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Study of physicochemical, microbiological and sensory qualities of Edam cheeses enriched with Avena sativa, Lepidium sativum and Salvia hispanica seed powders

Supported on: 25/06/2024 **In front of the jury composed of :**

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A allah for my avoire gives the frorce to preserve and keep pear for my future

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Abbreviations list

- **Abs** : Absence.
- **AFNOR** : French Standardization Association.
- **APG** : Angiosperm phylogeny group.
- **°C** : Degree Celsius.
- **BP**: The middle of Baird – Parker.
- **D** : Density.
- **D°** : Dornic degree.
- **DLA** : Deoxycholate.
- **IS :** Total Dry Extract.
- **FAO:** Food and Agriculture Organization of the United Nations.
- **WIRE** : International Milk Federation.
- **H2SO4** : Sulfuric acid.
- **JC** : Jesus Christ.
- **JORA**: Official Journal of the Algerian Republic.
- **LDL** : Low density lipoprotein.
- **LFB**: Boudouaou Dairy and Cheese Factory.
- **LS** : Lepidium sativum.
- **MG** : Fat.
- **NACL** : Sodium chloride.
- **WHO** : World Health Organization.
- **ONIL** : National Interprofessional Milk Office.
- **PCA** : Plate Count Agar.
- **CFU** : Colony Forming Units.
- **VRBG** : Violet Red Bile Glucose.

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Introduction

Since ancient times, the great civilizations of China, Egypt, Babylonian, Greek and Roman, have applied the beneficial properties of plants for medical, cosmetic, chemical, dietary, pharmaceutical, agricultural and industrial purposes. Currently, plants are regaining interest in this medication. The scientific community increasingly recognizes the effectiveness of empirical prescriptions relating to medicinal plants, as evidenced by the growing number of studies and scientific experiments. Among scientific disciplines, ethnobotany is considered a science that translates popular knowledge into scientific knowledge. Therefore, food is a hybrid of "nutrition" and "pharmaceutical" (Das et al., 2016).

At a global level, nutraceuticals are foods or food components that play a crucial role in modifying and maintaining normal physiological function that maintains the health of human beings. The growth of the global nutraceuticals market is mainly due to the current population and health trends. Nutraceuticals can be classified into several categories, including dietary fiber, prebiotics, probiotics, polyunsaturated fatty acids, antioxidants, and other natural or plant-based foods. These beneficial nutrients help combat some of the most pressing health problems of the 21st century, such as obesity, cardiovascular disease, cancer, osteoporosis, arthritis, diabetes, cholesterol and many other conditions. In summary, nutraceuticals have ushered in a new era of medicine and health, in which the food industry has become a research-driven sector (Bellakhdar, 1978).

The main objective of this work is the development of a cheese enriched with medicinal plants. In this context, this work includes four chapters: the first and the second represent a bibliographic synthesis of a general description of medicinal plants: classification, chemical composition, properties and application areas.

The third chapter is devoted to the description of the equipment used and the methods used for the production of a cheese enriched with medicinal plants. The last chapter deals with the results obtained from the different analyzes carried out, with their interpretations, which will be followed by a conclusion.

Finally, this work ends with a conclusion, highlighting the implications for future research in this area. It is followed by a list of references and then the appendices.

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Part I: Literature review

Chapter I

I. Medicinal plants

A medicinal plant is defined as a plant or part of a plant that has medicinal properties through the synergistic action of its active compounds, without having harmful effects at recommended doses. It contains one or more active ingredients capable of preventing, alleviating or curing a disease. Some plants containing a wide range of active ingredients can have very different actions depending on how they are prepared (Duke, 2002).

The use of medicinal plants is ancient, with writings dating back at least a millennium. Ishâ-Ben-Amran wrote the first known texts on medicinal plants in Algeria and the Maghreb were written in the 9th century. These treatises on simple medicine and drugs represent the region’s earliest known examples of written medical knowledge (Daoudi et al., 2008).

Food seeds can be used in various forms, including powder, flour, or catabolism component. They are rich in vitamins, minerals and healthy fats. Regular consumption of these seeds gives the body all the nutrients it needs. Seeds suitable for human consumption are very versatile, with some being able to be pressed to produce oils or sprouted for human consumption. Other seeds are consumed, such as snacks, breakfast cereals, oatmeal or baked goods, or mixed into smoothies and yogurts. This chapter discusses these types of dried seeds ready for consumption, regardless of their botanical classification (Serna-Saldivar, 2010).

I.1. *Salvia hispanica*

Salvia hispanica, also known as chia, was first described by the Swedish botanist Carl Von Linnaeus in 1753. The name Salvia comes from the latin "*salvare*", meaning "to save" or "to cure", and “hispanica” refers to the Spanish origin of the plant. Thus, *Salvia hispanica* can be translated as "Spanish plant to cure or save. Chia is a plant widely grown for its edible seeds, rich in nutrients such as fatty acids, omega-3, fiber and protein (Sosa et al., 2016).

Historically, this species has been traditionally cultivated in tropical environments such as the subtropics, particularly in mountainous areas of the Pacific Ocean. It should be noted that chia is currently grown not only in Mexico and Guatemala, but also in countries such as Australia, Bolivia, Colombia, Peru and Argentina, as well as in America and Europe. Mexico plays a vital role in global chia production, with the country recognized as the world's leading plant producer (Abdelhalim and Hanrahan, 2021).

This species is traditionally grown in tropical environments, particularly in the subtropical regions of the mountainous regions of the Pacific. Chia seeds are believed to have been a Mayans staple food since around 2,500 BC, along with corn, amaranth and beans. The term "seed of the gods" is said to come from Nahuatl, an indigenous language of Mexico, while the word "chia" comes from the Spanish "chain," meaning "oily" (Ullah et al., 2016).

I.1.1. Description

Salvia hispanica L. (chia) is an annual herb of the *Lamiaceae* family. It has a height of 1 to 1.5 m, branched stems quadrangular and hollow, leaves opposite to sawn edges, 80 to 100 mm long and 40 to 60 mm wide, with leaves opposite to sawn edges (Abdelhalim and Hanrahan, 2021).

Figure 01: Plants of *Salvia hispanica* (Chia) in bloom (Orona-Tamayo et al., 2017)

S. hispanica L. has hermaphrodite flowers (Figure 01), which can be purple, blue or white. They are generally fruity and are formed in branches of four oval monosperm nails 1.5 to 2 mm long and 1 to 1.2 mm in diameter (López et al., 2017). The seed is soft, shiny, and brownish-gray with dark brown spots. It can be white, small and light, which reduces its weight. Seeds of 1000 can range in size from 0.94 to 1.29 g (Busilacchi et al., 2013).

Salvia hispanica seeds (Figure 02) are usually very small, tiny, oval, measuring 2 mm long and 1 mm wide. The surface of the seed is smooth and shiny, and its color varies from black, gray or spotted black to white (Kulczynski et al., 2019).

Figure 02: Grains of *Salvia hispanica* (Chia) by different colors (Valdivia-López and Tecante, 2015).

I.1.2. Classification

The chia plant belongs to the Lamiaceae family. Its classification is as follows (Hernandez, 2012):

- **Reign:** Plantae
- **Sub-reign**: Tracheobionta (vascular plants)
- **Division:** Magnoliophyta (flowering plants)
- **Class :** Magnoliopsida
- **Subclass**: Asteridae
- **The order**: Lamiales
- **Family**: Lamiaceae (mint family)
- **Gender :** Salvia
- **Species**: *Salvia hispanica* L

I.1.3. Chemical compositions

Chia seeds contain a lot of linoleic acids, linolenic and omega-6. They are essential polyunsaturated fatty acids that cannot be synthesized by the human body and must be consumed. It is therefore recommended that seeds be included in animal and human diets. Seeds are composed of a number of different components, including proteins (Table 01), fatty acids, carbohydrates, dietary fiber, ash, minerals, vitamins and dry matter (Kulczyński et al., 2019).

Table 01: Composition of chia seeds (Kulczyński et al., 2019).

Elements	Concentration
Proteins	15-25%
Fatty acids	30-33%
Carbohydrates	26-41%
Dietary fiber	18-30%
Ash	4-5%
Minerals, vitamins and dry matter	90-93%

Additionally, chia seeds contain a high concentration of antioxidants. The oil extracted from chia seeds contains various fatty acids, including: -linolenic acid (C18:3), linoleic acid, oleic acid, palmitic acid and stearic acid. About 60% of the fatty acids in total oil are -linolenic acids. The seeds are rich in dietary fiber, protein, minerals and polyphenolic compounds (Ixtaina et al., 2008).

I.1.4. Application areas of *Salvia hispanica*

The Aztecs used chia as a food source, combining it with water to create a beverage, grinding it into flour, incorporating it into medicinal preparations, feeding it to birds, pressing it for oil, using it as a base for face and body paints, and as a protective agent. Religious statues and paintings from the elements, and as fighters going to war and women in childbirth, have all benefited from the revitalizing properties of chia seeds and flour. These seeds and flour could be stored for several years and were considered very energetic, making them an essential food during military exercises (Valdivia-López and Tecante, 2015).

I.1.4.1. Food and Nutrition

Super Food: Chia seeds are considered a superfood because they are wealthy in omega-3, fiber, protein, vitamins and minerals (Table 02).

Versatile Ingredient: They are suitable for baked goods, salads, yogurts, smoothies and the natural thickening of sauces and desserts.

Food for animals : They are nutritious for birds and can be used in animal feed.

Gluten-free: Chia seeds are an excellent option for people following a gluten-free diet (Ulbricht et al., 2009).

Table 02 : Nutritional values of *Salvia hispnaica* seeds (Kulczyński et al., 2019).

Value per 100 grams			
Calories	48	Sodium	16 mg
Lipids	31 g	Potassium	407 mg
Saturated fatty acids	3.3 g	Carbohydrates	42 g
Trans fatty acids	0.1 g	Dietary fiber	34 g
Cholesterol	0 mg	Protein	17 g
Vitamin C	1.6 mg	Vitamin B_{12}	0 mg
Calcium	631 mg	Magnesium	335 mg
Iron	7.7 mg		

I.1.4.2. Health and wellbeing

Disease prevention: Due to their high concentration of antioxidants, they help reduce oxidative stress and can help prevent chronic diseases.

Cardiovascular health: is favored by the omega-3 fatty acids in chia seeds (Nieman et al., 2009).

***Weight control*:** They are also favored by their ability to absorb water and create a gel, which can promote feelings of fullness and weight control (Vuksan et al., 2010).

I.1.4.3. Agriculture

Cultivable in Various Climates*:* Varieties of chia have been developed for cultivation in different latitudes, including Europe.

Sustainable agriculture**:** In France, for example, chia is grown using sustainable farming methods or organic farming (Baginsky et al., 2016).

I.1.4.4. Cosmetics and Personal Care

Salvia hispanica are rich in antioxidants, vitamins, essential fatty acids and minerals, chia seeds are faithful ally for beauty. They moisturize, protect and strengthen the skin and hair (Figure 03). They are also effective in stimulating skin growth, making skin more radiant, hydrating skin, reducing redness and inflammation, and reducing scarring.

Chia seed gel, obtained by soaking the seeds in water, can be used in many beauty treatments. Additionally, chia seeds can be eaten directly or incorporated into various foods to reap their nutritional benefits. They are a rich source of protein, dietary fiber, essential vitamins and minerals (Baghban et al., 2023).

Figure 03: Example of cosmetic products based on *Salvia hispanica* (Anonyme 1).

I.1.4.5. Industry

Due to their dietary fiber content, chia seeds are used as a raw material in the food industry. By processing chia seeds with water, one can extract the gum from the seeds' dietary fiber and use it as an additive to regulate the viscosity, stability, texture and consistency of food systems.

Chia seed gel is used in food products to replace animal fats. Rheometer measurements revealed that the replacement resulted in a softer texture of the dough, which decreased its storage and loss modulus values. Nowadays, we are increasingly using chia seeds in dairy products. Chia mucilage is used as a thickener in ice cream, while the olein portion of chia oil increases the omega-3 fatty acid content of ice cream, without having harmful effects to a certain extent (Ullah et al., 2016).

Eco-friendly material: Chia fibers can be used to manufacture biodegradable composite materials.

These application areas show the versatility of chia seeds and their growing importance in various sectors, ranging from food and agriculture to healthcare and industry.

I.2. *Lepidium sativum*

Garden cress, or *Lepidium sativum*, is an annual, edible herbaceous plant in the Brassicaceae family. The plant is currently used in a multitude of popular medical treatments. Its exact origin is uncertain, as it is grown worldwide, but it is believed to be native to Northeast Africa and Southeast Asia (Prasad et al., 2012). *Lepidium sativum* (L. sativum) is also called garden cress, peppergrass, Chandra sur or Hab. El-Rachad in certain regions. There are 3709 species, part of 338 genera (Al-Shehbaz et al., 2006).

L. sativum is one of the most represented genera in this family, commonly known as Egyptian watercress, but it is now cultivated throughout the world. Its peculiarity lies in its ability to grow in all climates and soils, as well as its ability to tolerate slight acidity. Additionally, it is a perennial plant and an indispensable green vegetable, often consumed by human beings, mainly as a garnish or leafy vegetable. Garden cress proliferates, reaching 20 to 50 cm when flowering. Well-cut and tender leaves, with a very pronounced taste (Assad Ahmad, et al 2020).

I.2.1. Description

The *L. sativum* plant is herbaceous, erect, and glaucous (Figure 04). It has a glabrous stem, is very finely striated, and it is abundantly branched. It can reach a height of 50 to 80 cm. The leaves of *L. sativum* are alternate, irregularly pinnate, about 12 cm long, 9 cm wide, and the petiole is 4 cm long; the leaflets (5-11), oval or obovate, pinnate, are generally irregular. The teeth are lightly hairy above and glabrous below, and the upper leaves gradually become linear. The upper leaves are generally simple and linear, sometimes lobed or toothed. The basal leaves have long petioles and the pinnate leaves are lanceolate (Saxena et al., 2015).

Figure 04: *Lepidium sativum* plant (Anonyme 2).

The fruit looks like a small flat capsule, round or oval, measuring between 4 to 6 mm long and 3 to 5.5 mm wide. Its color varies from pale green to yellowish, and its edges are decorated with tiny wings. It opens in two parts, usually releasing two or three tiny seeds (Manohar et al., 2012).

