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Study and design of a multiproduct plant of vegetable beverages

Estudio y diseño de una planta multiproducto de bebidas vegetales

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Algunas persones quieren que algo ocurra, otras sueñan con que pasará, otras hacen que suceda

Michael Jordan

En primer lugar, querría agradecer a mis dos tutoras Alicia Maestro y Esther Chamarro por su compromiso conmigo y por toda la ayuda incondicional prestada a lo largo de estos meses. Querría mencionar también a Manel Vicente por su aportación indispensable en el trabajo y su trato tan cercano y amigable.

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REPORT

INDEX

SUMMARY

The current project is focused on the development of several plant-based beverages in a multiproduct plant. The high percentage of lactose intolerant people, the great contribution of livestock to global warming and the increasing cow's milk allergies makes it crucial to find an alternative to the classical cow milk. Furthermore, people are becoming more aware about their fitness and lifestyle and these types of beverages are perceived as healthier as bovine milk, gaining importance in the market. Other reasons to bet for these types of products are their sustainability and their impact on the environment. As bovine milk needs a lot of water and huge areas of land for its production, plant-based milks don't require such amounts of water and land. In addition, CO_2 emissions are another problem of cow's milk and another reason why people decided to change to vegetable beverages.

This work is based on the development of formulated products, including all steps of this procedure: market study, product conceptualization, quality criteria, product formulation, design the manufacturing process and a scheduling to plan the production.

Three different types of plant-based milks have been selected to produce due to their popularity and consumption here in Catalonia. These beverages are soya milk, almond milk and oat milk. There is a general production process for all types of milk but obviously modifications have been made depending on the raw material used and the aims of the present thesis.

Two main quality criteria have been stablished to make this product especially appealing, which are their nutritional value and the flavor. When it comes to flavor, lipoxygenase and its oxidation reaction plays an important role when designing the production process and specially the equipment. In the present work one of the aims is to avoid the activation of this enzyme to improve the final flavor of the milk. On the other hand, to launch an alternative to cow's milk, the substitute must have similar qualities in terms of nutritional value. Depending on the raw material, amounts of these nutrients differ from each other but in all of them there is a specific way to make the addition of nutrients in order to enrich the beverages.

Finally, to plan the production and operate properly it has been made a scheduling. Firstly, a batch size of 6000kg is stablished according to the total production wanted per year, the way milks are delivered and considering a production unit of six carboards of one liter of milk each. Afterwards, time required for each stage is estimated to plan the number of batches carried out every month. In this amount of time, it is included not only the main operation but also other operations such as the charging of the product or the cleaning. Taking into consideration the time and the total production to be carried out, it is estimated how to operate in the plan.

1. INTRODUCTION

All health problems caused by bovine milk combined with a high concern of the population towards the climate change triggered the research of new trends and products. People demand more sustainable solutions, based on natural ingredients and, if possible, with high quality of taste and texture. This is how plant-based milks, a future new trend, is taking more importance step by step in our society.

Plant-based milks, also known as plant milks, are extracts of legumes, cereals, nuts and/or seeds emulsified in water. They do not contain neither cholesterol nor lactose, which are two important factors when choosing between them or cow's milk. Thus, plant-based milks are perceived by people as healthier than bovine milk. Although their late popularity, they have been consumed for centuries in the past. In Spain "Horchata" is made from tiger nuts, in Korea "Sikhye" is made from cooked rice and malt extract, and in Uganda "Bushera" is made from fermented sorghum [1]. These are some examples, but there are many typical vegetable drinks consumed around the world, especially in Asia. Plant milks can be classified in five categories:

- Legume-based milks.
- Cereal-based milks.
- Pseudo cereal-based milks.
- Nut-based milks.
- Seed-based milks.

Their production process is very similar between each other with some variations depending on the raw material. Usually, the process begins with a soaking step, followed by a grinding. Then there is a filtration/centrifugation to separate the solid of the liquid phase. Afterwards, a heat treatment is carried out (UHT or pasteurization), followed by a homogenization. And finally, some nutrients such as calcium or some vitamins are added to the product [1].

As mentioned before, people tend to a plant-based diet because of several reasons. The most common reason is due to the lactose intolerance. It is estimated that 65% of world's population is lactose intolerant, then the market has evolved through the years to find an alternative resulting in the sprout of plant-based milks.

Lactose intolerance is not the only reason why people choose vegetable drinks over cow's milks. Cow's milk allergy (CMA) is very frequent in children and is the result of an immunological reaction to certain protein in cow's milk, particularly β-lactoglobulin and casein, which can cause hypersensitivity reaction. Antibiotics, pesticides, and hormones also play an important role here because they are given to cows in order to increase their production.

Finally, a very important issue to take into consideration when people doubt between plant-based milk or bovine milk is the environmental impact that causes their production process. Livestock is responsible of 16% of the total greenhouse emissions [1] what makes a big drawback for bovine milk. Furthermore, some organizations like Food and Agriculture of the United Nations (FAU), stated the livestock sector as a great contributor to climate change. Another important thing to point out is the water footprint comparison between the animal-based products and the plant-based products. And finally, the land usage when producing bovine milk is much higher than the one required for plant-based milks. Naturally, these parameters depend on the vegetable beverage, but in general the land usage is much lower. It happens something similar to the CO_2 emissions throughout the production process of each milk. In Table 1 and Figure 1 is summarized all this information concerning the impact of cow's milk against the plant-based alternative:

Table 1: Water required to produce different types of milk [1]

Beverage	Water required [L]/Liter of milk
Cow's milk	628
Almond milk	371
Rice milk	270
Oat milk	48
Soy milk	28

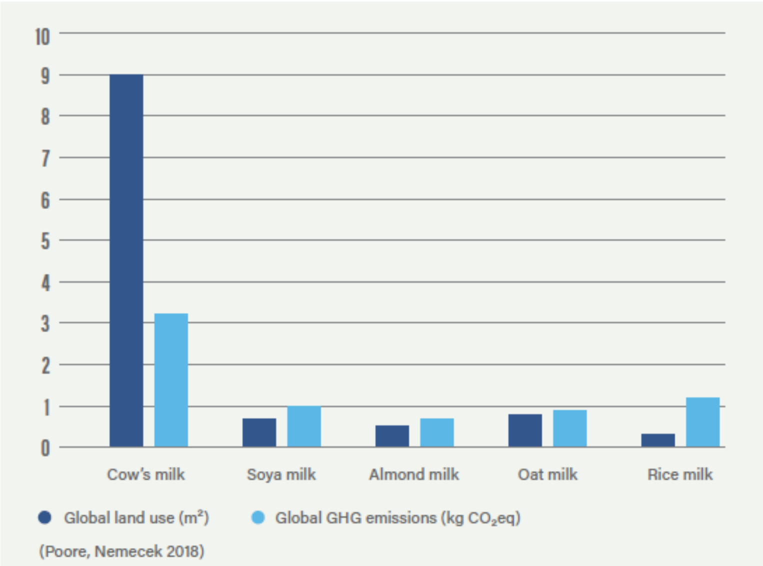

Figure 1:Represents on a scale from 1 to 10 the following concepts: Light blue corresponds to kg of CO_2 equivalent per 100g of protein. Dark blue corresponds to m^2 of land multiplied per years occupied per liter produced [1].

In terms of nutritional value and health benefits, plant-based milks provide a great deal of advantages when consumed. For example, the energy input per unit of milk produced is less compared with conventional cow milk. They also have fewer calories, less fat and lower carbohydrates content. Recent studies have concluded that the consumption of these beverages has a vital role in the improvement of immune system, they also have potential antimicrobial effects and help to reduce the risk of cardiovascular as well as gastrointestinal diseases [2]. Consumers state that introducing plant-based milk in their daily diets makes easier the digestive tract and they feel physically better.

1.1 LEGAL FRAMEWORK

When one comes to the nomenclature and how to address to all these products, it should be kept in mind that laws differ a lot depending not only on the country but also on the continent. In countries such as China, South Africa and India, milk alternatives based on soya are usually marketed as soya milk. However, in other countries this is a term absolutely forbidden. Food and Drug Administration (FDA) from the USA defines the Standards of Identity and describes milks as “the lacteal secretion of one or more healthy cows” [1]. Although there is a stablished definition, many manufacturers do not apply the definition and use the term milk for vegetal beverages. Something similar happens in Australia and New Zealand, but in Europe the term milk for vegan dairy is prohibited. There is a legal framework for naming dairy alternatives stipulated by Regulation (EU) 1308/2013 of the European Parliament and the Council [1]. It provides legal basis for the ban of dairy names for plant-based alternatives.

Then it can be concluded that here in Europe this industry is politically in disadvantage but the taxation of plant milk in EU varies from country to country. In Germany, plant milks bear 19% value added tax (VAT) and are classified as luxury food. Another interesting political fact is that a total of 23 countries have integrated plant milk into their national nutrition guidelines as an alternative to cow’s milk.

In some cases, like the one concerning “Tofutown [1]”, the firm was sued because they use these terms incorrectly and the legal framework stablishes that dairy products are the ones that contain secretion of animals [1]. Nevertheless, there are some exceptions when referring to some product from a plant-based origin. Some examples are coconut milk or peanut butter. The reason of this has a controversial explanation because, according to the decision 2010/791/EU of the Commission [1], these terms can be applied to the products, the exact nature of which is clear from traditional usage and/or when the designations are clearly used to describe characteristic quality of a product.

1.2 TYPES OF PLANT-BASED MILKS AND THEIR CHARACTERISTICS

Plant-based milks are proposed to be the substitutes of cow’s milk therefore, before designing a process to obtain these products, it is important to understand bovine milk properties. This way, the vegetable beverages have the suitable characteristics to replace cow’s milk.

Bovine milk is a complex colloidal dispersion consistent of tiny fat globules and protein nanoparticles suspended in a watery medium that contains various soluble compounds such as sugars and proteins. The composition of bovine milk depends on the type of cow, its age, and its health but in general it can be stablished the following [3]:

- 87 % water.
- 4 %-5 % lactose.
- 3 % to 4 % fat.
- 3 % of protein.
- 0.8 % minerals.
- 0.1 % vitamins.

The particle size of the suspended phase ranges from 4 µm to 5 µm for fat globules and 150 nm for casein micelles [3]. In case of fat globules, they are big enough to be carried to the surface by the gravity forces, destabilizing the emulsion and consequently making it unsuitable to be sold. This process is called creaming and it is usually avoided with a homogenization that reduces the size of fat globules to less than 500 nm by breaking them into smaller droplets. It is not completely eliminated the creaming risk but it takes much time. Then, using a homogenization, the shelf life of cow's milk (as well as plant-based milks) is improved.

Due to the high nutritional value of cow's milk, this is a perfect ecosystem for bacteria to thrive and they can cause quality deterioration or health problems when consumed by human. That is why a heat treatment is carried out to eliminate all these bacteria before a commercial distribution of the beverages. Again, the elimination is not permanent, and the duration of a suitable and edible milk depends on the process used to carry out the heat treatment.

Consumers are used to cow's milk sensorial and physicochemical properties attributes. Its bland flavor is one of the most important point to bear in mind, as well as its low viscosity and opaque creamy white appearance. Chemical reaction, microbial growth prior to consumption and the macronutrient composition are factors that determine all these attributes.

Cow's milk is a thermodynamically unstable emulsion and that's why homogenization is carried out. Nevertheless, there are other problems that can destabilize the beverage such as the flocculation or coalescence processes. By adjusting a pH or adding salts, this problem can be solved.

Finally, an aspect that should be studied throughout the launching of the product is the nutritional value of the beverage. As shown before, cow's milk has a specific macronutrient structure and the one from plant-based milk must be similar to attract consumers. However, this structure of the vegetable beverages differs a lot depending on the raw material used. Then, depending on the chosen products, there should be some changes in the quantity of nutrients added to the drinks.

Taking into consideration all this data, the purpose is to replicate a similar structure and characteristics but using vegetable raw materials. Obviously, there will be some big variations, such as the lack of lactose. In general, all plant-based milks have some common stages in their processes, and they will be summarized in the following points.

2. OBJECTIVES

The present work has the following objectives:

- Carry out the design of several plant-based milks including their formulation, their structure and the design of their production process, by making a market study to select the products as well as stablishing the quality criteria to make them appealing to be consumed. The types of packages used and the way milk is delivered is also included in the present project.
- Select and design the equipment necessary to produce industrially these beverages always bearing in mind the quality criteria stablished.
- Make a scheduling according to all data collected when working with discontinuous processes: Batch time, batch size and the critical stage. Thus, it is thought the best way to carry out the different processes and operations to produce in the plant.

