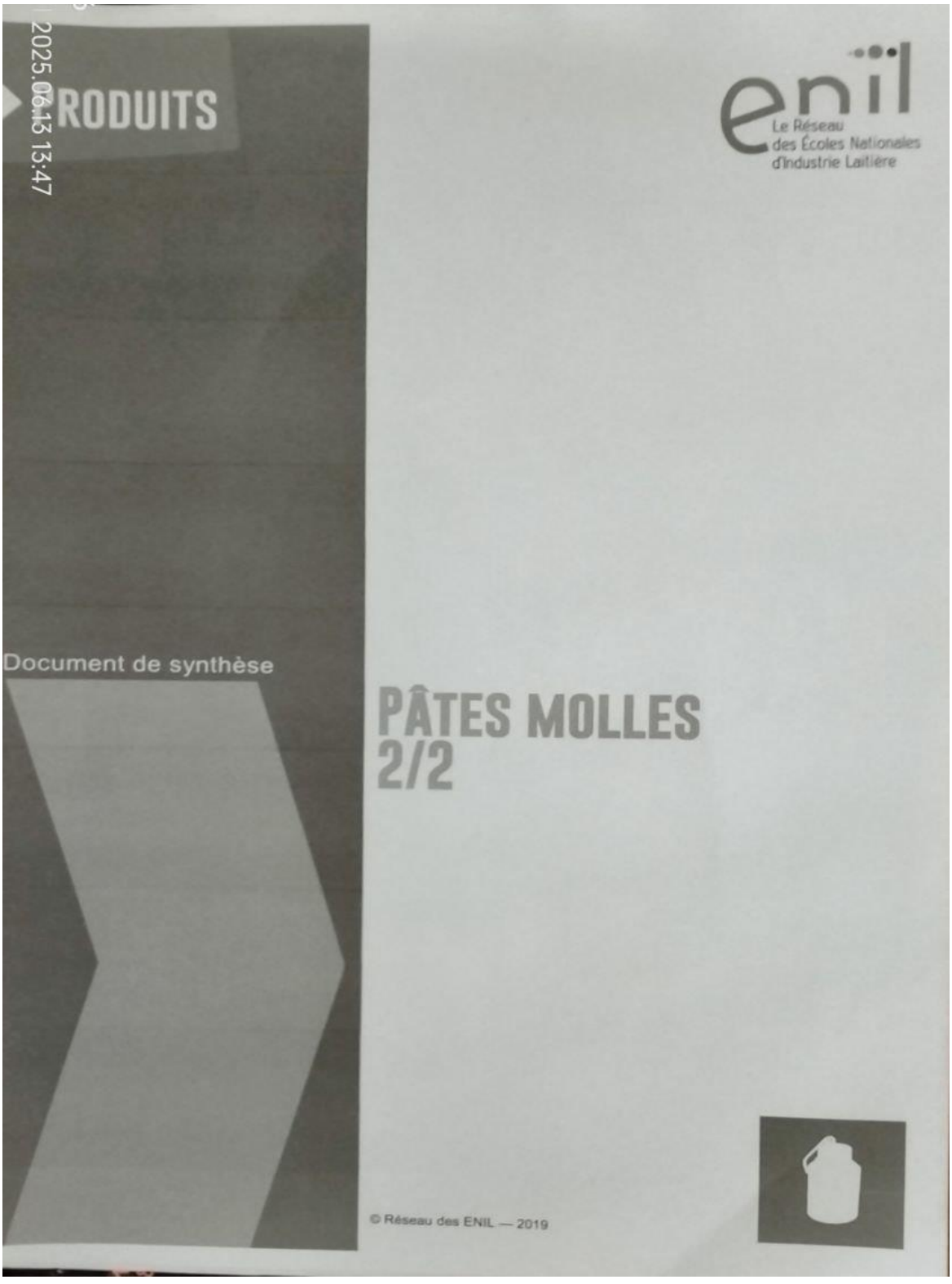
Date:

zone	paramètre	Cible	mesure
Lait entier	MG g/l		
	MAT /kg		
	densité g/l		
	pH	6,69	
	Acidité	16	
Poudre LH	MG g/l	5	
	MAT /kg	340	
MGLA	MG g/l	999,2	
Lait préparé	MG g/l	41	
	MAT /kg	39,5	
	densité g/l	1038	
	pH	6,69	
	Acidité	16	
Lait à Cam			
maturation	Température pasto C°	79	
	Température sortie C°	41,5	
	Ferment pour 3750L		
	ST801	50g	
	GCB	9 dose/9g	
	KL71	3g	
	PC12	3g	
	Ingrédient pour 3750L		
	CaCl2	8L	
	GDL		
	Lysozyme	80g	
	pH maturation	6,35	
	Acidité maturation		
volume B	MSU	69,00	
coagulation	Ultrage bassine	125L (selon standardisation MG/MAT, pour 150pièces)	
	pH emprésurage	6,3	
	acidité emprésurage		
	T° d'emprésurage	41	
	Présure	40ml/125L	
	temps de prise	8min	
	Temps de coagulation	30min	
	Tranchage	15*15*10	
	Temps de décantation	45min	
	brassage automatique	2 coups	
moulage	pH moulage		
Egouttage	paramètre Camembert	EST cible démoulage 42%	
Egouttage 2H	EST %		
	MG %		
	pH		
	Acidité sérum		
egouttage 5H	EST %		
	MG %		
	pH		
	Acidité sérum		
	Date:		
Démoulage	EST %	42,00%	
	MG %	19%	
	pH	5,05	
	HFD %	71,60%	
	G/S %	46%	
	poids moyen g	140	
	nombre de pièce		
	quantité de sel/pièce	3g	
	quantité de sel/claie	90g	
	Date:		
entrée cave	Taux de sel	1,30%	
	EST %		
	pH		
Conditionnement	EST %	47%	
	MG %	21,30%	
	pH	5,3	
	HFD %	68%	
	G/S %	46%	
	poids moyen g	125g	
	Ecart type		

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Annexes

Annex07:(Enil : le reseau des ecoles nationales d'industrie laitiére.pates molles2/2)



Annex07:Storage and tasting tips



Résumé

Ce mémoire explore la mise au point d'un fromage de type Camembert enrichi en Spiruline, une microalgue aux vertus nutritionnelles remarquables. Mené pour la première fois en Algérie, ce projet ambitieux conjugue tradition fromagère et innovation fonctionnelle en visant la création d'un aliment à haute valeur ajoutée, conforme aux exigences du référentiel ISO 22000. L'étude s'articule autour de la formulation, du suivi technique, des analyses microbiologiques, chimiques et sensorielles, et d'une comparaison avec le Camembert classique. Ce travail ouvre la voie à de nouvelles pistes d'innovation dans le domaine des produits laitiers fonctionnels à l'échelle locale et internationale.

Mots clés : Camembert, Spiruline, fromage fonctionnel, fermentation, coagulation, sécurité alimentaire, ISO 22000, algues alimentaires, analyse sensorielle, qualité nutritionnelle, innovation alimentaire, Algérie.

Abstract

This thesis investigates the development of a novel Camembert-style cheese enriched with Spirulina nutrient-dense microalga pioneered for the first time in Algeria. The project merges artisanal cheese-making techniques with functional innovation, aiming to produce a high-value, ISO 22000-compliant product. The research encompasses formulation, process monitoring, microbiological and physicochemical analyses, sensory evaluation, and a comparative study with traditional Camembert. This initiative represents a forward-thinking approach to dairy innovation with strong potential for national and international impact.

Keywords: Camembert, Spirulina, Functional cheese, Fermentation, Coagulation, Food safety, ISO 22000, Edible algae, Sensory analysis, Nutritional quality, Food innovation, Algeria.

الملخص

تتناول هذه الدراسة تصميم جبن كاممبير مدعّم بالسبيرولينا، وهي طحلب دقيق غني بالقيم الغذائية. ولأول مرة في الجزائر، يدمج المشروع بين الحرفية التقليدية لصناعة الجبن والابتكار الغذائي الحديث، بهدف إنتاج منتج عالي الجودة ومتوافق مع معيار ISO 22000. تشمل الدراسة عملية التكوين، المراقبة التقنية، التحاليل الميكروبيولوجية والفيزيوكيميائية، بالإضافة إلى التقييم الحسي والمقارنة بالجبن التقليدي. يفتح هذا الابتكار آفاقًا واسعة لتطوير منتجات ألبان وظيفية، محليًا وعالميًا.

الكلمات المفتاحية

الطحالب الغذائية، التحليل الحسي، الجودة ISO 22000 كاممبير، السبيرولينا، الجبن الوظيفي، التخمير، التخثر، السلامة الغذائية، الابتكار الغذائي، الجزائر