The tiny seeds of *L. sativum* are intriguing with their oval, pointed, triangular shape, with a smooth end. They are approximately 3-4 mm long and 1-2 mm wide, displaying a reddish-brown hue. A mysterious furrow runs across both surfaces, stretching downward, while a thin wing appears to extend over the edges of the seed. Immersed in water, the seed transforms into an enigmatic transparent envelope, covered with invisible mucilage with a mucilaginous taste (Prajapati et al., 2014).

Figure 05: *Lepidum sativm* seeds (Eberhard et al., 2005).

I.2.2. Classification

According to classification Angiosperm Phylogeny Group, *Lepidum sativm is* (APG III, 2009):

- **Reign:** Plantae plants
- **Sub-kingdom:**Tracheobionta Vascular plants
- **Supervision:** Spermatophyta Spermatophytes
- **Division:** Magnoliophyta Angiosperms
- **Class :** Magnoliopsida Dicotyledones
- **Subclass:** Dilleniidae
- **Order:** Capparales
- **Family :** Brassicaceae Mustard family
- **Gender :** Lepidium Pepper Herbs
- **Species:** *Lepidium Sativum* Flax (George, 1959).

I.2.3. Chemical composition

Garden cress is this mysterious and intriguing little plant that hides within it a multitude of essential nutrients for our well-being. Imagine, it is full of flavonoids, carotenoids, lutein and zooxanthin, as well as these precious B group vitamins (B2, B6, B9), vitamin A, vitamin C, vitamin K, without forgetting all these minerals such as copper, iron, magnesium, phosphorus and potassium. Ah, but that is not all, because this rare plant is also one of the rare ones to contain a good dose of iodine, which makes it even more fascinating and mysterious. Moreover, *Lepidium sativum*, the watercress, with its stems and leaves full of these glucosinolates, in particular Glucotropaeolin (Benzyl Glucosinolate) and its essential oil, so precious, steam distilled (Divanji et al., 2012).

The seeds, on the other hand, are small, smooth and reddish in color. They provide almost 25% of a semi-drying yellowish-brown oil, with has a peculiar and unpleasant odor. This oil is rich in oleic, linoleic and uric acids and it also contains imidazole alkaloids. In addition, the seed coat of the germinated seed contains a lot of mucilage, which contains an allelopathic substance called lipidimoid (Tokuma Getahun et al., 2020).

Interestingly, the composition of watercress seeds varies depending on several factors, including agronomic practices, the stage of seed harvesting and the climatic and geological conditions of the harvesting area (Gokavi et al., 2004). The approximate composition of Lepidium sativum (LS) seeds indicates the presence of significant quantities of different nutrients (Table 03).

Table 03: Approximate composition of Lepidium sativum seeds (Tokuma Getahun et al.,2020).

Elements	Concentration
Proteins	24.2%
Lipids	23.2%
Carbohydrates	30.7%
Dietary fiber	11.9%
Ash	7.1%
Humidity	2.9%

I.2.4. Application domain

In many Arab and Asian countries, this plant is used as a dietary supplement and as a treatment for diabetes, traumatic injuries, hepatitis, hypertension and kidney disease.

The plant's seeds possess several pharmacological properties, including antioxidant, anti-inflammatory, cardioprotective and hepatoprotective effects against liver injury and oxidative damage. They also have cryoprotective effects on the liver and pancreas in cases of diabetic disease, as well as an antidiabetic effect by reducing hyperglycemia and hyperlipidemia. Their composition of phenolic compounds, terpenoids, alkaloids, flavonoids and phytosterols explains their phytotherapeutic properties. Therefore, seeds represent an important area of current scientific investigation (Al-Yahya et al., 1994).

I.2.4.1. Medicinal applications

Lepidium sativum, commonly called garden cress, has exciting health properties. First, this plant contains bioactive compounds with antioxidant and anti-inflammatory properties. These properties could prove beneficial in the preventing and treating of inflammatory pathologies and those linked to oxidative stress. Furthermore, studies carried out on animal models have highlighted the hypoglycemic effects of garden cress extracts, suggesting potential in managing of diabetes. Finally, numerous studies have confirmed the antimicrobial properties of this plant against various pathogens. This opens promising perspectives for developming new agents (Farooq et al., 2013).

I.2.4.2. Nutritional applications

Watercress is remarkably rich in nutrients. This plant is full of vitamins, including vitamins A, C and K, and essential minerals like calcium, iron and magnesium. It is also an excellent source of dietary fiber. This complete nutritional contribution makes garden cress a most beneficial food supplement for improving the quality of the diet and maintaining good general health. In addition, the seeds of this plant contain significant levels of vegetable proteins and essential fatty acids. This particularity enhances garden cress as an ideal dietary supplement for people following a vegetarian or vegan diet (Gupta et al., 2010).

I.2.4.3. Agricultural applications

Beyond its nutritional and medicinal virtues, garden cress also has a certain interest in the agricultural field. This plant can in fact be used as green manure, benefiting the structure and fertility of the soil (Soliman et al., 2015).

Thanks to its ability to fix certain nutrients and fight against erosion, Lepidium sativum constitutes a most advantageous cover plant for improving cultivated land. Furthermore, certain bioactive compounds extracted from this plant have revealed promising insecticidal properties. This discovery opens interesting perspectives for the exploitation of garden cress as a natural biopesticide in the biological fight against various species harmful to agricultural crops (Nath et al., 2016).

I.2.4.4. Cosmetic applications

Skincare: Thanks to its antioxidant and moisturizing properties, *Lepidium sativum* is used in the formulation of cosmetic products intended to protect the skin (Figure 06) against damage caused by free radicals and to improve skin hydration (Barretto et al., 2014).

Figure 06: Moisturizing cream based on *Lepidium sativum* (Anonyme 3).

I.3. *Avena sativa*

Cultivated oats, whose scientific name is *Avena sativa*, are a grain with a fascinating history. Its Latin name, *Avena sativa*, comes from "Avea" in Greek, which means "to desire". This plant is frequently referred to as common oats or simply oats (Jansen, 2007).

Oats are native to northeastern Europe (Austria and Russia) and the highlands of Ethiopia and China. They are wild plants found in many different habitats. Oats are often used as a staple food in many cultures, whether for human consumption, animal fodder, or even in personal care products such as bath products. This plant also has health benefits, especially due to its fiber and nutrient content (Drouet, 2002).

Oats are an annual plant that forms a relatively clustered root system. Influential in the first 10 cm of the soil, its length varies between 50 and 200 cm, which is visible due to the adventitious roots at the level of the nodes (Salgado, 2008; Alain, 2009).

Since at least the 16th century, herbalists have used oats to treat a range of health problems, including fatigue, nervous disorders, depression, insomnia, rheumatism, scabies and leprosy. Oats have been used in the form of infusion tablets to stimulate the appetite and relieve sore throats and chest pains. Additionally, oat grains and bran have been shown to prevent coronary heart and cardiovascular disease. Whole oats have been shown to reduce blood sugar levels and contain an anti-tumor compound, beta-sitosterol. (Murphy and Hoffman, 1992).

I.3.1. Description

Oats (*Avena sativa* L.) are a cultivated annual herbaceous plant, sometimes called "common oats", "Byzantine oats" or simply "oats". They are a monocotyledonous plant in the family *Poaceae* (grasses), subfamily *Pooideae*. They are an annual plant with a profusion of fasciculated roots in the upper 10 cm of the soil (Figure 07). The adventitious roots can develop at the level of the nodes, on straws 80 to 150 cm high, in a simple way or by branching at the base, and they can also develop a significant tillering. They are a monocotyledonous plant with a cylindrical stem, which can reach 25 to 150 cm height (tela-botanica.org, 2013).

An oat plant comprises several stems, the largest of which are characterized by panicles. Seven or eight sheets can be inserted on as many nodes. The term “thatch” is reserved for stiff, erect, spindly, unbranched, and hollow stems, except for nodes. The leaves of a culm are aligned in two rows. The leaves are glabrous, long and tapered, measuring between 2 and 10 mm wide. They wrap around the stems, with a white ligule measuring 2 and 5 mm long. There are no earbuds at the insertion point on the stem (tela-botan3ica.org, 2013).

Figure 07: *Avena sativa* plant (Anonyme 2).

The flowers are hermaphroditic, meaning they have both male and female reproductive organs. They are self-pollinated by the wind. The fertile flowers are arranged in spikelets of two to three, measuring 20 to 25 mm long. They are surrounded by their upper and lower glumes, which are initially partially hidden by the upper and lower glumes of the inflorescence. The latter appears as loose panicles, measuring 8 to 30 cm long (tela-botan3ica.org, 2013).

The structure of the oat grain is characterized by a coated caryopsis enveloped in non-adherent lumps (Figure 08), with an indurated Emma tightly adhering to the grain (tela-botan3ica.org, 2013).

Figure 08: *Avena sativa* seeds (Anonyme 4).

I.3.2. Classification

Oats are a monocotyledonous herbaceous annual plant (Feillet, 2006):

- **Reign:** Plantae
- **Sub-kingdom:** Tracheobiona
- **Division :**Magnoliopha
- **Class**: Liliopsida
- **Subclass:** Commelinide
- **Order**: Cyperales
- **Family :**Poaceae
- **Subfamily :** Pooideae
- **Tribe:** Aveneae
- **Gender :** Avena
- **Species:** *Avena sativa*

I.3.3. Chemical composition

The oat plant is rich in nutrients (Table 04), essential and beneficial to nutrition.

Table 04: Chemical composition of oat grain (Sánchez et al., 2020).

Component	Average value%	Interval%
Starch	51.1	44-61
Proteins	15.2	11-20
Humidity	10.0	9-14
Fibers	8.9	7-11
Lipids	7.6	5-10
B-Glucan	4.2	2.2-6.6
Free Sugars	1,1	0.9-1.3

Among the main constituents of Avena sativa, we can cite:

- **The proteins**: The oat grain contains four main proteins: albumin, globulin, prolamin and glutelin. These proteins differ from those of other cereals in terms of concentration (Singh et al., 2013).
- ***Albumin***: It is one of the primary storage proteins in oats. It contains many essential amino acids for the human body, particularly lysine.
- ***Globulin***: It is also an important storage protein in oats, in terms of amino acid composition, it is similar to albumin.
- ***Glutin***: Another protein found in oats (Singh et al., 2013).
- **Lipids :** in oats play a crucial role in the composition and properties of the seeds. They are mainly stored in the endosperm, the interior part of the grain, and are distinguished by their high content of unsaturated fatty acids, generally representing more than 80% of total lipids. The high proportion of unsaturated fatty acids in oat lipids is beneficial to health, as these fatty acids are associated with reducing blood cholesterol and preventing cardiovascular diseases. In addition, they contribute to the stability and longevity of the oat grain, avoiding the rancidity of lipids, which is particularly important for preserving oat-based products. In addition to their role in the flavor and texture of the oat grain, lipids are also essential for its nutritional qualities. They provide an important energy source, as fat is one of the primary sources of calories in the diet. Additionally, unsaturated fatty acids are considered "good" fats for health because they are associated with better cardiovascular health and other health benefits (Zhou et al., 1999).

Oats are particularly rich in unsaturated fatty acids, notably oleic acid (C 18:1) and linoleic acid (C 18:2), representing approximately 40% and 36% of the total oil content, respectively. Higher levels of unsaturated fatty acids and lower levels of saturated fats may help reduce the risk of heart and vascular diseases. It is also thought that the high oil and fiber content may help induce a long-lasting feeling of fullness, which could be beneficial in terms of weight loss (Halima et al., 2015).

- **Fibers:** in oats are mainly made up of non-starchy polysaccharides, among which a component specific to oats called β-glucan stands out. β-Glucans are non-starchy polysaccharides consisting of glucoses linked by β(1–3)-(1–4) bonds. These specific bonds give β-glucans their unique properties. β-glucans are mainly present in the endosperm and aleurone cell walls of oats. This location makes them accessible when consuming oat-based products.

β-Glucans have been widely studied for their numerous health benefits. They are known for their ability to lower blood cholesterol levels, especially bad LDL cholesterol, which reduces the risk of cardiovascular disease. Additionally, β-glucans contribute to blood sugar regulation, making them essential in diabetes management and weight control. They also have prebiotic properties, promoting the growth of good bacteria in the intestinal microbiota (Clemens and Van Klinken, 2014).

I.3.4. Application areas

Avena sativa, or cultivated oats, appears to be a true superstar in herbal medicine, with an impressive range of health benefits. Here is a summary of its multiple applications:

I.3.4.1. Therapeutic applications

Nervous fortifier: Its beneficial action on the nervous system makes it a valuable ally against fatigue and certain nervous disorders (Figure 09), thus offering natural support.

Figure 09: Food supplement based on "Arkopharma" oats (Anonyme 1)

Arkopharma: Organic Avena sativa is a food supplement, thanks to its relaxing and soothing properties, it contributes to rest and relaxation, especially during periods of sustained activity. It also helps improve the quality of sleep (McKevith, 2004).

Hypocholesterolemic: The ability of oats to reduce cholesterol levels, particularly the LDL fraction, makes them an interesting choice for those looking to maintain their cardiovascular health (Baumann, 2007).

Blood sugar stabilization: Maintaining stable blood sugar levels, can benefit for people with diabetes or those seeking to regulate their blood sugar (Bao al., 2014).

I.3.4.2. Human Food

Indeed, oats are a very versatile and nutritious food, offering many benefits for human health such as:

Fibers: The fiber in oats has beneficial properties for digestive health, promoting regular intestinal flow and helping to prevent constipation. Additionally, fiber may contribute to feelings of fullness, which may be helpful in weight management (Jenkins et al., 1999).

Vitamins and minerals: Oats contain several essential vitamins and minerals, such as vitamin B1 (thiamine), vitamin B5 (pantothenic acid), iron, magnesium and zinc. These nutrients are vital in many bodily functions, such as energy production, bone health, and immune function (McKevith, 2004). Oats can be consumed differently, (Figure 10) making them easy to incorporate into the daily diet (Baumann, 2007).

Figure 10: Different forms of oats to consume (Anonyme 3)

I.3.4.3. Cosmetic field

Oat-based cosmetic products offer a gentle and natural approach to skin care, providing soothing, hydrating and nourishing benefits. Here are some common ways oats are used in the cosmetic industry

Moisturizers: Oatmeal is often added to moisturizers for its soothing and hydrating properties. It helps maintain skin hydration and relieve dry and irritated skin. This moisturizer's revolutionary formula (Figure 11) combines a triple oat complex, ceramides and rich emollients. It aims above all to restore and preserve the skin's moisture barrier. Additionally, it is fragrance-free and non-comedogenic. Clinically proven, this moisturizer effectively relieves ultra-dry skin (Reynertson et al., 2015).