3. GENERAL WAY TO PRODUCE A PLANT-BASED MILK

3.1 FIRST SELECTION

Before introducing the raw materials into any type of equipment of the process, a first inspection must be carried out in order to separate everything that does not correspond to the raw material, such as rocks, twigs or little animals. This is usually made manually by the operators of the plant or directly bought to a supplier without all these. The following process described uses the raw materials dehulled and ready to be treated.

3.2 SOAKING

A plant-based milk is an oil-in-water emulsion where the fat fraction is extracted from the plant used. To do it, a grinding process is necessary but to make it much easier, it is important to soften the beans, legumes or seeds selected. Then, the soaking plays a very important role in the following stages of the production because it affects to the texture of the raw material. The soaking consists of putting in contact the raw material with water for a certain period of time. Depending on the raw material, the solid absorbs more or less water. The traditional way to carry out a soaking is based on using a vessel at ambient temperature (25-30°C) and ambient pressure with no special characteristics [4]. This is the procedure followed throughout centuries in Asia but the problem in Europe and in USA is the grassy final flavor of the drink. Western societies are not used to this taste and, although the high benefits of plant-based milks, this is a big disadvantage when launching the product in a place like Spain.

3.3 CENTRIFUGATION

Once the raw material is soft enough it is separated from the soaking water. Here there are several possibilities but the fastest and most modern one is by centrifugation. The solid is kept and the water is sent to an EDAR due to the levels of DBO.

3.4 WET MILLING

At this point there is just the soaked raw material, and more water is added, to have a 15% of solids on the whole mix [5], to a wet miller. Here, the solids are grinded to obtain their oils that consequently will be emulsified. Proportion of water added will determine the concentration of the raw material in the final beverage, which is usually between 10% to 15%. This operation must be done in a wet miller capable of operating with solids and water. This equipment has a big advantage from the dry grinding in terms of safety processing. Here, with the presence of water, risks of dust explosions are very low making the operation much safer. In addition, there is no point on working with dry grinding when then water is added to the process.

3.5 FILTRATION

Right now, a mix of a grinded solid, oils and water is obtained. The aim now is to separate the liquid to further treat it and obtain the final milk. To achieve it, filtration is made, separating the liquid phase (oils and water), and taking the solids apart, which can be further used to produce food for livestock, as it is usually made in Asia [6].

3.6 HEAT TREATMENT

One of the most important points to take into consideration when producing something edible for humans is the shelf life of it and the fact that it must be free from any pathogens. One of the most used ways to achieve these objectives is based on the pasteurization. This process was patented in 1860 by Louis Pasteur and consists in treating the food at mild temperatures below 100°C to destroy pathogens for a period of time not higher than 30 minutes. Th aim is to eliminate every source of life that can cause the spoilage of the product or diseases on a human being. The process also includes a cooling step to destroy all spoilage organisms. However, pasteurization provides a very short period of time, in best cases about 21 days [7], where the food is free from harmful bacteria, whereas using other processes, like ultra-heat treatment commonly known as UHT, a much longer shelf life can be achieved eliminating 99.9% of bacteria from the milk. In this, the product reaches higher temperatures (140°C) and the drastic temperature changes is the fact with which milks can reach a shelf life that ranges from 30 days to 90 days [7].

3.7 HOMOGENIZATION

At this point of the process, there is a coarse emulsion of oils in water that quickly separates, so a fine emulsion must be prepared to finally obtain the milk. The drink is already sterilized, and the homogenization is proceeded. As it happened in the UHT unit, the homogenization is composed of several equipment and consequently, the usual thing to do here is to contact a specialist to buy the whole skid with the objective of obtaining the final product with the characteristics required. In this case, it must be noted that the drop size of 150 nm [3] is a quality criteria that must be achieved with the homogenization unit.

There are three types of homogenizers worldwide used and their characteristics are what make them suitable for a certain kind of activity [8].

Rotor/stator homogenizers are a quick and efficient solution to handle with plant and animal tissues and other solids materials. They have a long shaft with angled knives at the bottom that shred the material. Then, the material is drawn up into a stator tip and ejected from small holes in the side of the stator to be sheared again.

High pressure or also known as piston pressure are usually used with liquids. They force the material to flow though small gaps to disrupt the drops and achieve finer textures. This method is the one chosen to produce plant-based milks and it will be explained deeply in section 5.

Sonic disruptors use ultrasonic intense waves to break up the particles. Waves range from 18 to 50 Hz and they are capable of exerting pressures of about 500 atm.

3.8 ADDITION OF NUTRIENTS

One of the main problems in plant-based milks is the lack of some important nutrients for human beings. Vitamin D and calcium are essential, and they are often present in our daily diet, then consumers search for alternatives that at the same time could give them a suitable nutrition. In general, cow's milk is the main source of calcium for people and if it is not consumed this could result into long term health problems. There are different ways studied to make the addition, but it must be taken into consideration the bioaccessibility not only of calcium but also of the other nutrients added, such as vitamin D [9].

Nanoemulsions are one of the most versatile means of encapsulating micronutrients into food and beverages, especially for vitamins [9]. These systems are designed in a way to ensure good product attributes and as well as high bioavailability. Nanoemulsions are utilized to encapsulate oil-soluble vitamins within the lipid droplets, such as vitamin D, but these systems must be carefully designed and added to the mix to ensure stability and bioavailability.

3.9 PACKAGING

At this point of the process, the final milk is obtained, and the only stage left here is to prepare all the objects that contain the beverages. To achieve this objective, an aseptic packaging unit is selected. This is usually composed of a sterilized tank that has the main product and a dosing machine. This unit plays a crucial role in the final quality of the product because if there is a zone that is not sterilized then it affects to the shelf life of the milk and it could even have problems such an expiration date different from the one stablish in the product label.

It can be used the previous stirred tank from the nutrient's addition as the vessel where the dosing machine is connected to fill all the package. In this case, another nozzle must be added to this tank to fill all the free space with nitrogen and work in sterile conditions. The dosing machine must be capable of working through a period of time enough to fill the whole batch size into the chosen production unit. The selected package is the paperboard carton and one of the reasons of it is because its opacity. This product is made as natural as possible without the presence of flavor additives or colorants, then, it is possible that with time the aqueous and oil phase can separate each other, and this fact could have an impact on consumers when deciding to buy it or not. This way, this problem is avoided, and it must be bearded in mind that on the paperboard there must be a note saying, "shaking before consuming it".

The paperboard is coated on both sides with polyethylene to make it impermeable to liquids and to facilitate the sealing. It is also incorporated a thin aluminum foil layer (6 µm) which makes it impermeable to light and oxygen.

4. PRODUCT SELECTION

Plant-based milks is a wide market, and it is actually one of the growing-fastest ones. This means that it is changing every year and it depends a lot on the country and continent. This project will be focused on Catalonia's population, then it is important to know its preferences, which type of beverage is the most consumed one, the amount of drink consumed, and the possible problems detected in them to solve them if possible. In Table 2 liters per person consumed in every single region of Spain are expressed, including Catalonia:

Table 2: Liters consumed per capita of plant-based milks in Spain [10]

Canarias	7.17 L
Comunidad Valenciana	7.09 L
Islas Baleares	7.07 L
País Vasco	6.89 L
Cataluña	6.71 L
Navarra	6.58 L
Murcia	6.54 L
Cantabria	6.39 L
Aragón	6.18 L
Madrid	4.57 L
Galicia	4.23 L
Castilla y León	3.62 L
Asturias	3.21 L
Castilla la Mancha	3.15 L
Andalucía	2.92 L
La Rioja	2.64 L
Extremadura	2.13 L

The number of liters consumed of plant-based milks per year combined with the total population of Catalonia are important data to stablish a batch size and consequently design and select all equipment and elements necessary for the production. Nevertheless, choosing the milks that are going to be produced in the plant is the second step before making any type of calculation. In Figure 2 are summarized the most consumed plant-based milks around the world by percentage and the most famous ones are pointed out.

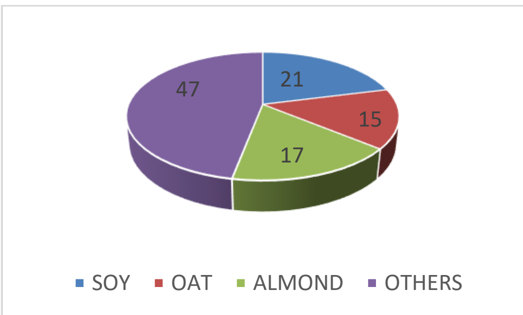

Figure 2: Consumption of plant-based milks [%] [11]

Taking into consideration the information from the previous graph, the designed plant will produce three different types of plant-based milks: Soy milk, almond milk and oat milk. The milk will be delivered in bricks of 1L packed in groups of six. Consequently, it is important to stablish a batch size divisible per six in order to plan the production.

It has been decided to produce an amount of soymilk, oat milk and almond milk equivalent to the 2% of the consumption of these beverages in Catalonia. Data to obtain these numbers is taken from statistical numbers [10] [12] and results from these calculations are reflected in Table 3.

Table 3: Production of the plant per year of each milk

PRODUCT	kg/year
OAT MILK	158400
SOY MILK	216000
ALMOND MILK	172800

Considering this information and the data from tables 2 and 3 and figure 2, a batch size of 6000kg is stablished.

4.1 Soy milk

Soy milk or soya milk, which belongs to the legume-based category, is still the most popular plant-based milk around the world. It is the only one that contains the same amount of protein as bovine milk with around 3g per 100mL and, when it is fortified adequately, it can be used as a nutritional cow's milk subtitute. This has been confirmed by institutions such as the US Department of Health and Human Services and the National Health and Medical Research Council in Australia [1]. Furthermore, due to the similarity in properties with bovine milk, soymilk can be used as a replacement when cooking, baking and other activities related with food.

This plant-based milk has great benefits in terms of human health. Studies show it can help to reduce the risk in heart diseases as well as some forms of cancer. However, it has been proven that some people are developing allergies when consuming this vegetable beverage. Although the levels are much lower than in bovine milk, this is an important drawback in this product.

4.2 Almond milk

Almond milk, which belongs to the nut-based category, is one of the most consumed plant-based milks throughout the years and in the middle ages it was already produced in Europe. Almonds have a high nutritional value with high amounts of calcium, fiber or magnesium in comparison with soybeans or other raw material used to produce vegetable beverages. Nevertheless, the problem when producing almond milk remains in the process, because most of its nutrients, especially protein content, remain in the pulp when this is filtered.

Academy of Nutrition and Dietetics recommends enriched almond milk as substitute to cow's milk for children that have developed allergies to it or simply do not want to consume animal-based milk.

4.3 Oat milk

Oat milk, which belongs to the cereal-based category, is the fastest growing market in plant-based milk industry not only for the nutritional value of the raw material but also for its taste. The presence of dietary fiber, phytochemicals and antioxidants make them especially appealing to people. In addition, studies have shown its positive effect on gastrointestinal problems as well as being anticarcinogenic [1].

Oats have a higher sugar content than most of the plant-based milk, therefore they taste slightly sweet. Nevertheless, its taste is still something different for western cultures and sometimes some manufacturers tend to add flavor additives to improve it.

4.4 Quality indexes and criteria

When a product is conceptualized, and the aim is to launch it to the market then it is expected an acceptance from people and consequently a consumption of the product. To make plant-based milk appealing it is important to stablish certain quality criteria to meet the requirements of the market and to consider these beverages as an alternative to the conventional bovine milk. Thus, plant-based milk must have similar characteristics to cow's milk but at the same time provide something different, in this case, its origin and the repercussions that this entails.

4.4.1 Visual attributes

The appearance of the product is always the first thing that consumers are focused on. Plant-based milks have a similar color as the conventional bovine milk, but they can sometimes differ from the typical white depending on the raw material. For example, in almond milk, the raw material is usually firstly roasted [13] to improve the organoleptic and taste attributes and consequently the color is a little bit brownish. It is possible to add colorants to make the product visually more attractive but these decisions is usually made when there are also added substances to change the flavor. An example can be a dark brown color plus a chocolate flavor [14]. In the present work neither colorants nor flavor additives are added. Thus, the usual color is white with the exception of the almond milk that is brownish. Analysis of color can be made using a colorimeter.

4.4.2 Textural attributes

The second important point of this products is how people perceived in their mouths and how it flows. Plant-based milks are dispersions of oil droplets in water which shear viscosity can be primarily predicted with empirical equation that stablish a relationship between viscosity and the concentration of particles. Viscosity increases fairly gradually as the particle concentration is raised but then it increases steeply when the particles are more closely packed. Figure 3 illustrates this behavior [14].