Figure 11: Moisturizing cream (aveenoo) made from oats (Anonyme 5).

Chapter II

II. General information about cheese

More than 1000 varieties of cheese are produced on an artisanal and industrial scale around the world. This diversity reflects the richness of cheese traditions and different terroirs, and the varied manufacturing techniques (Irlinger and Mounier, 2009). Cheese production is based on two fundamental elements: milk and ferments. Milk plays an essential role in the production of cheese. The characteristics of the final cheese are greatly influenced by the quality and type of milk used (Mahaut et al., 2000).

Research in the field of cheese manufacturing is dynamic. It has several objectives, including the creation of cheeses with organoleptic (taste, texture, aroma) and nutritional characteristics similar to those of traditional cheeses or even new and improved characteristics (Daoudi, 2006).

Cheese, in particular, is recognized for its high nutritional value, providing an important source of high-quality protein, lipids, vitamins and minerals. Recent studies have shown that cheese can play a beneficial role in a balanced diet. It is thought that cheese may contribute to bone health thanks to its calcium and vitamin D content. Some types of cheese contain probiotics which may support good digestive health. It would be interesting to continue research in this area to optimize production methods and maximize the nutritional benefits of cheese (Walther et al., 2008).

II.1. Definition of cheese

Cheese is a traditional food product made from coagulated milk. This coagulation is usually achieved by adding an enzyme called rennet, which acts on milk proteins to form a solid gel. Once coagulated, the gel is pressed and refined to produce cheese (Fox, 2017).

Cheese has a coagulation process that can be initiated by enzymatic agents, such as rennet, or by acids, this process is followed by separation of the whey (the aqueous phase) to obtain the desired consistency. The diversity of cheeses available reflects variations in raw materials used, coagulation methods and maturing techniques. Each cheese has unique sensory properties and a specific nutritional profile contributing to the rich variety of cheeses we enjoy today (Jeantet et al., 2007).

II.2. Composition and nutritional value of cheeses

Cheeses are known to be rich in notional elements such as:

II.2.1. The proteins

Cheeses are among the richest foods in protein, with a content generally between 10 and 30%. Pressed cheeses, in particular, are known for their high protein content, sometimes up to 30%. This characteristic makes it an essential source of protein in the diet, even exceeding the protein content of meat, around 20%. The process of making pressed cheeses helps to concentrate milk proteins, which explains their high protein content. This concentration is achieved by partially removing whey during manufacturing, leaving more protein in the final product (Renane et al., 2010).

II.2.2. Lipids

The degree of the creaminess of the cheese paste is determined by the composition of the lipids. During the maturation process, lipolysis occurs as a result of microbial lipase activity; lipids play an essential role in the texture and flavor of the cheese. They contribute to the smoothness of the dough and influence the sensory perception of the final product. During the cheese maturation process, lipids undergo lipolysis under the action of lipase enzymes of microbial origin. This lipolysis is generally limited, but it results in the formation of free fatty acids (Mahaut et al., 2003).

II.2.3. The minerals

Cheese is a rich source of minerals, the most abundant of which are iron, calcium and phosphorus. In fact, 100 grams of hard cheese can cover up to 50% of an adult's daily phosphorus needs (Tsuchita et al., 2001).

Calcium and phosphorus: Cheeses are an important source of calcium. The calcium content of cheeses varies considerably, from less than 100 mg per 100 g in fresh cheeses to more than 1,200 mg in some hard cheeses (e.g. Emmental and Parmesan), in a ratio of 1 to 15. Phosphorus contents are generally aligned with calcium contents, with a Ca/P ratio of approximately 1.3.

Sodium and potassium: The considerable variability in sodium content observed in cheeses (from 200 to 1000 mg/100 g) is a direct consequence of the salting process. In contrast, potassium levels have a much narrower range of variation, with values generally falling within a range of 100 to 200 mg/100 g (Gueguen, 1997).

II.3. Classification of cheeses

Cheeses are classified according to several criteria, here is a classification of cheeses based on their technology and their rind (Figure 12):

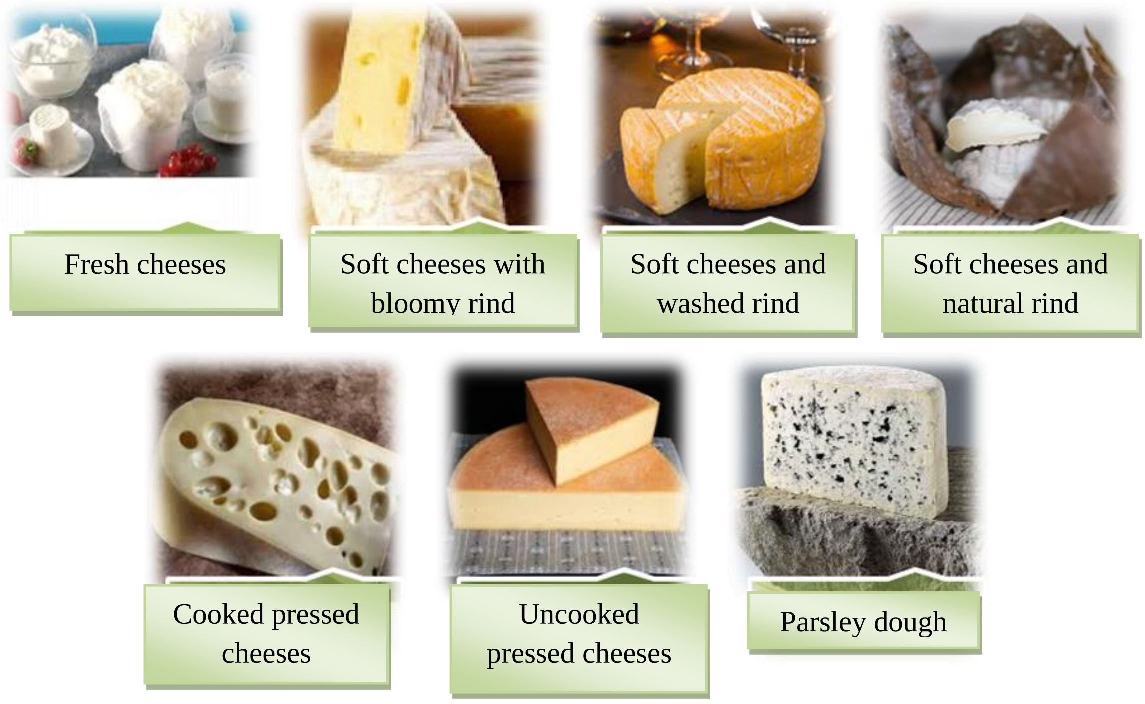

Figure 12: Different types of cheese (Mamenia et al., 2014).

a. Fresh cheeses

These products are distinguished by lactic fermentation, followed by light draining, without undergoing additional maturation. They are white in color and soft in texture, with a fresh taste (Katz and Weaver, 2003).

b. Soft cheeses with bloomy rind

The rind of this type of cheese is covered with mold, notably *Penicillium*, which gives it a white fluffy appearance like Brie and Camembert (Djaballah et al, 2022).

c. Soft cheeses and washed rind

They have an orange, sticky rind, and they can be rubbed with water, brine, alcohol or a combination of these to encourage the growth of bacteria and mold like Munster and Epoisse (Katz and Weaver, 2003).

d. Soft cheeses and natural rind

The rind of this type of cheese is covered in mold, particularly Penicillium, which gives it a fluffy white appearance, similar to that of Brie and Camembert. (Katz and Weaver, 2003).

e. Uncooked pressed cheeses

Uncooked pressed cheeses are a category that undergo a specific manufacturing process. They are pressed to remove the whey but not cooked such as Cantal and Morbier (Mahaut et al., 2002).

f. Cooked pressed cheeses

The curd has undergone heating greater than or equal to 50°C at the time of slicing. Examples include Emmental and Gruyère (Mahaut et al., 2002).

g. "Blue" or blue cheese

The cheese is matured and has a slightly salty paste with blue-green to white-gray internal molds. Some varieties, such as Roquefort, can be covered with aluminum foil to prevent a crust from forming. (Mahaut et al., 2002).

II.4. Edam type cheese

II.4.1. Historical

The history of Edam cheese dates back to the 14th century, when it originated from the small town of Edam in the Netherlands. At this time, the city became an important center for the trade in dairy products, notably thanks to its active port. Characterized by its spherical shape and its red wax coating, Edam cheese is appreciated for its good aging and shelf life, making it an excellent product for sea voyages (Jõudu et al., 2017).

Recent scientific research has explored the rheological and microbiological properties of Edam cheese. For example, studies of the viscoelastic properties of Edam showed that the cheese's properties changed significantly during the first weeks before stabilization). Furthermore, another study using next-generation sequencing analyzed the microbiome of Edam cheese, revealing that the microbial community changes with the seasons, which affects the quality and sensory characteristics of the final product (Nalepa et al., 2020).

II.4.2. Definition of Edam cheese

Edam cheese is a semi-hard cheese made from pasteurized milk and originating from the Netherlands, more precisely from the town of Edam. Traditionally, the cheese is molded into 1.7-to-2.5-kilogram spheres and covered with a layer of red wax to distinguish it (Figure 13). Edam is characterized by its firm texture and sweet, slightly nutty flavor. It is obtained by coagulation of milk, pressing of the curds, brine and maturation for at least four weeks (Haddad et al., 2021).

Figure 13: Edam cheese (Anonyme 6).

II.4.3. Nutritional value of Edam

Edam cheese stands out for its high nutritional value. This comes first from its rich content of superior quality proteins, composed of well-balanced essential amino acids. In addition, its composition rich in minerals and vitamins gives it all the advantages of a very nourishing cheese. Classified among fatty cheeses, with 45% fat, Edam also owes its characteristic taste and aroma to the presence of volatile fatty acids (C2 to C8) in these fats. Thus, this cheese combines high nutritional value and unique flavors thanks to the richness of its composition (McSweeney and Sousa, 2000).

II.4.4. General characteristics of Edam cheese

Edam cheese is a Dutch pressed cheese, characterized by its round shape and red wax coating. Made from pasteurized cow's milk, it has a firm, smooth texture and a mild flavor with nutty elements. Due to its great versatility in cooking, it is very popular in many dishes, whether eaten alone, melted in hot preparations or on a cheese platter (El-Galeel et al., 2017). The main characteristics of Edam cheese are grouped in table 05 (Bentorki et al, 2021).

Table 05 : Different characteristics of Edam cheese

Cheese ready for consumption	The crust	Dough	The holes
A semi-hard consistency.	A hard consistency	A firm texture that is easy to cut.	Few holes distributed regularly in the cheese mass.
In spherical form, slightly flattened at the lower or upper parts or in the form of a flat block of square or rectangular section.	A dry appearance and often coated with paraffin, plastic wax or a vegetable oil film, these coatings are yellow or red.	A yellowish color.	A more or less round shape.
Weight of 1.7-2. 5Kg for the spherical shape and 5 Kg for the flat block.	A yellow color.		Variations from a grain of rice to a pea.

II.4.5. Chemical composition of Edam type cheese

Like all types of cheese, Edam cheese is rich in nutrients. The main constituents and the energy value in (g) of Edam cheese are presented in table 060 (Bentorki et al, 2021).

Table 06: Main constituents and energy value of Edam cheese.

Composition/100g	Edam uncooked pressed cheese
Proteins	28g
Lipids	24g
Carbohydrates	03g
Water	45g
Energy	284-326 Kcal/100g

II.4.6. Main vitamins in Edam type cheese

Edam cheese contains several essential vitamins, but its main contributions are in proteins, lipids and minerals. Here is an overview of the main vitamins found in Edam with their typical amounts expressed in milligrams (mg) per 100 grams of cheese. Table 07 brings together the main vitamins present in Edam type cheese (Bentorki et al, 2021).

Table 07: Main vitamins (mg) in Edam type cheese.

Vitamins (mg) /100g	Edam cheese
Thiamine (Vitamin B1)	0.03
Niacin (Vitamin B3)	0.1
Riboflavin **(Vitamin B2)**	0.35
Retinol (**V**itamin A)	0.24

II.4.7. Physicochemical characteristics of Edam type cheese

Edam cheese, known for its round appearance and its layer of red wax, has specific physicochemical properties which influence its texture, taste and longevity. The chemical composition of cheese varies depending on the manufacturing process. The main components are water, fats, proteins and salts. Lactic acid is produced by lactic acid bacteria during the ripening process, which affects the acidity level. Its texture is influenced by its acidity, as well as its fat and water content, making it softer for young cheeses and firmer for older cheeses. Additionally, the moisture concentration and pH level change with the age of the product. The physicochemical properties of cheese play a role in the variety of flavors and textures (El-Galeel et al., 2017).

Edam type cheese has several physicochemical characteristics which are grouped in table 08 (Bentorki et al, 2021).

Table 08: Features physicochemical characteristics of Edam cheese.

Features	Standards according to LFB (AFNOR)
pH	5.3 ± 5.5
Dry extract	51 ± 1%
Fat	20 ± 1g/l
Fat/Dry	45%
NaCl	1.5-2%
Humidity	50 ± 2%

II.4.8. Manufacturing of Edam cheese

The production of Edam cheese is a complex process that follows several specific steps (Tamime, 2011):

- **Receiving and preparing milk**

Raw milk is filtered and standardized to adjust the fat content.

- **Pasteurization**

The milk is heated to approximately 72°C for 15 seconds to eliminate pathogenic bacteria. The milk is heated to approximately 72°C for 15 seconds to eliminate pathogenic bacteria.

- **Adding rennet and lactic ferments**

Specific bacterial cultures and rennet (enzyme) are added to milk to initiate fermentation and coagulation.

- **Coagulation**

The milk coagulates into a solid gel in 30 to 45 minutes.

- **Cutting the curd**

The curd is cut into small cubes to facilitate the evacuation of the whey.

- **Draining**

The curds are stirred and heated to further separate the whey.

- **Pressing**

The curds are placed in molds and pressed to form firm wheels.

- **Salting**

The cheese wheels are immersed in a brine to absorb the salt needed for preservation and flavor.

- **Refining**

The cheese is matured for several weeks to several months under controlled conditions of temperature and humidity.

- **Packaging**

After ripening, the cheese is vacuum-packed or wax-packed to extend its shelf life.

Part II:

Experimental procedures

Chapter III

III. Materials and methods

This work was carried out at Boudouaou Dairy-Cheese Factory of Boumerdes (Laiterie-Fromagerie de Boudouaou = LFB). It involves producing eight Edam-type cheeses enriched with several medicinal plants: chia seeds, sativum and oats.