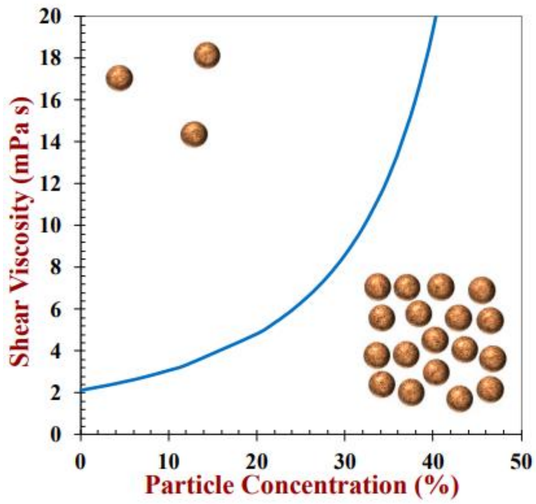

Figure 3: Shear viscosity of plant-based milks depending on the particle concentration [14].

In other words, viscosity is an important fact to take into consideration and it must be as similar as possible as cow's milk, which it ranges from 2 mPa·s to 22 mPa·s depending on the fat content [11]. Taking as a reference a 14% fat milk, its viscosity is 4.9mPa·s and the product to be developed in the present work must have viscosity values close to the interval 2mPa·s to 5 mPa·s. Soymilk for example ranges from 1.2 mPa·s to 9.9 mPa·s [12], almond milk has a fairly constant value of 3.9 mPa·s [13] and oat milk is of about 1.1 mPa*s [17]. In case this value wanted to be adjusted, a thickener should be added, but there is a general acceptance of this viscosity for these products and consequently there is no addition of any type to modify this property [14]. Analysis of viscosity can be made using a suitable viscometer.

4.4.3 Stability

Plant-based milk resistance to changes in the environment while conserving their properties or maintaining them throughout the time while they are stored is another important point to take into consideration. The stability of these products depends on the type of the particles dispersed and their size, the nature of the aqueous solution and also the addition of possible substances that can improve this aspect of this product.

The most common ways to destabilize plant-based milk are the ones based on various physical processes such as aggregation, creaming or flocculation. There are many solution to tackle these problems such as the steric repulsion or bridging attraction [14] but it has been proven that the addition of natural lecithin not only enables the formation of the emulsion but also it improves the stability by reducing the oil-water interfacial tensions and by forming a protective layer around the fat droplets to prevent them from aggregation [18]. This is applied to almond and oat milk and it is not necessary for soymilk because the raw material already contains naturally this compound.

Thus, particle size of plant-based milks plays a crucial role in terms of stability and the size is achieved in the homogenization step. A specific equipment must be selected to meet the requirements and get a particle size of about 150 nm [3].

4.4.4 Taste

When a product is launched to the market, and it is expected to be innovative around consumers it must have some specific characteristics to attract people and make it appealing. One of the two most important quality criteria stablished to make this product different is flavor.

There is a traditional way to produce plant-based milk where the raw material is soaked at ambient temperature and then is wet-milled. The problem here is that the raw material contains an enzyme called lipoxygenase. This enzyme carries outs a reaction which products are responsible of the formation of nine- and thirteenth-hyperoxide isomers of linoleic acid in which the hydroperoxide oxygen drives from the gaseous phase. The hydroperoxides in turn undergo some enzymatic and non-enzymatic reactions to produce volatile carbonyls and organic acids which have very low flavor thresholds [5]. Then, when all these reactions are done, the plant-based milk has its traditional grassy flavor that it is not widely accepted in the western culture.

The present project has the aim of improving this flavor by inactivating the enzyme. The solution here is to make a heat treatment to have the initial mix at certain temperature where this enzyme is denaturized.

To make the corresponding analysis a group of volunteers are enough, giving them a plant-based milk made taking into consideration the deactivation of lipoxygenase and a milk without caring about it.

4.4.5 Nutritional value

Plant-based milks are said to be implemented in the everyday lives of human beings as alternative to cow's milk. Nevertheless, one of the main problems of these vegetable beverages is the low content in some nutrients like calcium or vitamin D, which are vital for the good development of people. In turn, bovine milk has a higher content in these nutrients, and this is one of the reasons why in general plant-based milks are not fully accepted yet. However, lately, manufacturers realized about this problem, and they are managing to solve it by adding the nutrients in some stages of their production process while at the same time keeping the other properties of these drinks.

Table 4: Nutritional value of different beverages [16]

BEVERAGE	Ca^{+2} [mg/100mg]	Vitamin D [IU/100mL]
Bovine Milk	122-134	120
Soy milk	4.0-5.4	0
Almond milk	13.05-13.15	0
Oat milk	84.30-85.60	0

As it can be seen, vitamin D is scarcely found in food and specially in these types of products. Vitamin D is crucial to contribute to the absorption of calcium, one the main building blocks for strong bones. Otherwise, people can develop diseases like osteoporosis damaging the health of the human being [20]. Naturally, soybeans, almonds and oat contain amounts of vitamin D so low that they can be negligible. Furthermore, although milk contains vitamin D, it is not the main source for people to obtain this nutrient. For example, vitamin D content in salmon ranges from 288 IU to

988 [21] . This is the reason why both nutrients are added to the plant-based milks selected to produce, because this characteristic makes these products better than bovine milk in this aspect.

Column of vitamin D is in IU units which correspond to the international units. This is a unit to measure the amount of substance based on the biological activity. It changes depending on the substance studied and in the case of vitamin D each IU is the equivalent to 0.025 µg colecalciferol/ergocalciferol. Then, to convert IU to µg of vitamin D the value must be multiplied per 0.025 [21].

4.5 Composition of the final products

The present project focusses on the development of three different products which are soymilk, almond milk and oat milk. Because of the use of a different raw material in each case, the final composition of the drink is different. Table 5 shows a proposal for the composition of the milks to be produced in this plant.

Table 5: Composition of the milk produced in the present project.

PRODUCTS	FORMULATION
Soy milk	15 % soy 0.35 % calcium 0.1 %< vitamin D [0.012µg vitamin D/ g milk] 84.55 % water
Almond milk	15 % almond 0.11 % calcium. 0.1 %< vitamin D [0.012µg vitamin D/ g milk] 84.76 % wáter 0.03% Lecithin
Oat milk	15 % oat 0.40 % calcium 0.1 %< vitamin D [0.012µg vitamin D/ g milk] 84.4 % wáter 0.03 % Lecithin

5. SPECIFIC PRODUCTION PROCESSES OF EACH MILK AND EQUIPMENT

In this section the specific stages of every production process for each milk are explained, deepening in the different particularities of them and the decisions made in order to meet the requirements of the quality criteria and improve as much as possible the production.

5.1 Soymilk production process

Figure 4 illustrates the scheme of soymilk production process, which is the most generic one in plant-based milk industry. Almond milk and oat milk production processes have few variations from soymilk production process, but Figure 4 gives a general idea of how to produce these beverages.

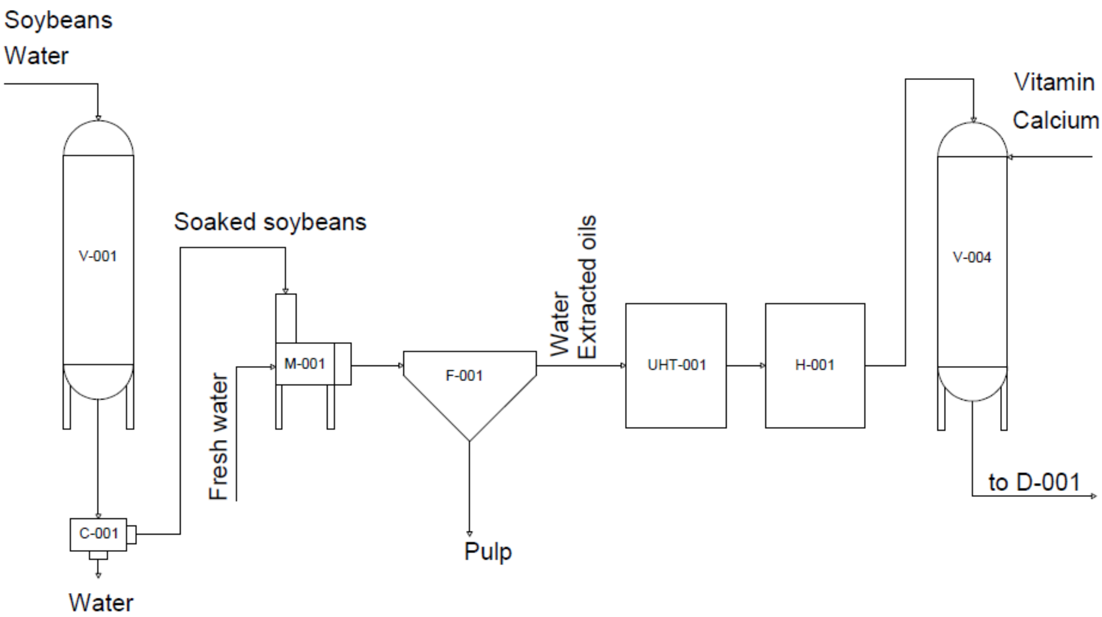

Figure 4: Soymilk production process. V-001 is the soaking tank; C-001 is a centrifuge; M-001 is a wet miller; F-001 is a filter; UHT-001 is the UHT unit; H-001 is the homogenization unit; V-004 is the final vessel where nutrients are added.

5.1.1 Soaking

The process to produce soymilk is probably the most generic one where all steps explained in section 1 are present. As soon as the raw material is selected, and all debris are separated the soaking stage begins in a vessel (V-001) big enough to contain an amount of water seven times higher than the amount of raw material used. As explained before, in this stage the solid and the liquid are in contact to improve the following stages. Time required for this operation is usually of 360 minutes for soybeans, as well as other raw materials such as oat [4]. However, this vessel not only has enough capacity to carry out this operation, specifically 15 m^3, but also it has other specifications to meet the requirements of the quality criteria.

5.1.1.1 Heating system design

Lipoxygenase reactions give an undesirable taste to plant-based milks, but inactivation of the enzyme can be achieved by heating. In fact, the whole activation of the enzyme occurs when the beans are grinded in the wet milling stage, then some considerations are taken to previously achieve the denaturation of lipoxygenase. A half coil jacked around the ferrule and bottom of the tank is the solution to achieve a temperature of 70 °C when the enzyme is inactivated [5]. The number of turns depends on the surface required to make the heat exchange and the thermic fluid used. Its distribution will be important because of the presence of a temperature sensor and a level sensor. Using steam is the most common way to make an increase of temperature in a tank when temperatures higher than 300°C are not required. Making the necessary calculation, to achieve the temperature of 70°C in 30 minutes, it is required an exchange surface of 11 m^2, which implies a length of 43.5 m. These numbers are obtained firstly calculating the energy required to increase the temperature from 30°C to 70°C of the whole mass (10500kg of water and 1500kg of raw material). To do it, equation 1 is used.

$$Q = m * Cp * \Delta T \quad (1)$$

Where "Q" is the energy required (W) to achieve the increase of temperature in 30 minutes, "m" the whole mass, "Cp" the specific heat calculated considering the water and the raw material, and "ΔT" the temperature increase.

Then, to know the area required to make the heat exchange, equation 2 is used.

$$Q = U * A * \Delta T \quad (2)$$

Where "Q" is the heat already calculated, "U" is the heat transmission coefficient which value is taken from bibliography [22], "A" is the area and ΔT is the temperature difference between the hot fluid (160°C of the steam) and the cold fluid. Temperature of the cold fluid increases from 30°C to 70°C, but to make these calculations, it is assumed the worst case considering that the cold fluid is at 70 °C of temperature. Finally, a typical diameter of DN80 for half coils is supposed to estimate a length.

The disposition, the number of turns or the separation between them must be defined by the manufacturer. Figure 5 illustrates how the heating system is designed.

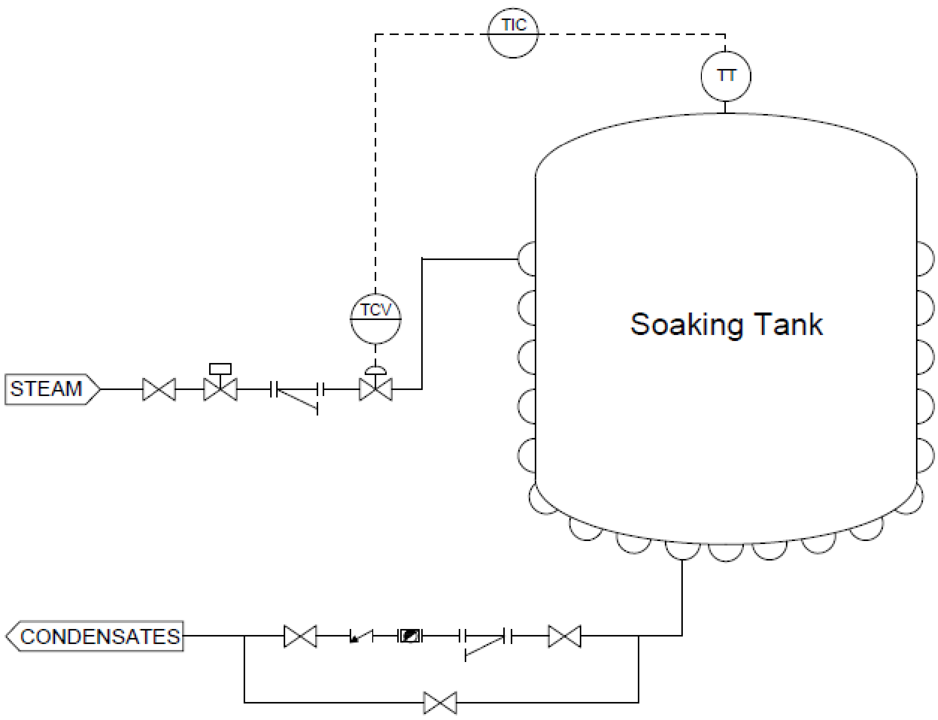

Figure 5: Scheme of a heating system for a soaking tank.

The flow of steam is regulated with a seat control valve (TCV), connected to a temperature indicating controller (TIC), placed in the control panel where the controlled variable can be seen. Eventually, the temperature indicating controller is connected to the temperature transmitter, which is located on the top of the tank. To ensure a proper operation of the half coil, some elements are disposed in order to avoid some possible problems. In the steam line from Figure 5, the elements from left to right are pointed out and their function is explained:

- A cut valve to cut the steam flow when maintenance is necessary, for example, to clean the pipes.
- An automatic valve to avoid leakages that can harm the half coil when steam is not used.
- A filter to prevent the entrance of solids to the control valve that can harm it.
- A control valve to regulate the flow of steam to heat the vessel.

A pressure control valve can be necessary depending on the pressure of the steam of the plant and the pressure of the steam required to carry out the operation. In this case, this valve would be installed in the beginning before the cut valve.

As it can be seen in Figure 5, it is also necessary some equipment to deal with the condensates. The elements from right to left are pointed out and its function is explained in the condensates line:

- A cut valve also used to cut the liquid flow when maintenance is necessary.
- A filter to avoid the entrance of solid particle into the trap.
- A trap that only allow the circulation of liquid. It can be possible that a certain amount of steam did not condensate and in a plant, it is important to separate the steam and the condensate pipe distribution.

- A retention vale to avoid the recirculation of the condensates into the trap that would break the instrument.
- Another cut valve used with the first cut valve and the bypassed cut valve to make maintenance work.

When designing this type of installations, it is very important to make some considerations not only to optimize the operation but also to prevent it from breaking. A very important fact is to place the temperature indicator above the half coil jacket and at certain distance to make the temperature reading properly and avoid problems due to the proximity of the source of heat. Furthermore, it could even break the instrument no matter if there is a probe sheath or not.

Connections of the pipes with the half coil must be done as in figure 5, where the steam is connected in the highest point and the condensates into the lowest point. The reason for this is to use the gravity to circulate the condensates and make the installation and the distribution of services much simpler.

Pipelines of steam as well as condensates must be heat insulated to avoid losses of energy or at least minimize them.

5.1.1.2 Blanketing

Lipoxygenase reactions consists of the oxidation of lipids of the raw materials. Then, to carry out these reactions it is required not only the activation of the enzyme but also lipids and oxygen. Then, another decision made to avoid this reaction is a blanketing operation with nitrogen to prevent the lipid from being oxidated. An entrance of nitrogen is designed to replace the presence of oxygen for nitrogen, which is an inert gas that rarely reacts. Figure 6 illustrates the scheme of a blanketing system, where “xx” corresponds to the pressure of the nitrogen on the plant, which is unknown.

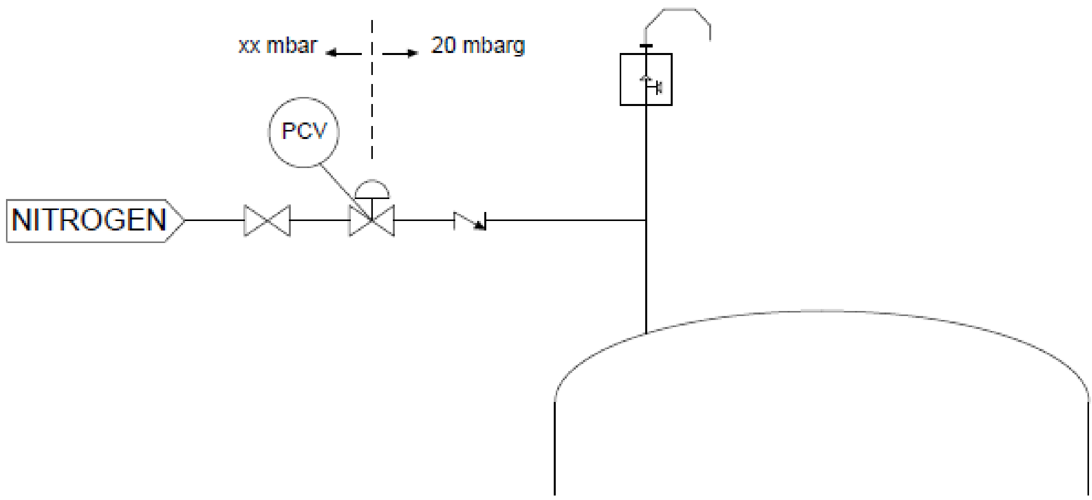

Figure 6: Blanketing system for a soaking tank.

From left to right in the nitrogen line from figure 6 there is firstly a cut valve to cut the flow when necessary. Afterwards there is a pressure control valve that reduces the pressure of the flow 1.2 bara. This is made to have a slight overpressure in the tank to avoid the entrance of oxygen. The inlet pressure depends on each plant or the source where it comes the nitrogen and if it is too high (for example 7 atm) it is usual to install two pressure control valves. This way there is a mid-pressure, and this high reduction of pressure does not lie on just one valve. In addition, there is a vacuum pressure valve tared at a pressure slightly higher of about 1.9 bara to avoid a constant loss of nitrogen and, in case the nitrogen flow fails, there is an air entrance, to avoid a collapse.

5.1.1.3 Other connections

Apart from the connections required for the blanketing and the heating system, the vessel requires other nozzles to carry out the soaking step. As it is logic, an entrance for the liquid water and another one to charge the raw material. In the case of the raw material, it is something solid that it is charged manually by operators that pour big bags of raw material through the manhole.

To make a homogenous heating the water with the raw material inside the vessel must be mixed. In this case, it is necessary a nozzle to connect the agitator with its engine. The agitator required here is as a typical one used for solids, an anchor type like the one in Figure 7.

Figure 7: Anchor agitator from "TINSA"

And finally, the vessel must be washed at every batch and the usual way to do this is with desalinated water using equipment called CIP balls. They spray the fluid at a high pressure in many directions while whirling to get the vessel cleaned. The CIP balls chosen depend on the size of the vessel and the flow required to clean. In this case, two balls are required due to the high size of the tank. Figure 8 illustrates a typical CIP ball.

Figure 8: Typical CIP ball.

Taking into consideration all this information about the soaking tank, it has been selected an equipment in the market that meets all the requirements. Figure 9 illustrates the one chosen, which corresponds to Pfaudler manufacturer and BE 12500 model with a nominal capacity of 12500L and an overall capacity of 14360L.

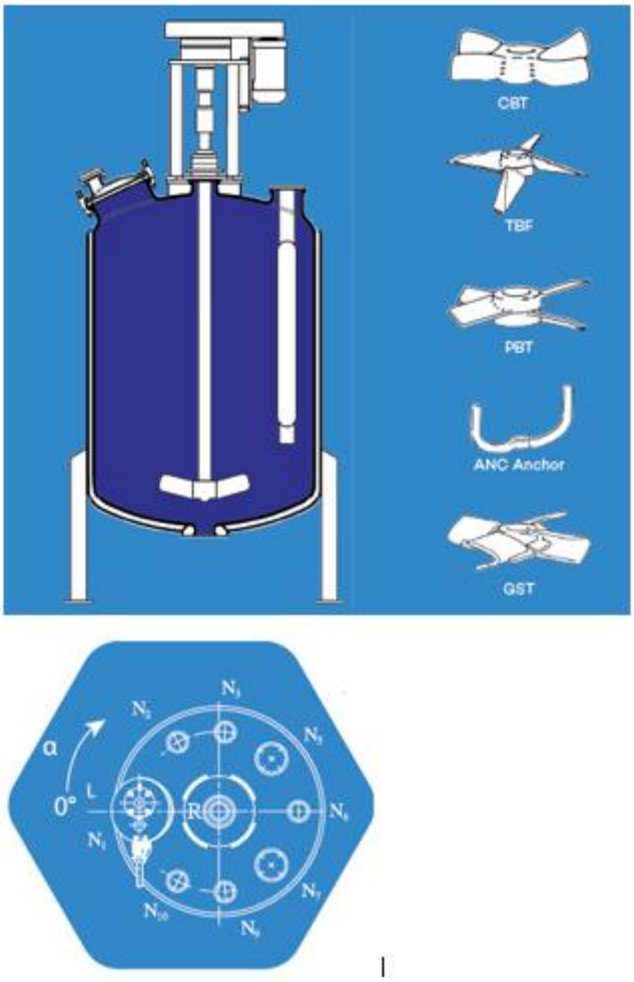

Figure 9: Pfaudler BE 12500 model.

5.1.2 CENTRIFUGATION

Once the soybeans are soaked and are ready to be grinded, a separation of liquid and solids is required. According to patents consulted, this step can be carried out either by filtration or centrifugation. In this case, it is very important to preserve the structure of soybeans and avoid its extrusion. Otherwise, their oils will be extracted and separated with the water and consequently the product characteristics will be different. Then, centrifugation (C-001) is the operation chosen. Taking into consideration this, and the 12000 kg to be treated a centrifuged from *"Flottweg Separation Technology"* model S4E. This centrifuge operates at a rate of 8000 L/h then the time estimated for this operation is of 90 minutes. Figure 10 illustrates the equipment selected:

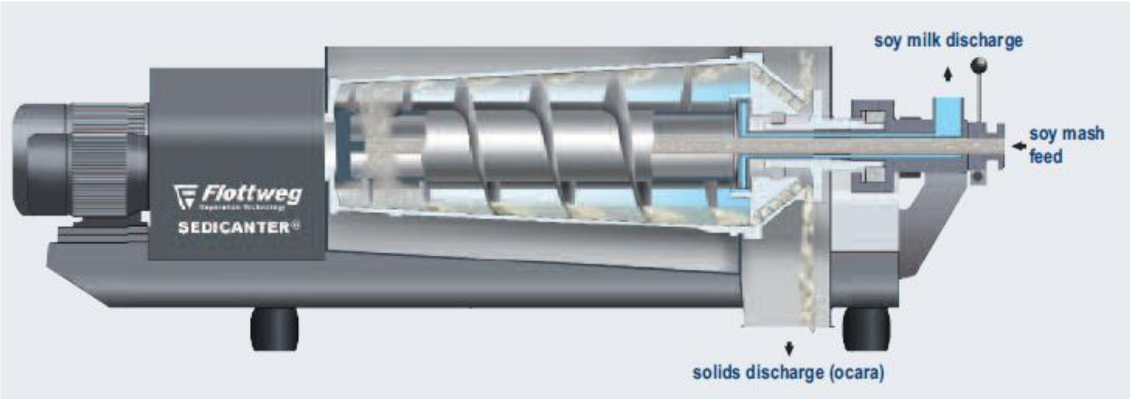

Figure 10: Centrifuge from Flottweg model S4E

5.1.3 WET-MILLING

At this point, the raw material has suffered a soaking operation that enables them to be grinded easier. The aim here is to mill the soybeans to extract their oils and consequently homogenize them with water to finally obtain the milk. Time required here depends on the flow rate and the equipment selected. In this operation is also added the water that will be further homogenized with the oil to obtain the final milk previously in another vessel (V-002). The amount of water added must be enough to finally obtain a product of about 15% of raw material. It must be taken into consideration that the raw material has already absorbed water in the soaking stage and this value differs depending on the raw material:

- Soybeans after soaking have an 8% of water content. Then, making the corresponding calculations, it must be added 5870 kg of water.
- Almonds after soaking have a 3% of water content. Then, making the corresponding calculations, it must be added 5955kg of water.
- Oats have a 10% of water content after the soaking stage. Then it must be added 5830kg of water.

Wet miller (M-001) selected to carry out this stage is from the manufacturer "IKA" and the model cone mill MKO 2000/50 that can operate with a flow of 6000L/h, which means that the operation takes about 75 minutes. Figure 11 illustrates the model chosen.

Figure 11: IKA MKO 2000/50 wet mill.