III.1. Presentation of Laiterie-Fromagerie de Boudouaou (LFB)

Located at the entrance to the town of Boudouaou in the wilaya of Boumerdes, the Boudouaou dairy and cheese factory (LFB) covers a total area of 7 hectares. Its main activity is the production and sale of milk and dairy products. Created in 1969 under the name of Mitidja cheese factory by a private group, it was nationalized in 1972 and transferred to the properties of the National Milk Office (ONALAIT). It was part of the Central Regional Milk and Dairy Products Office (ORLAC). The unit has 445 employees who work in three main areas: administrator and finance manager, business management, technical management.

The laboratories of the Boudouaou dairy and cheese factory (LFB) are made up of two departments. A physico-chemical analysis service and a microbiological analysis service. The physicochemical analysis department has a single handling room, a laboratory manager, two engineers and six technicians. The microbiological analysis department is equipped with a handling room, a testing room, a laboratory, a preparation room, a laundry and an autoclave, the team is led by a laboratory manager and includes laboratory technicians.

The analysis laboratories of the Laiterie-Fromagerie de Boudouaou (LFB) are responsible for ensuring the quality of the products and guaranteeing the safety of consumers. They have several missions, namely:

- Quality assurance and verification of product conformity;
- Daily verification of the manufacturing process;
- Guarantee optimal microbiological and physicochemical quality of the finished product;
- Ensure compliance with product manufacturing and marketing standards;
- Ensure compliance with hygiene standards.

III.2. Materials

III.2.1. Biological material

The production of Edam cheese begins with cow's milk, which is heated, inoculated with lactic acid bacterial cultures and rennet for coagulation. The curd is then cut, stirred and pressed to form Edam cheese.

Cow's milk (raw milk)

It comes from LFB's surrounding farms and transported to the factory in tanks.

Lactic acid bacterial cultures

The lactic ferments used in the manufacture of Edam cheese are specific bacteria that contribute to the development of the characteristic taste and texture of this cheese. Bacterial cultures used in cheese production can vary depending on the specific manufacturing practices employed by each cheese factory (Saoudik et al., 2019).

Rennet is an essential ingredient used in the production of Edam cheese. It is a coagulating enzyme of animal origin that facilitates the transformation of milk into curds, thus allowing the formation of cheese.

In summary, the main biological materials used in the production of Edam cheese are cow's milk, lactic acid bacterial cultures and rennet. These ingredients combined with the specific manufacturing process achieve the unique taste and characteristic texture of Edam cheese (AFNOR, 1986).

III.2.2. Plant material

The plant material chosen for this study ischia grains, sativum grains and oats which were purchased in February 2024 in a grocery store in the Wilaya of Bouira (Figure 14).

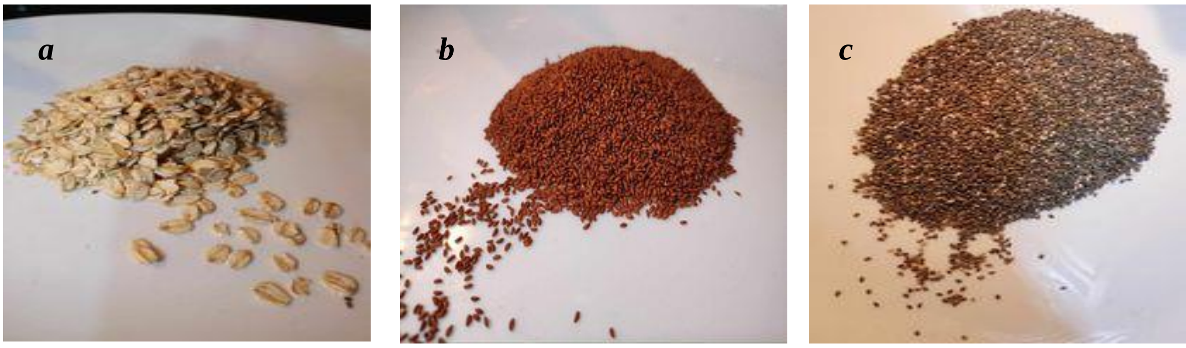

Figure14: Seeds of plant material used. a: Seeds of oats (*Avena sativa*), b: Seeds of Hab. El-Rachad (*Lepidium sativum*), c: Chia seeds (*Salvia hispanica)*(Original photo).

III.3. Methods

III.3.1 Preparations of medicinal plants

The seeds were well cleaned and ground until a fine powder was obtained. Subsequently, the powders obtained were sieved at 200 µm (Figure 15), then stored in glass ars at room temperature, in a dry place and protected from humidity and light until use.

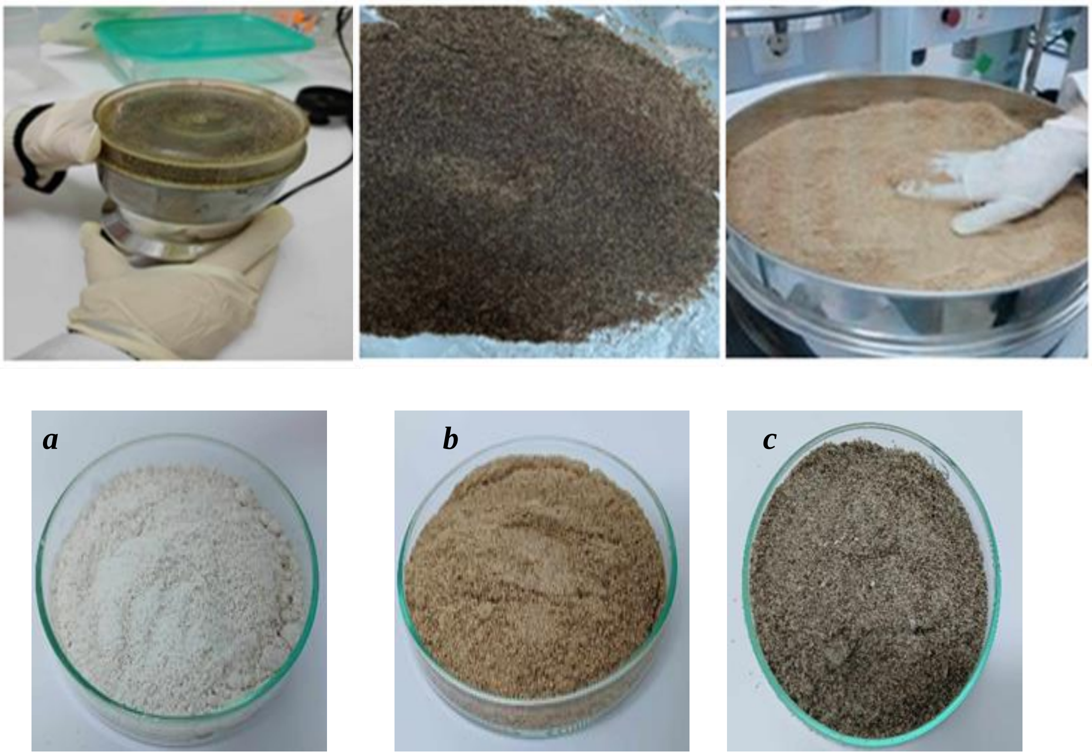

Figure 15: Fine powder of the plant material used. a: Oats powder (*Avena sativa*), b: Hab. El-Rachad powder (*Lepidium sativum*), c: Chia powder (*Salvia hispanica)*(Original photo).

III.3.2 Physicochemical analysis of raw milk

The raw milk was analyzed to determine its physicochemical characteristics.

a. pH

The pH is determined by immersing the pH meter electrode (Figure 16) in the raw milk sample (Saoudik et al., 2019).

Figure 16: pH determination (Original photo).

Operating mode

- Calibration of pH meter with a buffer solution

- Pour a quantity of sample to be analyzed (milk) into a beaker

- Insert the electrode into the beaker.

- Wait for the display to stabilize, then read the pH value directly on the screen.

b. Determination of density

The density of a substance is determined using a thermolactodensimeter. It is defined as the ratio between the mass of a given volume of milk and the mass of the same volume of water. To obtain a precise measurement, it is essential to establish this ratio at constant temperature and pressure (Bentorki et al., 2021).

Operating mode

Milk should be poured into a 250 ml test tube up to the edge (figure 17), avoiding the formation of foam. The thermo-lactodensimeter must then be inserted after having been balanced. The density and temperature must then be read (Bentorki et al., 2021).

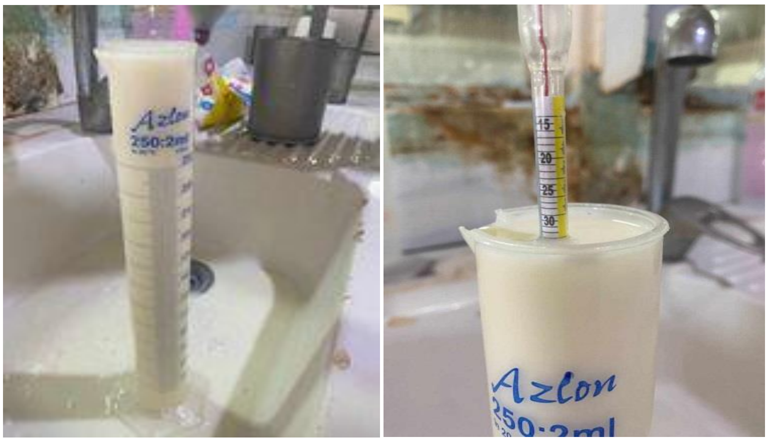

Figure 17: Determination of the density of raw milk (Original photo).

Expression of results

The density is expressed by the following formula: $\mathbf{D = D_0 \pm [(20-T) * 0.2]}$

If T > 20°C, D= C+0.2 (T-20),

If T < 20°C, D=C-0.2 (T-20), With: D_0: Density read on the lactodensimeter T: Temperature read on the lactodensimeter. D: Density in Dornic Degree

c. Determination of fat content

The fat content is determined by the butyrometric acid method. It is based on the dissolution of the components of milk by sulfuric acid under the influence of centrifugal force and thanks to the addition of one ml of iso-amyl alcohol, the fat separates in the form of a transparent clear coat (Bentorki et al., 2021).

Operating mode

Into a Gerber butyrometer (Figure 18), introduce 10ml of sulfuric acid (H_2SO_4) with a density (d=1.820). Pour 11 ml of raw milk, then add 1 ml of iso-amyl alcohol with a density (d=0.813).

Butyrometer is held in a vertical position and shaken horizontally in order to avoid too brutal an attack on the milk by the acid. Place the butyrometer in the centrifuge at a speed of 1100 rpm for 5 min (Bentorki et al., 2021).

Figure 18: Determination of raw milk fat (Original photo).

Expression of results

The fat content is expressed in % using the following expression:

MG= (AB) (%)

Where: A: the reading taken at the lower end of the bold column. B: the reading taken at the upper end of the fatty column

d-Research for antibiotic residues

The milk contains antibiotic residues can sometimes represent a risk for the consumer, but also for the industry, because they can disrupt the fermentation and maturation processes of widely consumed dairy products such as yogurt, cheese and other milks. It is therefore crucial to spot them (Bentorki et al., 2021).

Operating mode

- It is extremely important to ensure that the cap is secure and that all of the freeze-drying is at the bottom of the bottle.

- Before analysis, 0.2 ml of the milk sample to be tested must be pre-washed. The 0.2 ml of milk is then poured into the receiving bowl (Figure 19).

-The cuvette should then be recapitulated and shaken gently to facilitate dissolution of the freeze-drying.

- Then, the vial is placed in one of the incubation wells, which is maintained at a temperature of 47.5°C. After a period of three minutes, the strip is inserted into the bottle. The sample should be incubated at 47.5°C.

-Two minutes after incubation of the strip in the bottle, it must be removed and the result must be read immediately (Saoudik et al., 2019).

Figure 19: Determination of antibiotic residues on raw milk (Original photo).

Reading

- If the strip does not appear to be an intense pink color, the test is invalid.

- If the first band has an intensity greater than the reference band, the sample is classified as negative.

- If the first band has an intensity equal to or lower than the intensity of the reference band, the antibiotic concentration is low and the sample is classified as positive.

- If the first band is absent, the sample contains a high concentration of antibiotic and is classified as positive.

- If the first band is absent, the sample is considered to contain a high concentration of antibiotic and is therefore classified as positive (Saoudik et al., 2019).

III.3.3 Microbiological analysis of raw milk

a. Sample collection

A mixture of the sample, stored at a low temperature (4°C), to obtain a uniform distribution of microorganisms. Preparation of serial dilutions to facilitate colony counting. 1 ml of the mother suspension is taken and then introduced into a tube which contains 9 ml of physiological water which will give the dilution 10^{-1} (Figure 20).

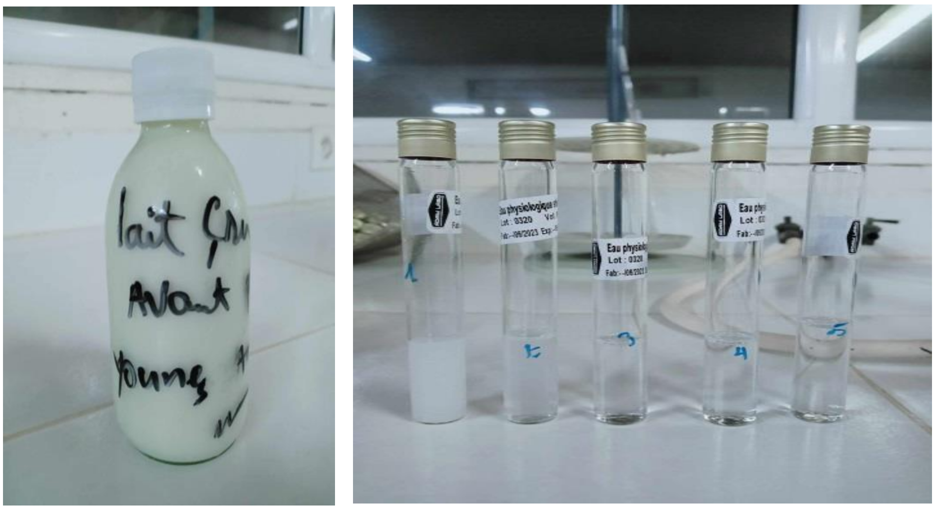

Figure 20: Dilutions of the raw milk stock solution (Original photo).

b. Seeding

b.1. Total germs

- Using a Pasteur pipette, take 1 ml, approximately 20 drops of the suspension of the 10^{-4} dilution and the 10^{-5} dilution then place them in Petri dishes respectively (Figure 21).

-We add the plate count agar “PCA” culture medium, specific for total germs, then we homogenize the boxes by forming a circle 8.

- After solidification of the agar, the Petri dishes are incubated at 30°C for 72 hours (AFNOR, 1986).

Figure 21: Search for total germs in raw milk (Original photo)

b.2. Fecal coliforms

- Using a Pasteur pipette, take 1 ml, approximately 20 drops of the suspension of the 10^{-4} dilution and the 10^{-5} dilution then place them in Petri dishes respectively (Figure 22).

- We add the purple culture medium Red bile agar (VRBG) specific for total germs, then we homogenize the boxes by forming a shape 8 movement.

- After solidification of the agar, the petri dishes are incubated for 24 hours to 48 hours at 37°C for total coliforms and at 44°C for fecal coliforms.

- Do the reading every 24 hours (AFNOR, 1986).

Figure 22: Testing for fecal coliforms in raw milk (Original photo).

III.3.4. Edam type cheese manufacturing process

We performed four productions where the plants were added in different quantities (1g, 2g and 3g in 100ml of raw milk) and with different powders.

The raw milk was taken directly from the collection tanks after homogenization. For the cheese samples, we carried out the analysis by operating at the sampling levels at unmolding; the samples were taken at the LFB dairy.

Physicochemical and microbiological analyzes of the finished Edam cheese product were carried out at the laboratory level of the LFB dairy.

The production of Edam type cheeses was carried out in several stages according to the protocol of the Fromagère de Boudouaou dairy (Saoudik et al., 2019).

a. Receiving raw milk

Raw milk arrives in insulated tanks at the LFB dairy. For each test 20l were sampled of raw milk for physico-chemical analysis, such as measuring the acidity and pH of the milk.

b. Pasteurization

The quantity taken (20 liters) of raw milk was put in a pot, and heated to a temperature of 85°C for 20 seconds. The aim of this operation is to inhibit the activity of heat-resistant germs (Figure 23).

Figure 23: Pasteurization of raw milk (Original photo).

c. Seeding

After cooling the heated milk for a few minutes, the lactic ferments (Mesophilic and thermophilic) are added in order to enrich the culture medium for lactic acid bacteria (Figure 24), This operation is carried out at a pH value between 5, 20 and 5.40 and at a temperature of 38°.

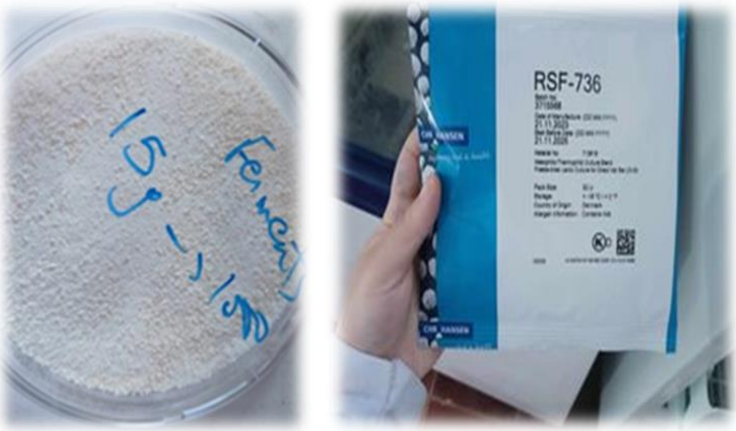

Figure 24: Inoculation of raw milk with lactic ferments (Original photo).

d. Renneting

In this step, the rennet is added to the mixture, the pH value must be between 6.4 and 6.5, the acidity of the mixture is 18°D, renneting is done at a temperature of 38°C. The milk will coagulate in 20-30 minutes (Figure 25).

Figure 25: Renneting of raw milk (Original photo).

e. Spalling

Shutting is the step of cutting the curdled milk which is a gel obtained by coagulation of milk with rennet. Once the milk has taken the form of a firm coagulum, the curds are cut into small cubes. The shucking is done using a knife until it is the size of a grain of corn (Figure 26).

Figure 26: Curd breaking (Original photo)

f. Brewing / Delactosing

The curd is left to rest before brewing then the pieces of curd are stirred to remove the whey, in this stage the acidity is between 10 and 12°D, this operation aims to facilitate the separation between the grain of curd and the whey finished, a second stirring is carried out in order to eliminate all of the whey.

As soon as the lactose removal operation has lowered the acidity of the curd. Hot water (40°C) is added, the volume used represents half of the whey (Figure 27).

Figure 27: Brewing / Delactosing curds (Original photo)

g. Enrichment with powders

The plants are sterilized by drying in the oven at 50°C, for several cycles. Enrichment is carried out by addition of fine powders (<200µ) of the seeds in cheese. Then mix the enriched cheese pastes well (Figure 28).

Figure 28: Enrichment with powders (Original photo).

For each 100g of cheese 1g of powder for each seed was added. The following table gives the quantities and code of each cheese.

Table 09: Types of Edam cheese prepared

Coded	Powder quantity	Quantity of cheese
HAS	Control (without powder)	200g
B	2g Chia	200g
VS	2g Sativum	200g
D	2g Oats	200g
E	1g Chia +1g Sativum	200g
F	1g Chia +1g Oats	200g
G	1g Sativum + 1g Oats	200g
H	0.66g Chia + 0.66g Sativum + 0.66g Plane	200g

h. Pre-molding/Molding

We cover the molds with cloths and fill them with the curds. The filled molds are pressed using a 4-bar plate for 5 to 6 hours, turning over every 30 minutes (Figure 29).

Figure 29: Pre-molding/Molding stage (Original photo).

i. Salting

Salting is a process that consists of adding sodium chloride to the dough in order to enrich it. This substance acts directly on the development of microorganisms and the activity of enzymes by reducing water activity. It also completes the evacuation of whey and facilitates the formation of the cheese rind (Saoudik et al., 2019).

Salting consists of immersing the cheese balls in a brine containing 35% Na Cl, the temperature between 10-12°C with a concentration of 19° Baumé. After salting, the cheese balls are briefly drained to remove the film of water on the surface of the cheese. Immerse the ball in a salt solution for 5-6 hours (Figure 30).

Figure 30: Salting stage (Original photo, 2024).

i. Refining

We will put the ball in a drying room at a fixed temperature of 12°C and at a humidity level of 85% for a period of 21 days. Refining is an important step which occurs in the maturation of cheese biologically under the action of enzymes (Figure 31).

Figure 31: Refining stage (Original photo).

j. Paraffining

After 21 days of maturing, the ball is scraped with a knife to remove the hard outer crust. At the end the cheese is coated with melted paraffin, after a certain time the cheese is allowed to dry then vacuum-packed in cellophane paper (Figure 32).

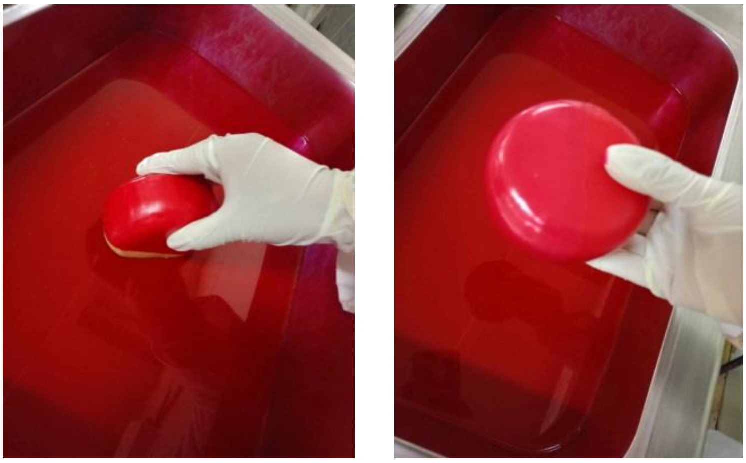

Figure 32: Paraffining stage (Original photo).

k. Packaging (Vacuum packaging)

The cheeses are vacuum-packed with labeling and stored at 6°C, pending marketing (Figure 33).

Figure 33: Packaging and vacuum packaging (Original photo).

III.3.5. Physicochemical analysis of Edam cheese

The samples of Edam type cheese obtained, with different combinations and dosages of the seed powder used, were the subject of a physicochemical analysis.

A physicochemical analysis makes it possible to examine the characteristics of a product or material in order to ensure its conformity and performance before it is placed on the market (AFNOR, 1986)

a. pH

The pH measurement is done by injecting pH and temperature probes into the cheese ball. The result is read directly on the pH meter display (Figure 34).

Figure 34: Measure the pH of cheese during maturation (Original photo).

b. Determination of fat content

The cheese is cut into small pieces (Figure 35), a quantity of 3 g of cheese is weighed into a butyrometer cup. A volume of sulfuric acid with a density (d=1.520) is added until the cheese completely emerges. Then the butyrometer is placed in the water bath at 70°C with stirring every 5 to 10 minutes until the cheese is completely dissolved.

Subsequently, sulfuric acid is added until reaching 35% of the scale after the addition of 1 ml of iso-amyl alcohol. Close the cap tightly and place the butyrometer in the centrifuge for 5 minutes (Saoudik et al., 2019).

The percentage of fat content is expressed as follows: **Fats (MG) = (A*B) (%)**

Where: A: the reading taken at the lower end of the fat column, B: the reading taken at the upper end of the fat column.

Figure 35: Determination of fat content (Original photo)

vs. Determination of total dry extract

A quantity of 1.2 to 1.5g of Edam cheese cut into small pieces is placed in a desiccator with a temperature set at 95C°.

A pre-weighed aluminum foil should be spread evenly with the specified quantities of the respective ingredients, namely 2.5 ml for whey and milk, and 1.2-1.5 g for cheese. The drying process should then begin (Figure 36). Dry matter is determined when the desiccator automatically stops operating. The value is then read directly on the screen, expressed as a percentage (Saoudik et al., 2019).

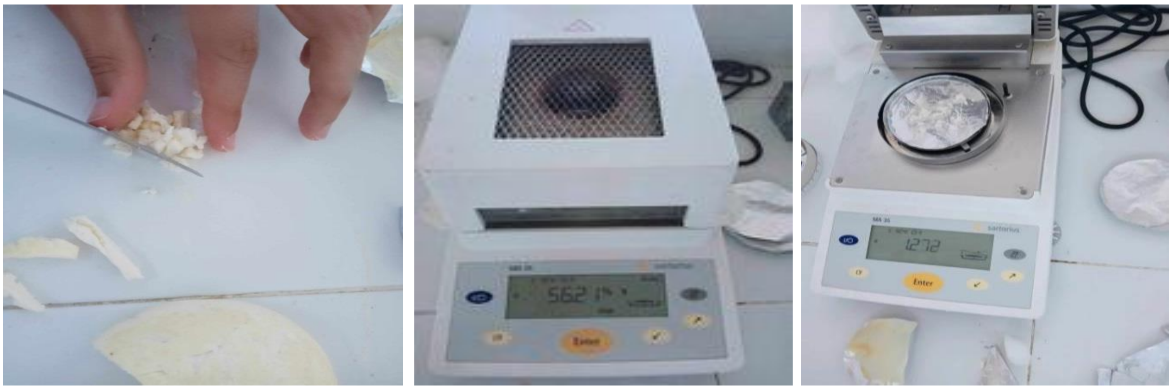

Figure 36: Determination of total dry extract (Original photo).

III.3.6. Microbiological analysis of Edam cheeses

The objective of the microbiological analyzes was to verify the safety of the materials used and that of the finished product through continuous monitoring carried out during the manufacturing process for the detection of fecal coliforms and *Staphylococcus aureus* (AFNOR, 1986).

Using a metal probe and a sterilized knife with a sharp blade, 25 g of Edam cheese are taken from each enriched ball and placed in the non-selective broth medium containing 225 ml of physiological water. After homogenization we obtain the stock solution (Figure 37).

Figure 37: Preparation of the stock solution for microbiological analysis (Original photo)

b. Fecal coliforms

Thermotolerant coliforms are made up of bacteria with the same characteristics and fermentative properties as total coliforms, but at an incubation temperature of 44°C. The presence of fecal coliforms, and more particularly that of E. coli, which is considered a good indicator of fecal contamination (AFNOR, 1986).

To obtain the 10-2 dilution, take 2 drops (0.1ml) of the homogeneous stock solution using a sterile pipette and for 10-1, place 20 drops (1ml) of our stock solution in the box. Petri dish (Figure 38). The culture medium (deoxycolate) is added to detect the presence of total germs, then the boxes are homogenized by forming a circle 8. Then incubate the boxes at 44°C for 24 hours (AFNOR, 1986).

Figure 38: Testing for fecal coliforms in enriched Edam cheese (Original photo).

b. Staphylococcus aureus

*Staphylococcus aureus*is a ubiquitous aero-anaerobic facultative thermosensitive bacterium, belonging to the Gram-positive *Micrococacea* family, non-sporulating, it develops at a temperature around 37°C (AFNOR, 1986).

From the stock dilution, 3 drops are added using a Paster pipette, then it is inoculated onto the surface of Baird Parker (BP) agar poured into a Petri dish (Figure 39). After incubation at 37°C for 48 hours, we read (JORA n° 39, 2017).

Figure 39: Detection of *Staphylococcus aureus* in enriched Edam cheese (Original photo).

III.3.7 Sensory analysis of prepared Edam cheeses

Sensory analysis can be used to assess the preference or acceptance of a product. A preference test involves comparing two or more products and choosing a single or an order based on the subject's preference. While acceptance testing involves assigning a rating to each product studied on a specific scale (Schlich et al., 2010).

In this evaluation, eight samples of Edam cheeses made from oats, sativum and chia were identified by the letters A, B, C, D, E, F, G and H, and different sensory characteristics are necessary and required according to the steps described in the questionnaire used. The development of the questionnaire was based on the color, odor, flavor, taste, texture and preference of the testers' choice.

Figure 40: Representative tasting bench for sensory analysis (Original photo).

Chapter IV

IV. Results and discussion

The first phase of our research consisted of the small-scale production of an uncooked pressed cheese of the “Edam” type, with a production volume of 3 liters. Then the technology for producing this cheese was implemented on an industrial scale.

Physico-chemical and microbiological analyzes were carried out on the raw milk and on the cheese after pressing, before ripening, and finally on the finished product after 21 days of ripening. These analyzes were carried out in the LFB’s physicochemical and microbiological laboratories.