5.1.4 FILTRATION

At this point of the process, there are the grinded soybeans, their extracted oils and water. Now the aim is to separate again the liquid part from the solid part to take the first one. In this case, filtration is the chosen operation, specifically a press filtration (F-001). The reason for this is that the press applied to the soybeans to be filtration contributes to the final extraction of oils by squeezing the grinded soybeans. The machine selected to carry out this operation is from the manufacturer "M.W. Watermark"and the model corresponding to "1500mm" that can work with a charge of until 275ft^3 (7787kg) of mix. Figure 12 illustrates the filter selected.

Figure 12: M.W. Watermark filter 1500mm.

5.1.5 UHT

As explained in the previous point, the UHT provides a shelf life to plant-based milks of several months and it is composed of a series of unit processes in order to transform a non-sterile milk into a sterile milk. Sterilization occurs at 140°C then, to avoid water boiling, the system is pressurized at 0.4 to 0.5 MPa. The major steps of UHT are the following ones:

- Pre-heating.

- Heating to sterilization temperature.
- Holding at sterilization temperature.
- Initial cooling.
- Final cooling.
- Storage.

In the first stage, the product is heated form 20°C to about 80°C in a heat exchanger. To optimize the process, in this first part it can be used the final product to make this temperature increase. Over 90% of the heat can be regenerated this way [23]. When the product achieves 80°C then enters to a holding tube which maintains the temperature for 120 seconds. This step is made to stabilize the proteins and prevent them from fouling. It may also reduce the amount of sediment in the product and the forming of deposits at high temperatures.

Then, there is a second heating step, and the aim is to reach a temperature of 140°C. The most common way to achieve it is by indirect heating using steam. Other ways are more complex, such as the direct heating with steam, that implies a pretreatment of the steam because the product is edible, and it is in contact with the heating source. In this indirect heating, steam at high pressure is used as it is the most common way to increase the temperature in industrial processes. Equipment used to carry out this stage is a shell and tube heat exchanger because these are the most common ones and they have some big advantages, such as the robustness when working at high pressures like this case.

The third step is the initial cooling where the product decreases its temperature from 140°C to at least 25°C. To optimize the plant, it is usual to use the incoming product at room temperature (20-25ºC) to make this heat exchange and avoid using a brand-new refrigerator. Otherwise, it can be used mains water.

In the final cooling, heat exchangers are used to decrease the temperature of the product with chilling water. Then, the product is stored in a tank to be ready for the following step.

Several equipment is required to carry out this process. It is usual in the industry to hire what is called a skid. These are packs that contain the equipment necessary to carry out a specific operation. In skids are included pumps, heat exchangers, valves and even small tanks used, for example, to store a specific fluid. Thus, the most pragmatic decision here is to contact a firm specialized in this type of operations and hire a whole skid.

Figure 13 illustrates a scheme where all steps and the most important equipment is summarized. It must be pointed out that all heat exchangers operate in countercurrent regim.

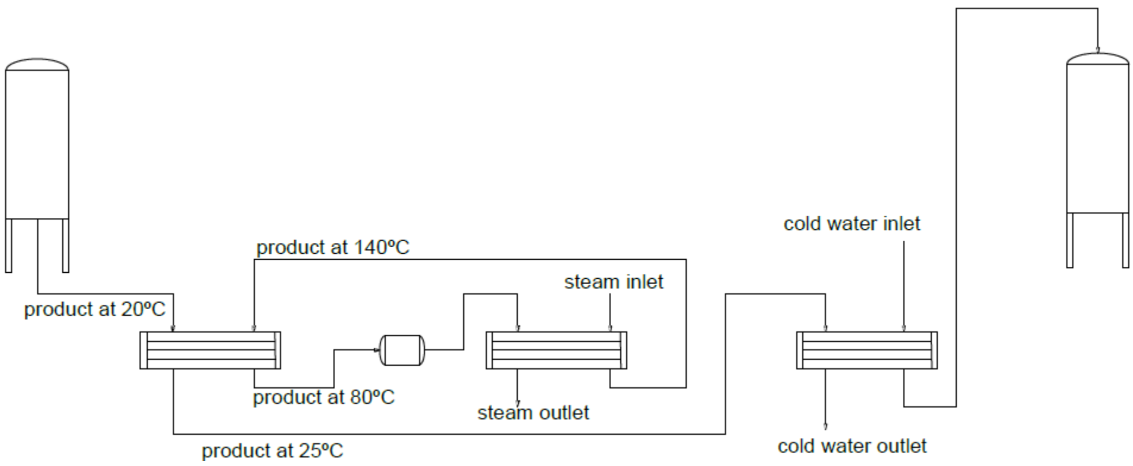

Figure 13: UHT scheme.

It must be pointed out that this operation is made in continuous mode, then an intermediate vessel (V-003) is necessary to store the liquid phase obtained from the filter and pump it to the UHT unit.

Equipment selected to carry out this operation is from the manufacturer “Tetra Pak” model “DC” from the UHT indirect heating. Tubular heat exchangers are used achieving the temperatures described previously. It operates at rates of until 40000L/h which means that to work with a rate of 6000 L/h the time required for this are 30 minutes approximately, adjusting the flow to 12000 L/h. This is made because the following stage operates also at this rate and consequently it makes the installation much simpler and avoids the presence of an intermediate tank. Figure 14 illustrates the equipment selected:


Figure 14: UHT unit from Tetra Pak model DC.

5.1.6 HOMEGENIZATION

At this point of the process, the aim is to homogenize the oiling part with the aqueous part. To do it, a drop size of 150 nm [3] must be achieved using the suitable equipment to, at the same time, preserve the main properties of the product. The main aim of an ultra high-pressure homogenization, also called dynamic homogenization, is to fragment particles to make a finer texture of a product, modify the viscosity of the product and even achieve inactivation of microorganisms. To be called ultra-high-pressure homogenization, the process must work at pressures around 350 to 400MPa [8]. In Figure 15 is summarized the scheme of an ultra-high pressure homogenizer:

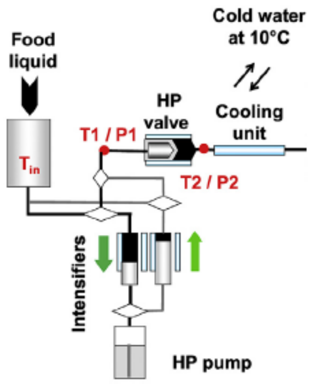

Figure 15:Scheme of a ultra-high pressure homogenizer [5].

The process begins when the liquid mixture enters to the pressure intensifiers to achieve around 400MPa. This way, the milk gains pressure energy, which is very important to understand the principle of this process. Then, the liquid passes through a high-pressure valve, which is a very small orifice that provokes a pressure drop and consequently now the fluid has a high kinetic energy. In this step is where the particles are reduced because of the low gap between the walls and the needle of the high-pressure valve, as shown in Figure 16.

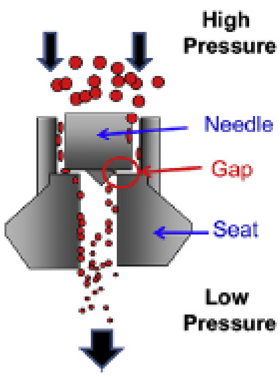

Figure 16: Scheme of a high-pressure valve [8].

The resulting pressure drop causes intense mechanical forces and elongation stress at the valve entrance and cavitation, turbulence and impacts with the walls of the valve at the outlet of it. The increase of velocity in the fluid induces an increase of temperature (14 °C-17°C per 100 MPa) too, that must be controlled using water at 10°C in a cooling heat exchanger. Indeed, the temperature is already increased in the pressure intensifiers (2 °C-3 °C per 100 MPa).

A way to improve drop reduction results in ultra-high-pressure homogenization consists in recycling the emulsion once or twice as a result of cumulating residence times of the fluid in the high-pressure valve [8]. In this case where, as explained before, the particle size requires is 150nm, it can be achieved a drop size of 138nm by carrying out a process at 200MPa with 2 passes (cycles). But when these passes are made it is necessary an intermediate tank between passes because the process operates discontinuously. Then, once the mix is homogenized in the first pass, then is stored in a tank with a capacity of minimum 6000 kg and then the mix is again resent to the homogenizer to make the second pass.

The piston-gap type homogenizer chosen to carry out this operation is the model "Ariete 3160" from the manufacturer "GEA". It is necessary to treat 6000kg in 30 minutes, then the equipment selected must be able to treat a flow of 12000 L/h. Searching the possibilities of the model commented, this machine can operate at 400MPa. Figure 17 illustrates the chosen homogenizer.

Figure 17: Ariete 3160 model from GEA.

The intermediate vessel selected to store the mix between passes must be able to withstand atmospheric pressure and temperature. CIP connections must be included to the tank to wash them between batches. The selected equipment is from the german manufacturer "Hutch" and the corresponding model is a Gross-Buffer storage tank GPS without the option of "insulation". Figure 18 illustrates the selected vessel:

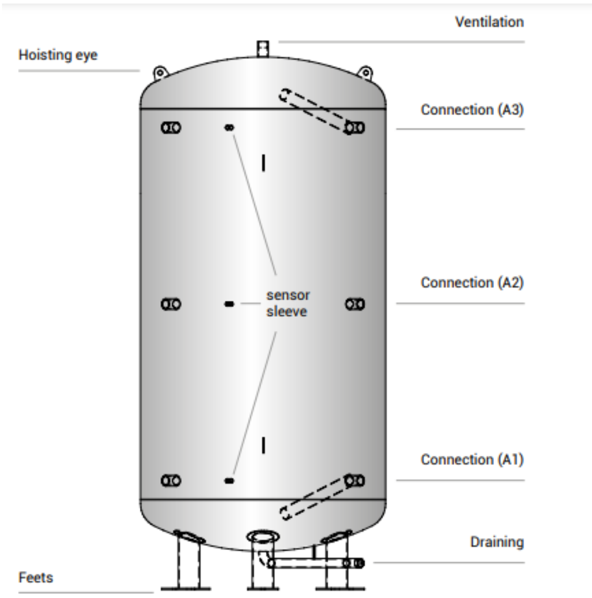

Figure 18:Scheme of gross-buffer storage tank GPS.

It is also important to mention that all recirculation is made with positive-displacement pump because they are better than centrifugal pumps when working with viscous fluids or fluids that contain solid particles. They are very common in food industries.

5.1.7 ADDITION OF NUTRIENTS

The final step before storing the product is the addition of the essential nutrients for a human being in his diet. Concerning calcium fortification, there are some ways to add this nutrient to the milk but according to studies, the best way to do so is by using colloidal calcium ($CaCO_3$) [9]. It does not prompt particle aggregation as $CaCl_2$ does, because there are fewer calcium ions. At the same time, both types of calcium were studied with vitamin D to see the biaccesibility of it to human bodies. It was concluded that $CaCl_2$ causes a kind of "soup" in the intestine that reduced vitamin D bioavailability whereas $CaCO_3$ does not have this problem.

To add vitamin D to the product, a nanoemulsion must be prepared previously, composed of a plant-based oil (corn oil) and a surfactant (quillaja saponin). The later is an emulsifier that produce droplets which are highly stable to aggregation [9]. The aqueous phase and the oil phase are prepared separately, dispersing vitamin D in corn oil to obtain a 4 wt % solution and stirring and dispersing the emulsifier in water to obtain a solution 1.11 wt %. Then, both parts are mixed to obtain the nanoemulsion, which proportions are 10 % oil phase and 90% watery phase. They are stirred to obtain a final nanoemulsion of 0.4 w t% of vitamin D.

Once the nanoemulsion is prepared then it is added to the homogenized milk and is stirred for 30 minutes. Finally, carbonate calcium is added and the whole product is stirred for 2 hours [9].

According to general formulations in the market [24], in soymilk is usually added 1.36 mg of Ca^{2+}per gram of milk which corresponds to 20.5 kilos of $CaCO_3$ to produce a batch of 6000 L. Concerning the vitamin D, 0.54 IU/ of it per gram of milk is added, which corresponds to 82 mg of it for the batch size stablished. Table 6 summarizes the nutrient's addition for soymilk.

Table 6:Nutrient's addition for soy milk.

PRODUCT	CaC03 added [kg]	Vitamin D [mg]
SOY MILK	20.5	82

All these operations are carried out in a stirring tank of 8m^3 to contain the 6000kg batch size and here it is used a rod stirrer that makes the final mix. The presence of two stirrers could be a good idea due to the high dimensions of the vessel but must be confirmed with the manufacturer. Inside, there are just water, the raw material and the nutrients (in low quantities) thus, a carbon steel vessel is suitable enough to carry out this operation at atmospheric pressure and temperature. In this case, it is just necessary a nozzle to introduce the emulsion and another one to introduce both carbonate calcium (solid) as well as the microemulsion. Two additional nozzles are usually added in case in the future the tank is used for another purpose. Agitation of the mix depends on the final model selected from the manufacturer but it should be of about 1200 rpm [9]. A proposal of equipment to carry out this operation is illustrated in figure 19. It corresponds to a product from the manufacturer "Pfaudler".