IV.1. Physicochemical analyzes of milk

Raw materials must be carefully monitored, which makes it possible to refuse those which are not in satisfactory condition.

IV.1.1. Raw milk

On a physicochemical level, the composition of the milk would have experienced significant variations or present certain insufficiencies which have repercussions on its cheese-making behavior, for example, its ability to coagulate. (Dafal and Guiri, 2010). Table 10 presents the results of the physicochemical analyzes of raw milk.

Table 10 : Physicochemical analysis of raw milk

Features	pH	GM (g/l)	Acidity (°D)	Density (g/l)	Antibiotic
Raw milk	6.69	32	16	1031	Abs
Pasteurized milk	6.55	30.07	15	1039.4	Abs
Raw milk, LFB standard	6.4-6.7	30-40	15-18	1030-1033	Abs
Raw milk, AFNOR (1986)	6.5-6.6	34-40	16-18	1030-1033	Abs
Pasteurized milk, AFNOR (1986)	6.4-6.6	36	19-21	1038-1042	Abs

- **pH**

The results demonstrate that the pH of raw milk (pH=6.69) before pasteurization complies with the standard AFNOR (1986), which specifies a pH standard of 6.5 to 6.6. pH is an essential physicochemical parameter in the dairy industry, as it determines the acceptability of milk in the production process. An acidic pH indicates a potential breakdown in the cold chain, either on the farm or during transport of milk to the factory (Bentorki et al., 2021).

- **Acidity**

Acidity control is the second most crucial physicochemical parameter after pH, providing information on the freshness of milk (Bentorki et al., 2021).

The results show that the acidity of the milk before pasteurization complies with the AFNOR standard (1986), with an acidity range of 16-18°D.

- **Fat**

The results obtained indicate that the fat content of milk is lower than the standard, with a value of 32 g/1. According to regulations AFNOR (1986), the fat content of raw milk is set between 34 and 40 g/1. This could be explained by the nature of the cows' diet. Cows fed rations rich in energy but low in hay have less fatty milk. It has been observed that the fat content of milk is higher in colder climates. Additionally, the fat content of a cow's milk tends to decrease during the first few weeks after calving (Dafal and Guiri, 2010).

- **Density**

From the results, we see that the density of the milk used for making cheese is equal to 1031 which complies with the standard AFNOR (1986).

The role of density in cheese production is crucial, as it impacts many processes such as milk coagulation, whey draining, pressing, ripening and final product quality. In some cheeses, adequate density ensures optimal coagulation, efficient draining, optimal pressing and adequate ripening, which has an important effect on texture, taste and hole distribution. At each stage, cheesemakers adjust the density in order to obtain quality cheeses with the desired characteristics (Bentorki et al., 2021).

- **Antibiotics**

Antibiotic residue results indicate its absence in raw milk. This confirms the good health of the cows on the different farms which supply milk to the LFB unit.

The presence of residues of antibiotics used to treat mastitis is one of the frequent causes of disruption of lactic fermentation. The presence of antibiotics harms acidification, which leads to coagulation, drainage, aromatization and maturation defects. This results in a dough that remains too wet, which allows excessive microbial and enzymatic activity, as well as excessive proteolysis, which can cause a more or less collapsed runny dough and the appearance of abnormal tastes, notably bitterness. (Dafal and Guiri, 2010).

The development of undesirable flora is also to be feared. One of the most significant risks of late acidification is the abnormal growth of coliform bacteria, which can occur very early, even during draining, and lead to texture and flavor defects. The presence of antibiotics in milk constitutes a potential health risk, as it can lead to a reduction in natural immunity and the appearance of resistant mutant bacteria, which can lead to therapeutic failures (Dafal and Guiri, 2010).

IV.1.2. Milk after pasteurization

- **pH and Acidity**

The results demonstrate that heat treatment has no impact on the pH and acidity of milk during pasteurization where the values were6.55 and 15°D, respectively. This indicates that the heat treatment used during pasteurization does not affect the chemical composition of the milk, thus preserving its nutritional and organoleptic properties while guaranteeing its safety (El-Galeel et al., 2017).

- **Fats**

After pasteurization, the sample had a fat content of 30.07 g/l, which is lower than the standard value of 36 g/l. It has been shown that pasteurization can influence the fat globule membrane, resulting in the release of fats and making them accessible to lipases (El-Galeel et al., 2017).

- **Density**

The phenomenon of density change is attributed to the influence of heating on the heat-labile constituents of milk, including vitamins, whey proteins and even certain enzymes. The density was 1039 for pasteurized milk, this indicates a typical density for this product after the pasteurization process. This suggests that pasteurized milk meets the density standards expected for this type of product.

The pasteurization process can influence the density of milk due to the chemical and physical changes that occur during heat treatment. However, a specific gravity of 1039 indicates that pasteurized milk generally retains its normal specific gravity after processing, suggesting that changes in density caused by pasteurization are minimal (Bentorki et al., 2021). The physicochemical results of the milks are grouped in the following figure.

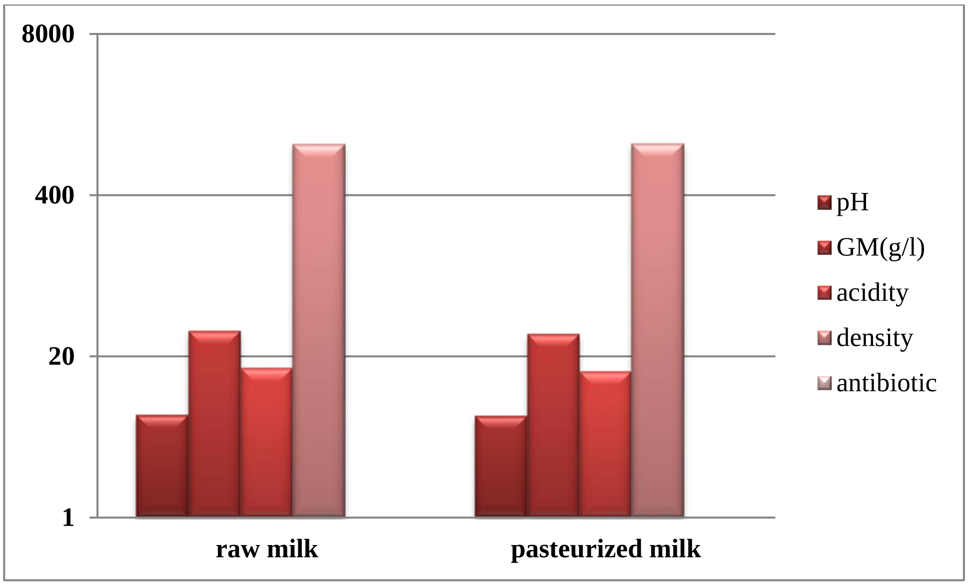

Figure 41: Evolution of physicochemical parameters of milk before and after pasteurization

According to Figure 41 which summarizes the evolution of pH, acidity, density, fat and antibiotic residues of milk before and after pasteurization we conclude that the heat treatment (pasteurization) undergoing milk has no influence on these parameters (Bentorki et al., 2021).

IV.2. Microbiological analysis of milk

The standards used in our study to evaluate the microbiological quality of raw milk and the finished product are those of(AFNOR1986). It is widely recognized that microorganisms are almost always the cause of spoilage in milk and dairy products. They are also the main cause of cheese defects. This is why microbiological analyzes are carried out on well-defined germs or groups of germs (Hadad et al., 2021).

Our microbiological study is based on analyzes of the raw material and the finished product.

IV.2.1. Raw milk

Milk is a favorable environment for the multiplication of most germs. . Microbiological analysis is of great importance because it provides us with information about the production process and conditions. Table 11 presents the results of microbiological analyzes of raw milk.

Table 11 Results of microbiological analyzes of raw milk.

Types of bacteria	Number of bacteria (UFC/ml) AFNOR 1986	
Total coliform	4.0.102	Max 10^3
Fecal coliform	Abs	Max 10^3
Staphylococcus	Abs	Abs
Salmonella	Abs	Abs

The results for raw milk show that fecal coliforms and pathogenic germs (Staphylococci and Salmonella) are completely absent. The presence of total coliforms is indicated at a level of 4.0.102 CFU/ml), which is below the standards (max 103). The results demonstrate that the raw milk sample in question contains 400 colony forming units (CFU) of total coliforms, which is well below the maximum standard of 1000 CFU. This indicates that the raw milk in question complies with current food safety standards, thus ensuring its safety for consumption in terms of total coliform contamination (El-Galeel et al., 2017).

IV.2.2. Milk after pasteurization

Table 12 presents the results of microbiological analyzes of raw milk after pasteurization.

Table12: Results of microbiological analyzes of milk after pasteurization

Types of bacteria	Number of bacteria (UFC/ml) AFNOR 1986	
Total coliform	Abs	Max 1
Fecal coliform	Abs	Max 1
Staphylococcus	Abs	Abs
Salmonella	Abs	Abs

The results indicate that pasteurization of raw milk results in a significant reduction in microbial contamination. These results are consistent with the standards AFNOR (1986).

This allows us to conclude that the heat treatment carried out at the LFB unit is satisfactory (72-75°C) for 15 seconds in terms of destruction of pathogenic germs and various alterations. When a microbial population is subjected to the action of a given temperature for a given time, a certain proportion of this population is destroyed (Bentorki et al., 2021).

In the same vein, the FAO(1995) states that the effectiveness of heat treatment depends on the initial microbial load present in the milk. Therefore, the importance of maintaining hygienic conditions throughout the processes of collection, cooling and rapid processing of milk cannot be overemphasized (Bentorki et al., 2021).

IV.3. Results of physicochemical analyzes of enriched Edam cheeses

The results of the physicochemical analyzes of Edam cheeses enriched with the different powders (eight samples) are represented in table 13.

Table 13: Physico-chemical analysis of enriched Edam cheeses

Setting	Edam manufactured	Standard applied by LFB (AFNOR)
pH	5.4	5.2 – 5.5
Fat (%)	21	20 – 22
Total dry extract (%)	50.64	50 ±1
Fat/dry	41.4	40 – 42

The physicochemical analyzes were carried out according to the standards issued by the LFB which are based on AFNOR standards. Physicochemical analyzes of cheeses enriched with chia seed powder, sativums, oats, oats + chia, oats + sativum, chia + sativum, chia + sativum, 3 powders of seeds and finally the control after refining comply with standards, which means that there is no impact of the powders on the physicochemical parameters tested. These elements confirm the excellence of our cheeses.

IV.4. Results of microbiological analyzes of enriched Edam cheeses

Table 14 summarizes the results of microbiological analyzes of cheeses enriched with chia seed powder, sativum powder, oats, oats + chia, oats + sativum, chia + sativum, chia + sativum powder, chia + sativum powder, chia + sativum powder, and finally the control after refining

Table 14: Results of microbiological analyzes of cheeses after ripening

Types of bacteria	Cheese after ripening
Total coliform	Abs
Fecal coliform	Abs
Staphylococcus	Abs
Salmonella	Abs

There is an absence of fecal coliforms, total coliforms and pathogenic germs (*staphylococci*, *salmonella*). In general, pathogenic microorganisms come from milk that has been harvested under suboptimal hygienic conditions and has undergone inadequate pasteurization.

It is essential to carry out a microbiological analysis of the finished product, as it provides valuable information on the hygiene of the production process and compliance with certain parameters. It is therefore crucial to control the parameters likely to lead to contamination of the finished product (Hardy, 2006).

Contamination can be due either to the quality of the raw materials or to the contribution of microorganisms during the manufacturing chain on the other hand. The hygienic quality of cheeses is evaluated by comparing the results obtained during the study to the standards established by JORA and WHO (Hardy, 2006).

IV.5. Sensory analysis results of enriched Edam cheeses

A taste test was carried out on eight samples, of which color, odor, flavor, taste, texture and preference were evaluated.

- **Color**

The results of the color test of the eight samples of Edam cheese enriched with the different powders are shown in Figure 42.

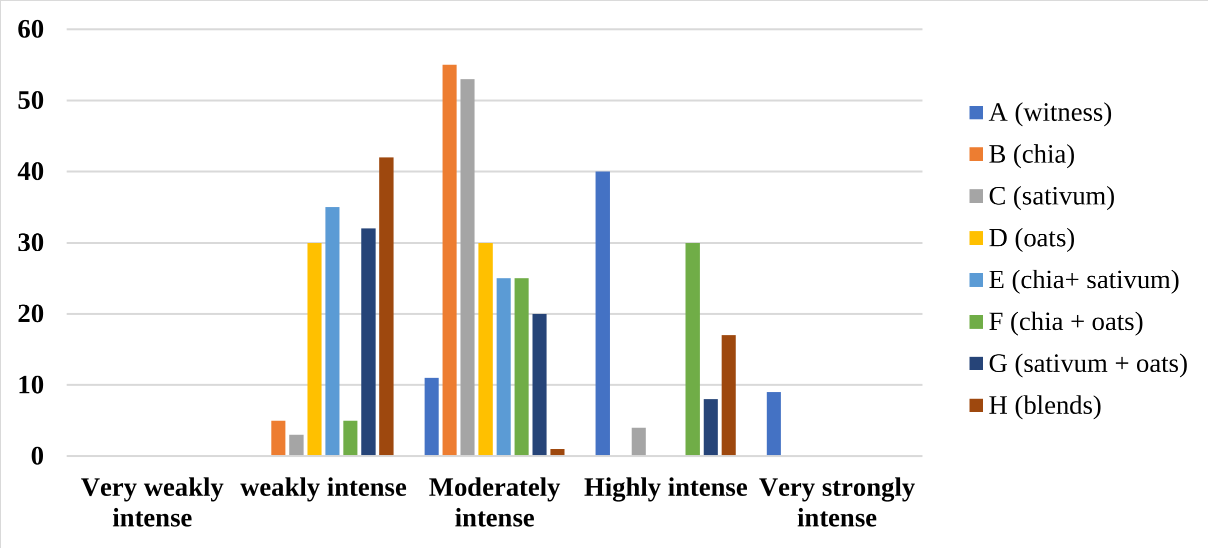

Figure 42: Results of testing the color of enriched Edam cheeses (Original photo).

From the results obtained in Figure 42, it was found that the majority of tasters noted that cheese B enriched with chia powder and cheese C which is enriched with sativum powder and cheese D which is enriched by oat powder have a moderately intense color. Cheese enriched with oats, the chia and sativum mixture, and the sativum and oat mixture presents a weakly intense color.