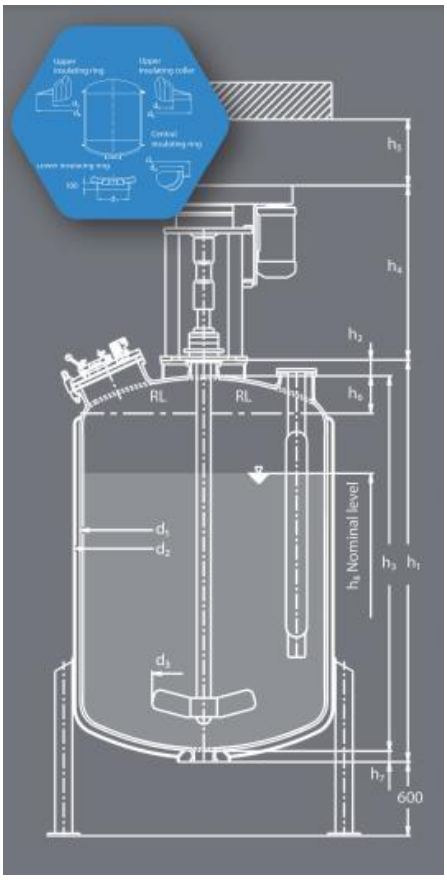

Figure 19: Stirred tank model DIN BE from Pfaudler.

5.1.8 PACKAGING

As explained in section 4, in this stage the milk is introduced in paperboards of 1L capacity and they are packed in 6-packed together to have it ready to be delivered in the market. To carry out this step of the process it is used the previous stirred tank and a dosing machine. To obtain the final product in the proper conditions the tank as well as the dosing machine must operate in sterilizing condition. In case of the tank, it has an entrance of nitrogen to avoid the presence of oxygen in the extra space of the vessel. In case of the dosing machine, it must operate in condition where the milk is not contaminated by bacteria that could spoilage the product. The dosing machine selected from the manufacturer "IPI", the model is "NSA EVO" and it can operate 6000L in 1 hour, in other words, each batch can be packaged in 1 hour. Figure 20 illustrates the dosing machine selected for this stage:

Figure 20: Dosing machine from IPI model NSA EVO.

5.2 Almond milk production process

One of the advantages of plant-based milk production is its similarity. Almond milk process is the same as soybean process just including one extra step. There are some changes to be explained because the raw material is different but all the steps in soymilk production process are present in almond milk production process, with the exception of the centrifugation. In this case, due to the characteristics of almond, using a mesh connected at the bottom of vessel V-001, to take the solid and separate it from the water. Then the solid is charged directly to another vessel (V-002) to prepare the mix with water and consequently feed it to the wet miller.

5.2.1 ROASTING

As commented in section 4, flavor is one of the most important quality criteria of the plant-based milks produced. Then, an important point when working with almonds it is its roasting.

The roasting operation is simply introducing the raw material in industrial ovens and achieve certain temperature that alter the organoleptic properties. It results in a brownie color and a crunchy texture, which will be softened in the following stage of soaking. The temperature of the roasting is what basically alters the almond properties and it usually ranges from 130 °C to 154 °C [13].

Almonds are rich in unsaturated fatty acids and the high degree of it makes this raw material susceptible to oxidations reactions during processing or storage. This fact degrades the quality of the almonds and consequently the final taste of the plant-based milk. If low roasting temperatures of 130 °C are applied, this helps to preserve the microstructure of almonds and maximizes the shelf life.

Equipment selected to carry out this operation industrially is from manufacturer "Chike Machinery" and is illustrated in figure 21.

Figure 21: DCCZ 5-5 Roaster from Chike machinery.

5.2.2 LECITHIN SOLUTION PREPARATION

An important point when launching a product in food industry is its shelf life and stability. This is the reason why sometimes it is necessary to add extra substances to improve some features of the final product, such as emulsifiers or thickeners. In some cases, these substances are present naturally in the main product and thus, it is not necessary to make these operations. This is what happens with soymilk, because the raw material contains soy lecithin, which is an emulsifier that improves the stability of the vegetable beverage.

Lecithin is a yellow-brownish fatty substance occurring form animals and plant tissues which are amphiphilic, what means, that they attract both water as well as fatty substances. They are used for smoothing food textures, emulsifying, or replying sticking materials. It facilitates the formation of the emulsion and its stability by reducing the oil-water interfacial tensions and by forming a protective layer around the fat droplets to prevent them from aggregation. Lecithin is naturally found in soybeans, thus in production process of soybeans it is not necessary to add a substance to improve the stability of the milk. In case of almond milk, it has been proven that a 0.03% of lecithin improves the stability of the milk in comparison with a milk with no lecithin. Results were observed from day 2 to day 7, where layers of sedimentation appeared on the product [18].

The addition of lecithin is made in the water used in the wet milling operation. The final product must have a 0.03% of this emulsifier, thus for a batch of 6000L, it is required 1.8kg of it. It has a low solubility in water, then it would a problem to prepare a solution of lecithin in water and consequently add it to the raw material. However, this substance is soluble in oils, then it is added during the wet milling stage where raw materials oils are extracted [18]. It must be pointed out that lecithin is added in a liquid state, thus when the filtration is made after the wet milling it will be obtained on the one side the solid residues and on the other side the liquid phase composed of water, oils, and lecithin.

5.2.3 NUTRIENTS ADDTION

Apart from the roasting and the lecithin addition, the other difference from the rest of plant-based milk processes of the present project is found in the nutrient's additions. The soaking, centrifugation, wet milling, filtration, UHT and homogenizations are carried out in the same equipment in the same conditions.

In this case, according to market studies [22], it is added 0.45mg of Ca^{2+} per gram of milk, which corresponds to 6.8 kg of $CaCO_3$ to produce a batch of 6000kg. In case of vitamin D, it is added 0.54IU/g of milk. Making the appropriate calculation, it must be used 68 mg of vitamin D. Table 7 summarizes the addition of nutrients for almond milk.

Table 7: Nutrients addition for almond milk.

PRODUCT	$CaC0_3$ added [kg]	Vitamin D [mg]
ALMOND MILK	6.8	68

5.3 Oat milk production process

In the oat production process, the steps followed are the same as the ones from soymilk production process, including the addition of lecithin made in the almond milk process. The differences here are an extra stage after the filtration, which consists of a starch degradation that improves the final taste of the milk. In addition, nutrients added here are in different proportions.

5.3.1 Starch degrading

One of the most distinguishing properties of oat is its high content in starch. What it is usually done here is the hydrolysis of starch to obtain maltose not only to improve the final flavor but also the nutritional aspect. Maltose is an easily digestible sugar used in products such as baby drinks and baby porridges.

The best way to carry this operation is combining α-amylase and β-amylase. According to experiments, adding them simultaneously and not sequentially improves the results in terms of the amount of enzyme used. This is because α-amylase acts as a catalyst promoting both the rate of reaction of β-amylase and the yield [25].

This operation occurs after the filtrations and just before the UHT operation. At this point of the process, the mix is composed of the aqueous part and the oil part, there are no solids. In a stirred tank of $8m^3$, the mixture is pumped and afterward, the mix of enzymes are added. In this case, immobilized enzymes are used to avoid possible contamination of the product and other purifying operation. This tank has a half coil of different dimensions but controlled in the same way as it is in the soaking tank. Then, figure 5 and 6 can be used as well to describe the heating system in vessel V-004.

Making the corresponding calculation, in this case, it is necessary a half coil of 3 m^2 and a length of 12 meters. Again, distribution, number of turns and its separation depend on the manufacturer and calculations are made equally as in the soaking tank V-001.

According to the patent consulted [25] and making the appropriate calculations, to produce a batch of 6000kg it is necessary 1kg of α-amylase 35 FAU and 4 kg of β-amylase of DP. FAU and DP are the units that indicate a specific feature of each enzyme. FAU (fungal amylase unit) is the quantity of amylase enzyme that will convert a quantity of cereal starch to maltose, then it is related with the activity of this enzyme. DP indicates the activity degree of β-amylase and for example and this is stablished by manufacturers such as SPEZYME BBA 1500.

Once the two enzymes are added to the mix, the tank is stirred for about 90 minutes at a temperature of 55 °C using steam though the half coil to achieve this.

5.3.2 Nutrient's addition

In case of oat milk, it is added 1.59 mg of Ca^{2+} per gram of milk and 0.45IU of vitamin D per g of milk. These concentrations, to produce a 6000kg batch size, correspond to 24 kg of $CaCO_3$ and 68 mg of vitamin D. The way these nutrients are added is exactly the same as explained in soymilk production process. Table 8 summarizes the nutrients addition for oat milk.

PRODUCT	$CaC0_3$ added [kg]	Vitamin D [mg]
OAT MILK	24	68

Table 8: Nutrient's addition for oat milk.

6. BATCH DATA

This project is based on the development of a product manufactured in a discontinuous plant. Consequently, one of the most important issues to stablish the batch size and all the other factors related with it, such as how to operate or the time that takes each step. The batch size decided is of 6000kg, to get a number divisible per six and consequently plan the production considering the production unit a pack of six carboards. There are some factors to take into consideration when thinking about the planification of the production:

- Process duration: It is crucial to know how much it takes to carry out each process. Consequently, and according to the number of days worked annually, a batch of a certain number of kilos can be established.
- Time to clean all equipment: It is important to clean the equipment when every single batch is finished and consider the time required for it.
- Time to carry out a quality control: When every batch is concluded a quality control is conducted to analyze if the product has the desirable conditions to be sold.

As explained in the first point previously, it is very important to know the duration not only of the whole process but also of each step to know the limiting stage and further optimize the process. There are similarities between the three processes but some of them have additional steps and consequently additional time required. Table 9 ilustrate the time required for main operations.

Table 9:Duration of just the operations of each process.

PRODUCT	STAGES OF THE PROCESSES [min]										
	Soaking	Centrifugation	Wet milling	Filtration	UHT	Homogenization	Addition of nutrients	(Roasting)	(Starch degradation)	Packaging	TOTAL
Soy milk	390	90	95	90	30	70	150	xxx	xxx	310	1225
Almond milk	210	xx	115	90	30	70	150	30	xxx	310	1005
Oat milk	390	90	95	90	30	70	150	xxx	120	310	1345

Production must be carefully planned always considering a shelf life of the product of 90 days (3 month) and the fact that the plant works seasonally, producing a certain type of milk during a certain period of time and not the three types all at once. Otherwise, there would be problems when delivering the milk and selling the whole production on time before their shelf life. To keep planning the production is crucial to know the exact time required for a batch, considering not only the main operations, but also operations like cleaning, charging, or discharging the products. It must be pointed out, that this project is focused on a plant that produces not only these three types of milk but also other products of the food industry. Then, equipment described in point 5 is always working in different process except when the plant stops producing for maintenance operations.

7. PROCESS OPERATIONS

To plan all the production of this plant and achieve the goals annually a study of the duration of the process, of each stage and each operation must be carried out. As explained in section 6, the process has several stages until the final product is obtained but at every stage some operations must be done and each of them required a certain period of time. In this section all these issues will be discussed taking into consideration each process depending on the raw material used.

7.1 SOYMILK PRODUCTION PROCESS

In the following point there are a number of tables describing all the operations carried out in each stage of the three processes.

Table 10:Soaking tank V-001 operations.

OPERATIONS	EXPLANATION
1. Raw material charge	Raw material is obtained in big bags of 1000 kg size and 250 kg. Their content is directly introduced into the soaking tank by an operator that works with a hoist. Time expected to do this is of about 20min.
2. Water charge	A total of 10500kg of water into the soaking tank must be charge in an estimated time of 10 minutes using a pump.
3. Heating	Once the solid and the liquid are inside the tank, the time required to achieve the desired temperature since the steam valve is opened is of 30 minutes.
4. Soaking	The whole soaking time required is of 390 minutes. Here are included the 30 minutes that are necessary to achieve the desired temperature because during this time, the solid and the liquid are already in contact and there is soaking operation
5. Discharge to the centrifuge	The discharge of the tank is made using a pump because the following operation (centrifugation) operates continuously and at a certain constant flowrate of 8000L/h. Duration of the discharge is of 90 minutes.
6. Cleaning	Because of the operation in a food industry, the cleaning operations must be done meticulously to eliminate everything from the previous batch and avoid a contamination in the following batch. According to manufacturers of CIP balls, such as Alfa Laval, 30 min is the duration for this vessel of this size.
7. TOTAL	540 minutes.

Table 11: Centrifuge C-001 operations.

OPERATIONS	EXPLANATION
1. Suspension charge, operation and discharge	The centrifuge operates continuously at a flow rate of 8000L/h. To operate with the whole batch mass, it is required 90 minutes for the operations of charge, centrifugation and discharge.
2. Cleaning	30 minutes.
3. TOTAL	120 minutes.

Table 12: Vessel V-002 operations.

OPERATIONS	EXPLANATION
1. Solid charge	As explained section5, the centrifuge operates at a constant rate of 8000 L/h, thus this rate is also the discharge rate. Time required for this is again 90 minutes. The discharge of the solid is made using the gravity, consequently, the vessel V-002 must be at a point lower than centrifuge C-001.
2. Suspension discharge	Discharge from vessel V-002 to wet miller M-001 must be done at a certain flow rate using a pump, because the wet miller operates continuously at 6000L/h. Making the corresponding calculation, time required for this is of 85 minutes. It must be added 10 minutes of time, the reason of this is explained in Table 13.
3. Cleaning	30 minutes.
4. TOTAL	215 minutes.

Table 13: Wet miller M-001 operations.

OPERATIONS	EXPLANATION
1. Suspension charge, operation and discharge	The wet miller operates continuously at a flow rate of 6000L/h. To operate with the whole batch mass, it is required 85 minutes for the operations of charge, milling and discharge. The extra 10 minutes explained in table 7 are used for a control and ensure that the size of the particle is not lower than 125mm [5], otherwise there will be problems in the following filtration.
2. Cleaning	30 minutes.
3. Total	125 minutes.

Table 14: Filter F-001 operations.

OPERATIONS	EXPLANATION
1. Product charge	Charge of the slurry from the wet miller is made at a constant rate of 6000L/h and consequently time required for the filter charge is of 95 minutes, the same as the wet milling discharge.
2. Filtration and discharge	According to the manufacturer, when working with these types of processes and with these quantities, a estimated value for the filtration times is 90 minutes.
3. Cleaning	In this case, filtration Is much more difficult and according to specialist like “MSE Filterpass”, for these amounts of batch, a time of 180 min is required.
4. Total	365 minutes.

Table 15: Vessel V-003 operations.

OPERATIONS	EXPLANATION
1. Product charge	As filter F-001 is operating, the vessel V-003 is being charged at the same time. Then, duration of this operation is of 90 minutes as well.
2. Product discharge	The following operation (UHT) operates again continuously at a certain flow rate. Consequently, product from vessel V-003 must be pumped at a rate of 12000L/h, which is the operating rate of the UHT unit. Then, time required for this is of 30 minutes
3. Cleaning	30 minutes.
4. TOTAL	150 minutes.

Table 16: UHT H-001 operations.

OPERATIONS	EXPLANATION
1. Product charge, operation and discharge	These systems operate continuously, then while the mix is being charged it is also being operated and circulating through the different heat exchangers and is also discharged to the following equipment. Time required for all this is, operating at 12000L/h is of 30 minutes.
2. Cleaning	To clean the UHT installation, it is first circulated water through it, then a solution with bleach and finally a cleared up. Its durations is three times the one for a normal UHT process, which corresponds to 90 minutes.
3. TOTAL	120 minutes.

Table 17: Homogenizer H-001 operations.

OPERATIONS	EXPLANATION
1. Product charge, operation and discharge	Again, it happens something similar as in UHT installation because it operates continuously. It operates at 12000L/h and time required here is of 70 minutes, because it circulates two times through the same equipment. Between each pass, the product is stored in a vessel, which implies 10 more minutes in the process.
2. Cleaning	In this case, it is made something similar as UHT. Three circulations, first with water, then a solution of bleach and finally a clear up. The duration of these is of 90 minutes (each circulation of 20 minutes).
3. TOTAL	160 minutes.

Table 18: Vessel V-004 operations.

OPERATIONS	EXPLANATION
1. Product charge	6000kg of batch (without counting the losses) must be charged into a stirred tank to finally add the nutrients. Estimated time is of about 30 minutes, because the homogenization unit operates at a constant rate of 12000L/h. Here is included the addition of calcium and vitamin D as well
2. Operation	Duration of this operation, as explained in previous section, is of 150 minutes
3. Cleaning	30 minutes.
4. TOAL	220 minutes.

The final step of the process is the aseptic packaging, where the milk is dosed in the paperboard bricks. In this case, a dosing machine operates continuously and handles the whole production of a batch in 60 minutes. Afterwards, the packaged milk must be grouped in packs of 6. Considering that an automated plant can prepare a pack in 15 seconds, then it is necessary 250 minutes to get ready the whole production. All in all, the aseptic packaging stage requires a total of 310 minutes.

7.2 ALMOND MILK PRODUCTION PROCESS

Almond milk production process is very similar to the soy milk one. Nevertheless, the raw material is different, and this causes variations in the duration of some operations and also the addition of different steps in the process, as explained in section 5. Tables 14, 15, 16 and 17 illustrate just the stages that differ from soymilk production process either in terms of operation duration or because it is an extra stage in comparison with soy milk production process.

Table 19: Roaster R-001 operations.

OPERATIONS	EXPLANATION
1. Charge	Solid charge is made in a similar way as in soymilk production process. Time required for this, in big bags of 1000kg, is of 30 minutes
2. Operation	This operations lasts 30 minutes according to the patent consulted [18].
3. Discharge	The discharge of this solid to the soaking tank can be made using a conveyer belt. Estimated time for this is of 10 minutes.
4. Cleaning	30 minutes.
5. TOTAL	80 minutes.

Table 20: Soaking tank V-001 operations.

OPERATIONS	EXPLANATION
1. Raw material charge	It is required 10 minutes to charge it as it has been explained in the discharge operation of the roaster R-001. Water is already charged in vessel V-001.
2. Heating	30 minutes, as in soymilk production process
3. Soaking	In this case, almond does not need so much time for the soaking and with 210 minutes the raw material is ready to be grinded.
4. Discharge to the centrifuge	In this case, in the following stage there will not be a centrifugation because it is enough using a mesh to retain the solid. This stage requires a total of time of 15 minutes and then 10 more minutes to charge it to the vessel V-002 to then add the corresponding amount of water.
5. Cleaning	30 minutes, as in soymilk production process.
6. TOTAL	265 minutes.

Table 21: Vessel V-002 operations.

OPERATIONS	EXPLANATION
1. Solid charge	10 minutes are required to take the mesh with the solid from the soaking tank V-001 and discharge it to the vessel V-002. In this vessel there is already the water with a 0.03% solution of lecithin.
2. Suspension discharge	Discharge of vessel's V-002 content to the wet miller M-001 requires 115 minutes using a pump because the wet miller operates at constant rate. This is why filter F-001 in the almond milk process is charged in 115 minutes as well, but the rest of the filter operation is the same as in soy milk process.
3. Cleaning	30 minutes.
4. TOTAL	215 minutes.

Table 22: Wet miller M-001 operations.

OPERATIONS	EXPLANATION
1. Suspension charge, operation and discharge	In this case, it is required more time to mill the raw material due to its features. A total of 115 minutes are required to charge, mill and discharge the suspension of almond and water.
2. Cleaning	30 minutes.
3. Total	145 minutes.

The rest of stages in almond milk production process are the same as in soy milk production process, taking the same amount of time to carry out them and the same equipment is used.

7.3 OAT MILK PRODUCTION PROCESS

This process has more similarities with the soy milk one than with the almond milk one. There is just one stage that differs from soymilk production process and is the one that occurs in vessel V-003, when there is a reaction of hydrolysis in the raw material used. In table 18 these stages are illustrated.

Table 23: Vessel V-003 operations.

OPERATIONS	EXPLANATION
1. Charge	30 minutes are required to charge the liquid, the reason is the same as in soy milk production process.
2. Operation	150 minutes are required for the degradation of oat's starch, including the charge of α-amylase and β-amylase.
3. Discharge	10 minutes.
4. Cleaning	30 minutes.
5. TOTAL	220 minutes.

8. SCHEDULING AND PLANNING

Once the processes are clear and it is known how long it takes to carry out them then it is time to plan the production. This plant operates by batch processes and the idea is to produce just one type of milk during a certain period of time and when this period is over then it is changed the product. To make all this decision, firstly, it is important to know the batch time and the cycle time of each milk. Tables 24, 25 and 26 point out the time required for each operation and the occupation time of each equipment.

Table 24: Scheduling of soymilk.

EQUIPMENT	START [min]	END [min]	Charge [min]	Operation [min]	Discharge [min]	Cleaning [min]	$T_{occupation}$ [min]
V-001	0	540	30	390	90	30	540
C-001	420	540		90		30	120
V-002	420	635	90	0	95	30	215
M-001	510	635		95		30	125
F-001	510	875	95	90		180	365
V-003	605	755	90	0	30	30	150
UHT-001	695	815		30		90	120
H-001	695	855		70		90	160
V-004	725	945	30	150	10	30	220
D-001	905	1255	10	310		30	350

Table 25: Scheduling of almond milk.

EQUIPMENT	START [min]	END [min]	Charge [min]	Operation [min]	Discharge [min]	Cleaning [min]	$T_{occupation}$ [min]
RO-001	0	100	30	30	10	30	100
V-001	60	325	10	210	15	30	265
V-002	295	450	10	0	115	30	155
M-001	305	450		115		30	145
F-001	305	690	155	90		180	385
V-003	420	570	90	0	30	30	150
UHT-001	510	630		30		90	120
H-001	510	670		70		90	160
V-004	540	760	30	150	10	30	220
D-001	720	1070	10	310		30	350

Table 26: Scheduling of oat milk.

EQUIPMENT	START [min]	END [min]	Charge [min]	Operation [min]	Discharge [min]	Cleaning [min]	$T_{occupation}$ [min]
V-001	0	540	30	390	90	30	540
C-001	420	540	90			30	120
V-002	420	635	90	0	95	30	215
M-001	510	635	95			30	125
F-001	510	875	95	90		180	365
V-003	605	875	90	120	30	30	270
UHT-001	815	935	30			90	120
H-001	815	975	70			90	160
V-004	845	1065	30	150	10	30	220
D-001	1025	1375	10	310		30	350

From Tables 24, 25 and 26 can be extract two important concepts very common in batch operation. The batch time, which is the duration of a whole batch, and the cycle time, which is the time, from which it is possible to start another batch. The cycle time is equivalent to the duration of the longest occupation time. These two concepts are important when considering to work with overlapping operation or not in a process. Table 27 illustrate the batch time and the cycle time of each product.

Table 27: Batch time and cycle time of soy milk, almond milk and oat milk.

PRODUCT	BATCH TIME [min]	CYCLE TIME [min]
SOY MILK	1255	540
ALMOND MILK	1070	385
OAT MILK	1375	540

Considering the values from table 27, it is proposed to work in three different shifts to deal with a batch. When working with batch operation, there is a possibility to overlap the different stages of a process. Figures 22, 23, 24, 25, 26 and 27 show how can operate the three processes (with or without overlapping).

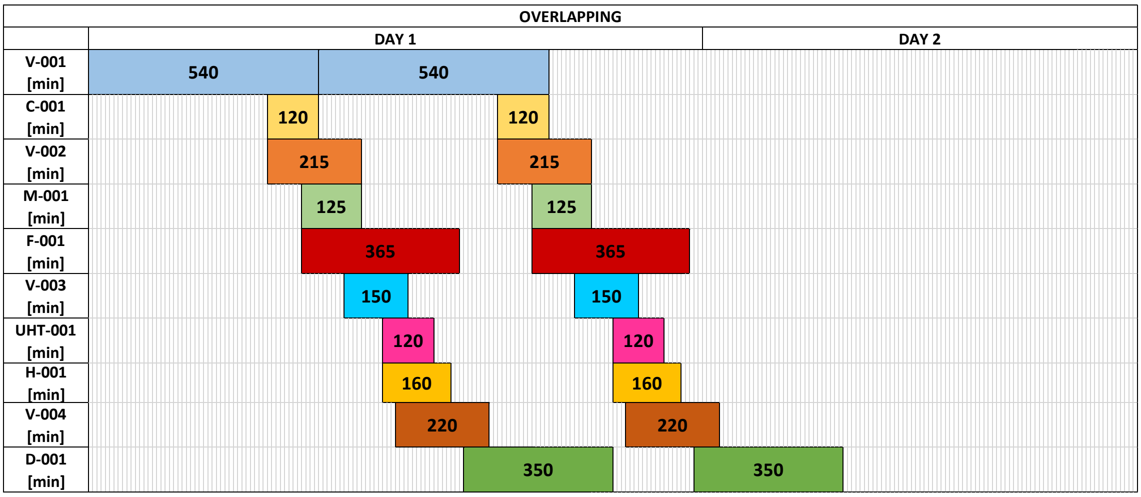

Figure 22: Representation of the operation of two batches of soy milk operating overlapping.