While the control and that which is enriched by the chia and oat mixture, such as the cheese enriched by the mixture of the three plants, present a strongly intense color. We can say that the colors of samples B, C and D are less intense (Figure 43) compared to the colors of samples A (control). This can be explained by the addition of medicinal plants which has a light color which is less intense.

This is because fresh grass contains a greater amount of beta-carotene than hay that was fed to cows during the fall and winter months. Beta-carotene is lost when hay is dried, and it is this substance that gives cheese its yellowish tint (Codex, Stan, 265-2007)

Figure 43: Representative color of enriched Edam cheeses (Original photo).

- **Smell**

The results of the odor test of the eight samples of Edam cheese enriched with the different powders are shown in Figure 44.

From the results obtained in the figure above, it was noted that the majority of tasters reported that the cheese enriched with sativum (C) and control cheese (A) had a moderately appreciated odor while the cheese enriched with Oats (D) and cheese enriched with chia (B) and which is enriched by the mixture of the three powders (H) and cheese enriched with sativum (C) are highly appreciated.

The same smell was attributed to cheese enriched with chia and oats (F) and cheese enriched with sativum and oats (G), while cheese enriched with chia and sativum (E) was very highly appreciated.

In general, we can say that the smell of samples B, D, H have a strong smell compared to sample A, this smell is probably due to the addition of grain powders, we played on the color and the 'smell. Edam cheese known for its acceptable or moderately appreciated smell (Cheriet, 2021).

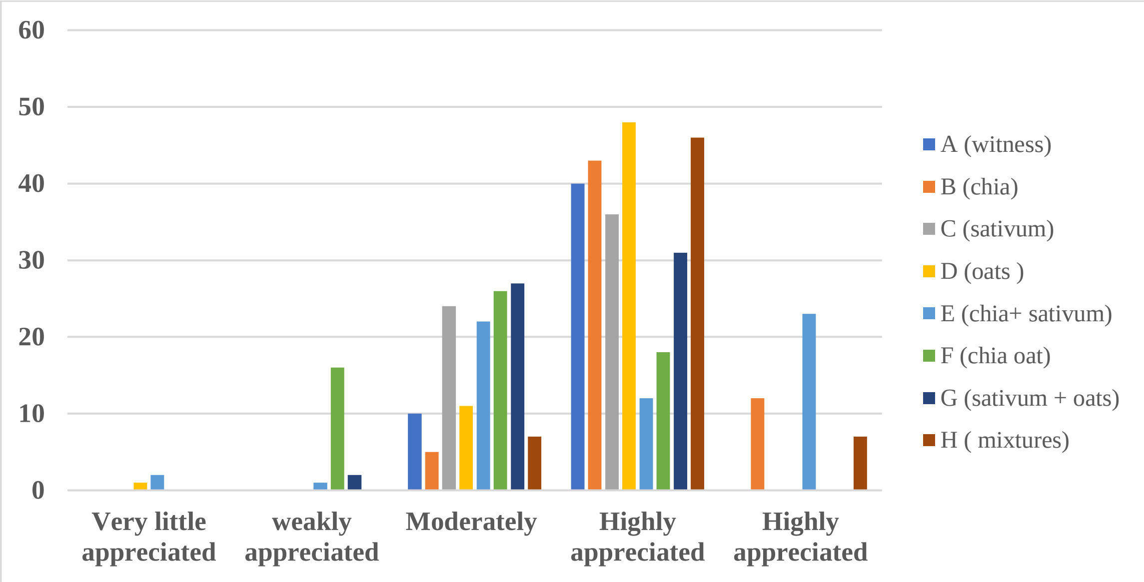

Figure 44: Results of the smell of enriched Edam cheeses (Original photo).

➢ **Flavor**

The results of the flavor test of the eight samples of Edam cheese enriched with the different powders are shown in Figure 45.

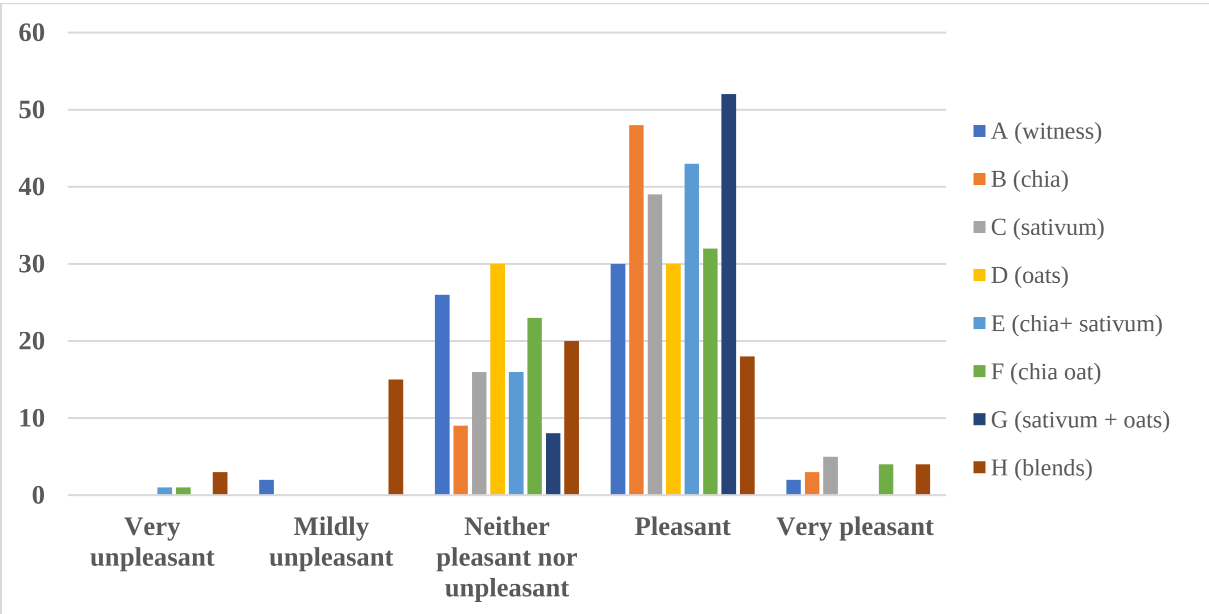

Figure 45: Flavor results of enriched Edam cheeses (Original photo).

From the above results, the majority of tasters found that cheese enriched with chia (B), cheese enriched with sativum (C), cheese enriched with sativum and chia (E), and cheese enriched with sativum and oats (G) presented a pleasant flavor compared to the control cheese (A) and the cheese enriched with oats (D) and the cheese enriched with chia and oats (F) which presented a neither flavor pleasant nor unpleasant.

Cheeses can exhibit a range of flavors and aromas, including sweet, salty, sour, bitter and umami, which are perceived by the taste buds on the tongue. Additionally, they can exhibit floral, fruity, earthy and herbaceous aromas, which are perceived through the nose (Teilet al., 2024).

- **Taste**

The results of the taste test of the eight samples of Edam cheese enriched with the different powders are shown in Figure 46.

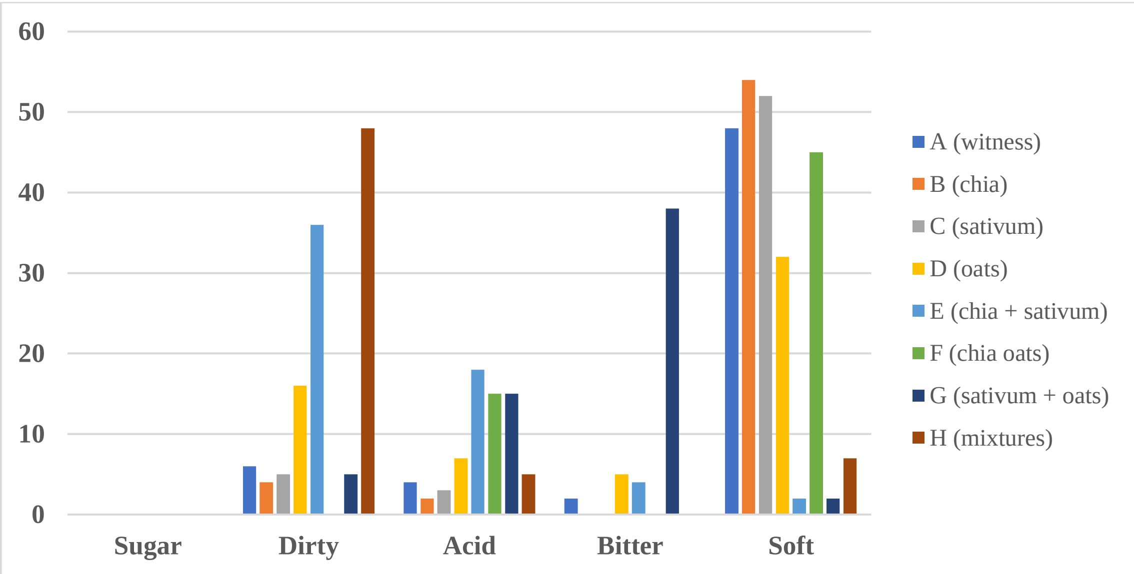

Figure 46: Results of the taste of enriched Edam cheeses (Original photo).

According to the results obtained and presented in Figure 46, the majority of tasters noted that the cheese enriched with chia and the cheese enriched with oats and the cheese enriched with sativum have a mild taste. For the cheese which enriched by the three plants has a salty taste, and for the control cheese has an acidic and bitter taste.

In general, the tasters preferred the taste of samples B enriched with chia, C enriched with sativum and D enriched with oats with a (mild) taste compared to the control cheese (A) and the cheese enriched with the mixture of the three powders. (H). Originating from Laville, edam cheese has a characteristic semi-hard paste and sweet, salty taste (Health Passport, 2022).

- **Texture**

The test results of the texture of eight samples of Edam cheese enriched with different powders are shown in Figure 47.

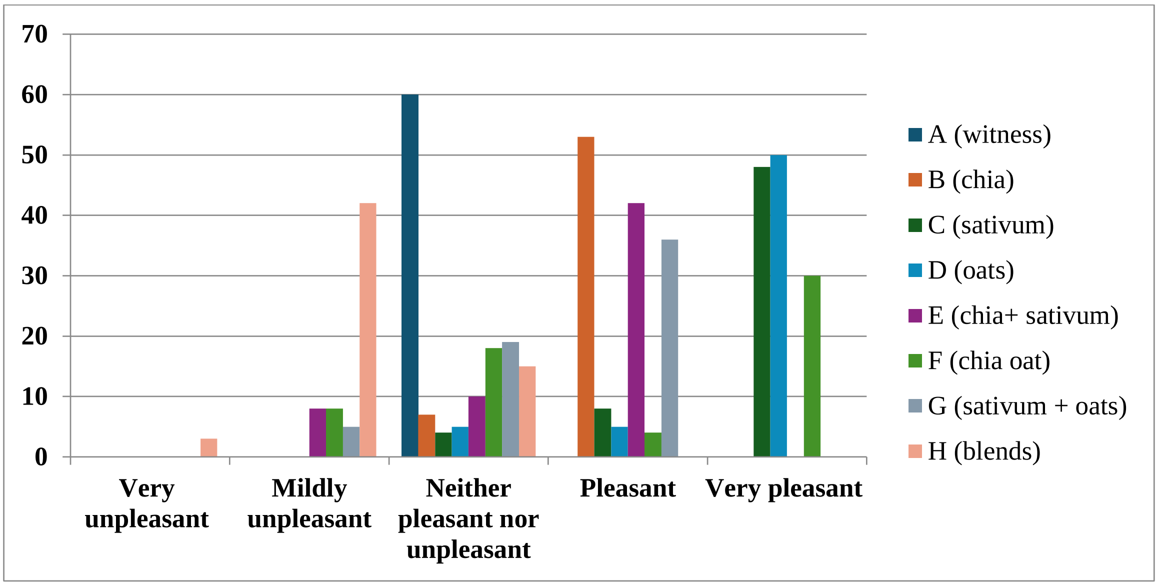

Figure 47: Results of the texture of enriched Edam cheeses (Original photo).

From the above results, the majority of tasters found that cheese B (chia) and cheese E (chia + sativum) and G (sativum + oats) have a pleasant texture. This indicates that the cheese in these samples is smooth when tasted, therefore the texture of the latter is homogeneous.

The cheese enriched with oats has a very pleasant texture. This indicates that this cheese is very smooth when tasted, so the texture of the latter is very homogeneous. Cheese A (control) has a texture that is neither pleasant nor unpleasant. This shows that the control cheese was not perfectly smooth, that there were a few lumps when tasting, so the texture of the latter is intermediate.

H cheese (mixtures) enriched with the three plants have a slightly pleasant texture. This perhaps indicates the presence of lumps during tasting; the texture of the latter is heterogeneous.

Acidification of milk and curd contributes to the taste, texture and openness of dairy products through proteolysis and flavor production. These bacteria are widely used today in the form of selected sourdoughs.

This category encompasses a wide range of cheeses, presenting a spectrum of textures and flavors, depending on the length of maturation (Bugaud et al., 2002).

- **Pr**
- **preference**

The results of the preference test for the eight samples of Edam cheese enriched with the different powders are shown in Figures 48 and 49.

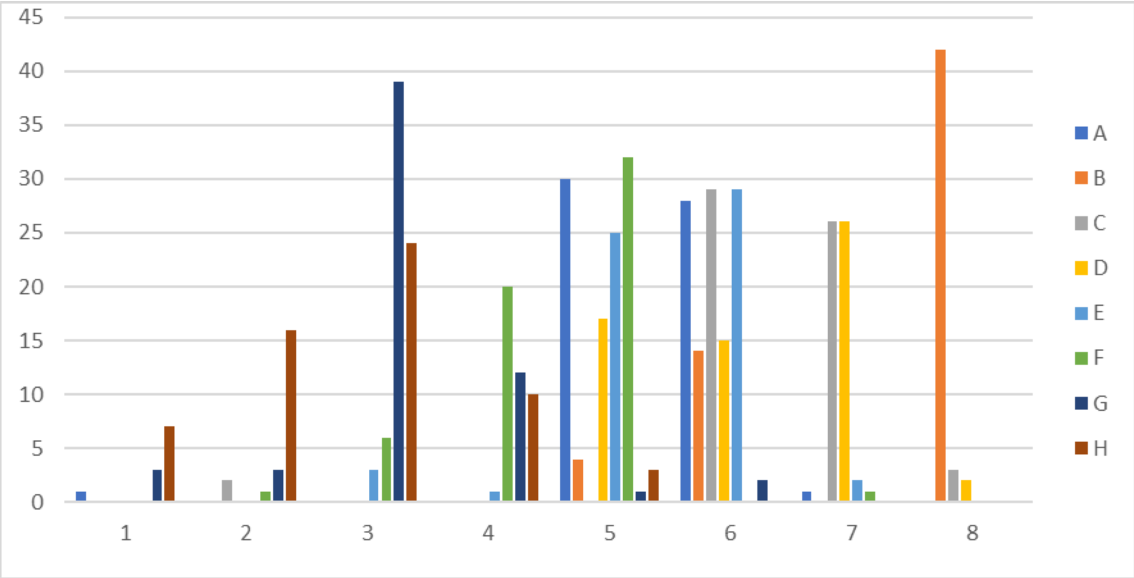

Figure 48: Results of preference of cheeses Edam enriched (Original photo).

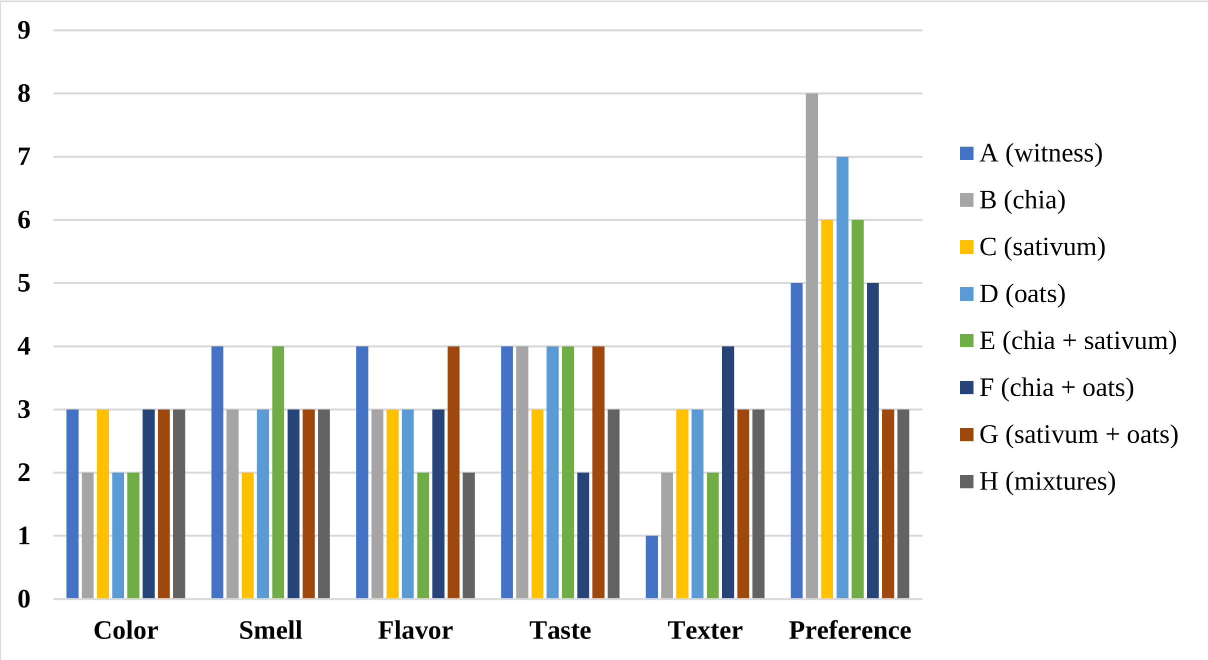

Figure 49: Overall evaluation results of the tasters (Original photo).

The results obtained presented in Figures 48 and 49 showed that, compared to the majority of tasters, the control cheese (A) has a score of 5, while the cheese enriched with chia (B) has a score of 8, and for cheese enriched with sativum (C) has a rating of 6 out of 8.

Cheese enriched with oats (D) has a rating of 7 and for cheese enriched with chia and sativum and chia (E) has a rating of 6, such as cheese enriched with chia and oats (F) has a rating of chia 5 out of 8 While cheese enriched with sativum and oats (G) has a rating of 3 and cheese enriched with all medicinal plants (H) has a rating of 3 out of 8.

In general, tasters' favorite cheese is chia-enriched cheese, with an average rating of 8, while oat-enriched cheese is closest to this rating, with an average rating of 7. These results indicate that the majority of tasters liked the cheese enriched with chia (B). In summary, cheese prepared with medicinal plants was considered acceptable by the majority of tasters.

Conclusion

Our internship at the Boudouaou cheese factory allowed us to closely observe the industrial manufacturing process of uncooked pressed cheese of the "Edam" type enriched with medicinal plants. In addition, we were able to appreciate the approach adopted by the staff to evaluate the physico-chemical and microbiological quality of this product.

In this context, we were able to identify the different factors likely to influence the final quality of the cheese produced. These factors are essentially linked to the quality of the raw material, technological processes and the conditions of product development.

The results of the physicochemical analyzes indicate that the pH and acidity, fat content and density of raw and pasteurized milk comply with standards and that there is a complete absence of antibiotic residues.

For our cheese, the results obtained show compliance with standards for physicochemical criteria. From a microbiological point of view, the results indicate a low total coliform load in raw milk, which is below the normative threshold. This confirms that a simple heat treatment of raw milk gives a good result which translates into a reduction in total germs and compliance with standards. Our results confirm the good hygienic quality of the finished product which is very satisfactory.

Through this work, we have identified the following perspectives:

- ✓ Determination of biological activities such as antioxidant, anti-inflammatory and antimicrobial activity of the seed powders studied in order to highlight their medicinal importance;
- ✓ Determination of the chemical profile of the seed powders studied to isolate bioactive molecules of industrial and medicinal interest;
- ✓ Determination of the antimicrobial activity of the powders of the seeds studied once verified in the cheese matrix with the aim of proposing them as biopreservatives and bioadditives.

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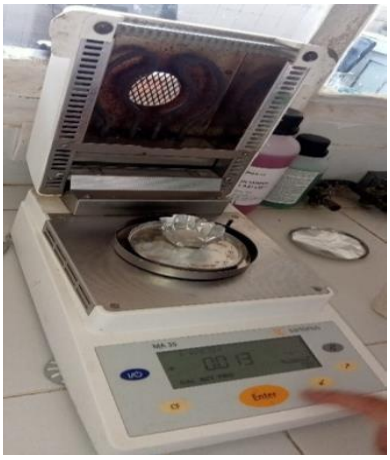
Appendices

Annexe I : The material and culture media used during physicochemical and microbiological analyzes.



Centrifugeuse

Dessiccateur

PH-mètre

Thermo-lacto-densimètre

Butyromètre

Phénophtaléine

Hydroxyde de sodium

Étuve de 43 degrés **étuve de 12 degrés** **étuve de 30 degrés**

L'eau physiologique Acide sulfurique

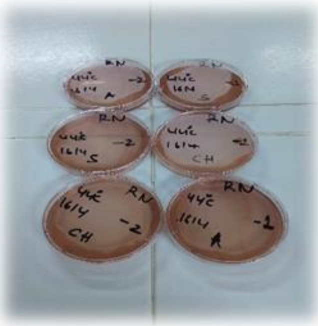
La gélose nutritive La gélose lactosée au désoxycolate

Fromage +eau peptone

La gélose Violet Red Bile Glucose

Eau peptone

fromages edam avant affinages



Les resautas microbiologiques

Annexe II : Questionnaire d‘analyse sensoriel

Age : ………. Ans **Date ....** /…… / 2023

Sexe : Féminin ☐ **Heure :** ………………

Masculin ☐

Consommez-vous le lait ? : Oui ☐ Non ☐

Fréquence : Très souvent ☐ Souvent ☐ Rarement ☐ Jamais ☐

Dans l’optique d’une caractérisation sensorielle du lait, neuf échantillons codés A, B, C, D, E, F, G, H, vous sont présentés. Il vous est demandé de les examiner et de les goûter successivement, puis répondre aux questions qui suivent en cochant sur la case correspondante à votre réponse :

NB : A la fin de chaque dégustation d’un échantillon, rincez votre bouche avec de l’eau.

1. Couleur : Selon l’intensité de la couleur blanche, attribuez une note de 1 à 5 sur l’échelle suivante pour chaque échantillon :

1 = très faiblement intense
2 = faiblement intense
3 = moyennement intense
4 = fortement intense
5 = très fortement intense

A	B	C	D	E	F	G	H

2. Odeur : - Par le nez sans mettre le produit en bouche.

- Selon le degré d’appréciation de l’odeur, attribuez pour chaque échantillon une note de 1 à 5 sur l’échelle suivant :
1 = très faiblement appréciée
2 = faiblement appréciée
3 = moyennement appréciée
4 = fortement appréciée
5 = très fortement appréciée

A	B	C	D	E	F	G	H

3. Saveur : Selon le degré d'appréciation de la saveur, attribuez pour chaque échantillon une note de 1 à 5 sur l'échelle suivant:

1 = ni agréable ni désagréable
2 = très désagréable
3 = désagréable
4 = agréable
5 = très agréable

A	B	C	D	E	F	G	H

4. Gout : - Selon le degré d'appréciation du gout, attribuez pour chaque échantillon une note de 1 à 5 sur l'échelle suivant :

1 = Sucré
2 = Salé
3 = Acide
4 = Amer
5 = Doux

A	B	C	D	E	F	G	H

5. Texture : Selon le degré d'appréciation de la texture (présence ou absence des grumeaux), attribuez pour chaque échantillon une note de 1 à 5 sur l'échelle suivant :

1 = très désagréable (très hétérogène (présence des grumeaux à la dégustation))
2 = désagréable (hétérogène (présence des grumeaux à la dégustation))
3 = ni agréable ni désagréable (intermédiaire (pas totalement lisse, présente de quelques grumeaux))
4 = agréable (lisse à la dégustation)
5 = très agréable (très lisse à la dégustation)

A	B	C	D	E	F	G	H

6. Préférence : Attribuez pour chaque échantillon une note de préférence entre 1 et 9, sachant que le numéro 1 correspond à l'échantillon le moins préféré et le numéro 9 à celui le plus préférez.

A	B	C	D	E	F	G	H

*** Merci pour votre coopération ***

Résumé : L'objectif de cette étude est de produire des fromages de type « Edam » enrichis en plantes médicinales et d'évaluer leurs propriétés physico-chimiques, microbiologiques et sensorielles. Les fromages seront enrichis avec des grains de chia, de sativum (Heb el-rachad) et d'avoine à différents dosages. Le fromage EDAM est un fromage à pâte pressée non cuite à haute valeur nutritionnelle, fabriqué à partir de lait cru. Dans cette étude, nous avons préparé du fromage avec une petite quantité de lait en utilisant la technologie de LFB. Les résultats ont ensuite été comparés aux normes réglementaires. Les résultats des analyses physico-chimiques de la matière première avant et après pasteurisation ont montré que le lait de la région de Boudouaou donnait des résultats favorables à cette production. Les analyses microbiologiques ont révélé que le lait cru contenait un taux élevé de coliformes totaux, mais inférieur au seuil normatif. Ceci indique qu'un simple traitement thermique du lait cru est une méthode efficace pour réduire les germes totaux et assurer le respect des normes. Enfin, un groupe de dégustateurs a effectué une analyse sensorielle afin d'identifier les qualités sensorielles (couleur, odeur, goût et texture) de nos fromages et de les classer en fonction de ces caractéristiques. Les résultats de cette analyse ont démontré que le fromage enrichi en graines de chia était le plus apprécié.
Mots clés: Fromage Edam, plantes médicinales, Analyses physico-chimiques, Analyses microbiologiques, Analyses sensorielles.

Abstract

The aim of this study is to produce 'Edam' cheeses enriched with medicinal plants and to assess their physicochemical, microbiological and sensory properties. The cheeses will be enriched with grains of chia, sativum (Heb el-rachad) and oats at different dosages. Edam cheese is an uncooked pressed cheese with a high nutritional value, made from raw milk. In this study, we prepared cheese from a small quantity of milk using LFB technology. The results were then compared with regulatory standards. The results of physicochemical analyses of the raw material before and after pasteurization showed that milk from the Boudouaou region gave favorable results for this production. Microbiological analyses revealed that the raw milk contained a high level of total coliforms, but below the normative threshold. This indicates that simple heat treatment of raw milk is an effective method of reducing total coliforms and ensuring compliance with standards. Finally, a group of tasters carried out a sensory analysis to identify the sensory qualities (colour, smell, taste and texture) of our cheeses and to classify them according to these characteristics. The results of this analysis showed that the cheese enriched with chia seeds was the most appreciated.
Keywords: Edam' cheeses, Medicinal plants , Physicochemical analyzis, Microbiological analyzis, Sensory analyzis.

الملخص: الهدف من هذه الدراسة هو إنتاج أجبان من نوع "إيدام" غنية بالنباتات الطبية وتقييم خصائصها الفيزيائية والكيميائية والميكروبيولوجية والحسية. سيتم إثراء الجبن بحبوب الشيا والساتيفوم (حب الرشاد) والشوفان بجرعات مختلفة . جبن الإيدام هو جبن مضغوط غير مطبوخ ذو قيمة غذائية عالية، مصنوع من الحليب الخام. في هذه الدراسة قمنا بتحضير LFB. الجبن من كمية صغيرة من الحليب باستخدام تقنية ثم تمت مقارنة النتائج بالمعايير التنظيمية. أظهرت نتائج التحاليل الفيزيائية والكيميائية للمواد الخام قبل وبعد البسترة أن الحليب من منطقة بودواو أعطى نتائج إيجابية لهذا الإنتاج. وكشفت التحليلات الميكروبيولوجية أن الحليب الخام يحتوي على مستوى عال من مجموع القولونيات، ولكن أقل من العتبة المعيارية. يشير هذا إلى أن المعالجة الحرارية البسيطة للحليب الخام هي وسيلة فعالة لتقليل إجمالي القولونيات وضمان الامتثال للمعايير.أخيرًا، قامت مجموعة من المتذوقين بإجراء تحليل حسي للتعرف على الصفات الحسية (اللون والرائحة والطعم والملمس) لأجباننا وتصنيفها وفقًا لهذه الخصائص. أظهرت نتائج هذا التحليل أن الجبن المخصب ببذور الشيا كان الأكثر تقديرً
الكلمات المفتاحية: جبن الإيدام ،النباتات الطبية تحليالت فيزيائية كيميائية، تحليالت مكروبيولوجية، تحليالت حسية.