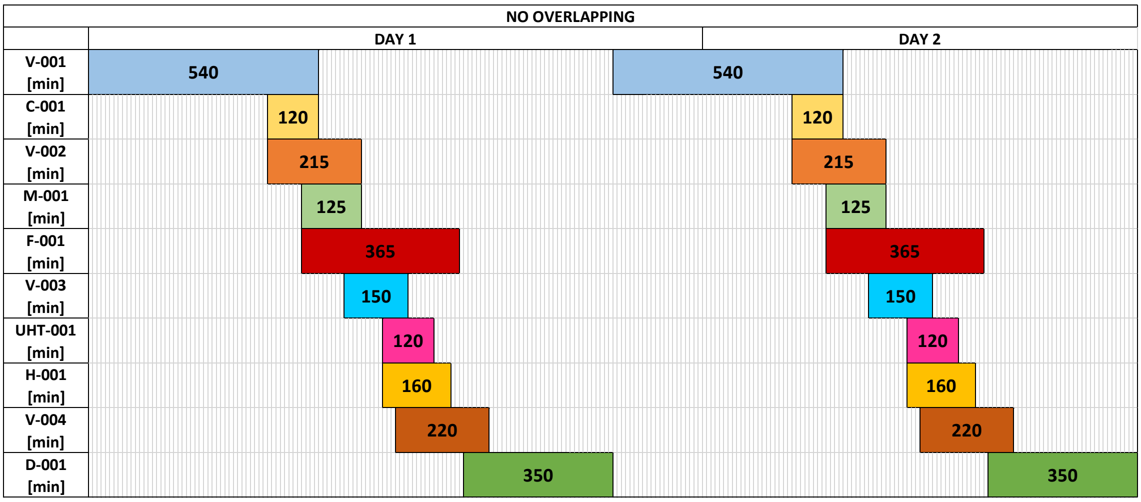

Figure 23: Representation of the operation of two batches of soy milk operating without overlapping.

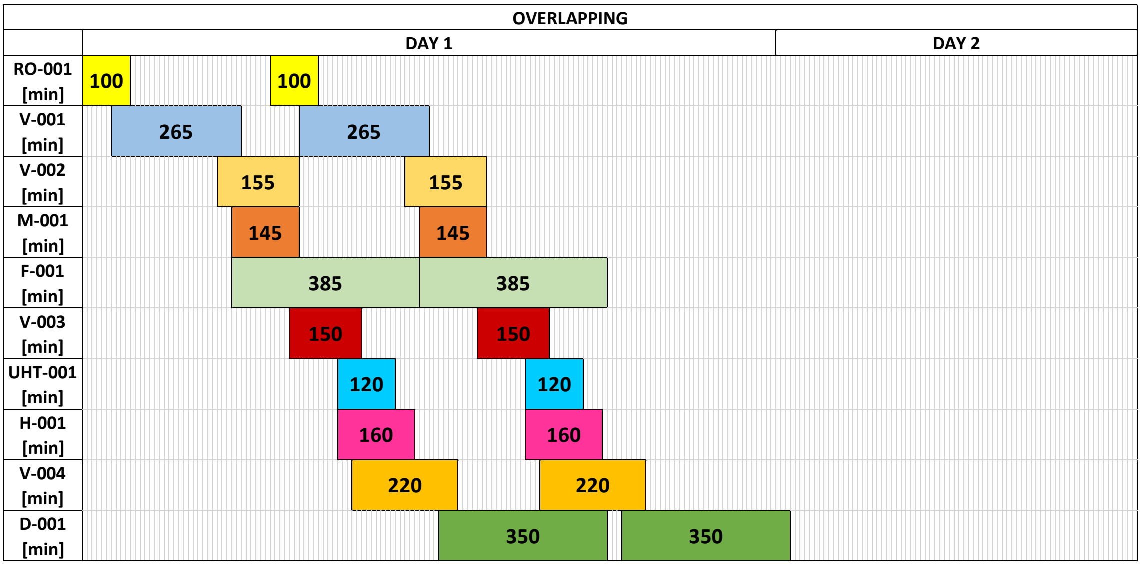

Figure 24: Representation of the operation of two batches of almond milk operating overlapping.

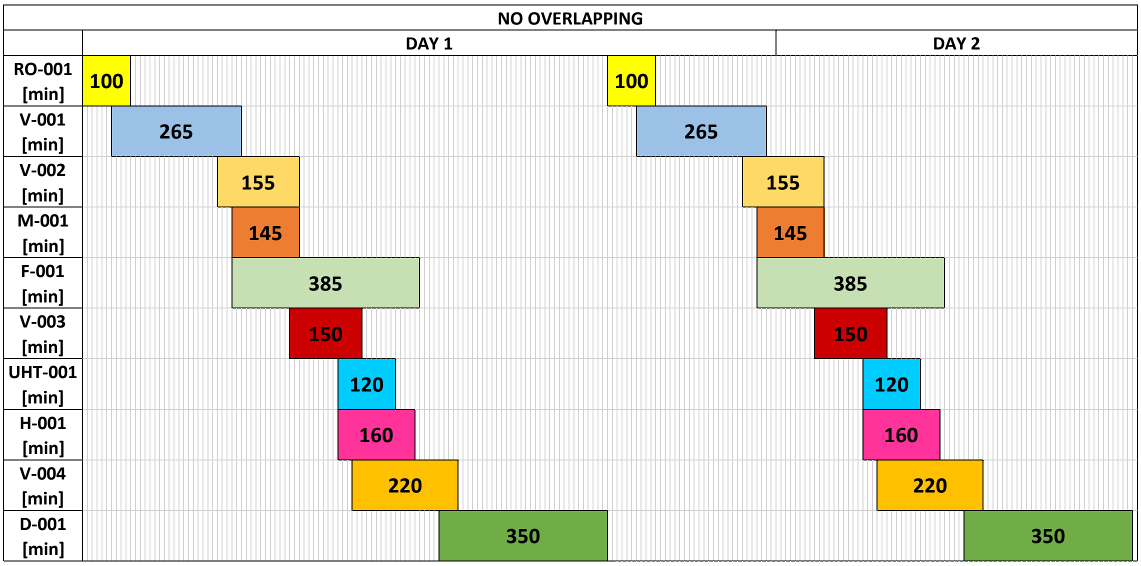

Figure 25: Representation of the operation of two batches of almond milk operating without overlapping.

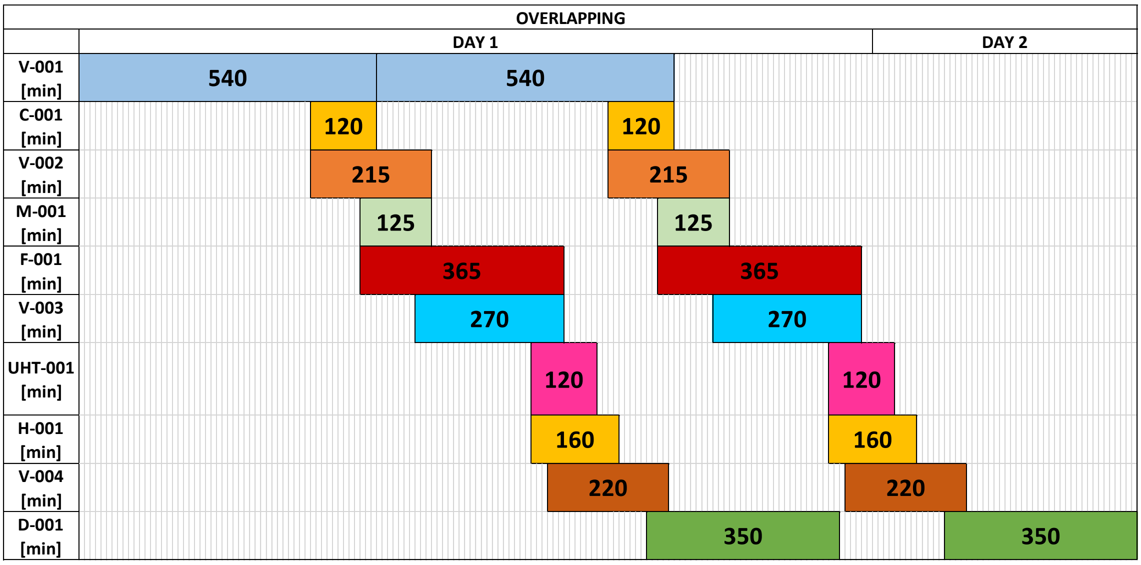

Figure 26: Representation of the operation of two batches of oat milk operating overlapping.

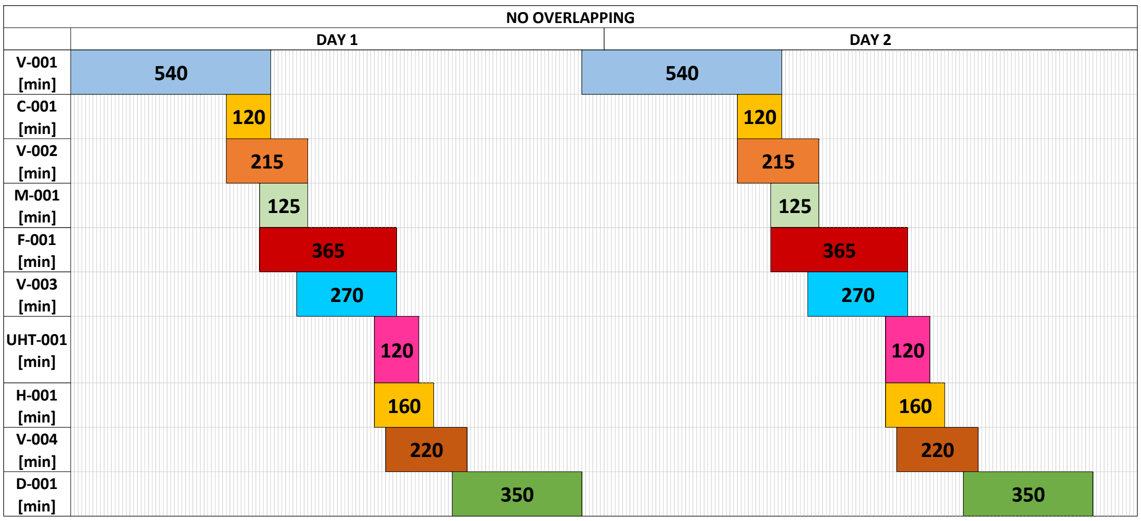

Figure 27: Representation of the operation of two batches of oat milk operating without overlapping.

Before finally focusing on the planification of the production, there is still a concept that must be defined. The concept is the "SKU" (Stock keeping unit) which corresponds to the smallest sales unit. In this case is a pack of 6 paperboards of one liter each. It is also very important when planning the production that a necessary minimum stock to deal with possible unexpected situations.

With all this information and considering the values from table 3, the annual and monthly objectives of this plant are summarized in table 28 for each product:

Table 28: Annual and monthly objectives of the plant.

ANNUAL OBJECTIVES			
Sales Volume/ Year	**OAT**	**SOY**	**ALMOND**
Volume [kg/year]	158400	216000	172800
Tetra bricks/ year	158400	216000	172800
SKU/year	26400	36000	28800
MONTHLY OBJECTIVES			
Sales Volume/ month	**OAT**	**SOY**	**ALMOND**
SKU/month	2200	3000	2400
Tetra bricks/ month	13200	18000	14400
Volume [kg/month]	13200	18000	14400

As explained before, the plant operates discontinuously and per campaigns. Then, another decision to make is how many campaigns are made per year and once it is decided this, stablish a number of batches per campaign. To make this decision is very important the shelf life of the milks, which is of 90 days. Thus, a whole production of a certain milk cannot be made in a couple of months because, although there would be enough time to produce it, it would not be possible to deliver it and sell it on time before the date of expiry. Consequently, the amount produced each month of each milk must be suitable to meet these requirements. As shown in figures 22 to 27, plenty of time is save by operating with overlapping. Considering that the plant can produce other products then the operation will be carried out according to figures 22, 24 and 26.

Considering the whole production and the batch size, it is calculated that for soymilk are required 37 batches, for almond milk 29 batches and for oat milk 27. Table 29 summarizes the time required for the whole production of each milk operating with overlapping.

Table 29: Time required to deal with the whole production of each milk.

PRODUCT	Time for whole production [days]
Soymilk	14
Almond milk	7.5 days
Oat milk	10.5

As shown in table 29, for a whole year production there is time to spare to achieve the annual objectives. Of course, it must be considered the shelf life of the milk and the time required to deliver the production. Then, it is decided to carry out a total of 12 campaigns per product every year but the amount of batches of each campaign varies depending on the product and the month. Table 30, 31 and 32 illustrate a proposal where the number of batches for each campaign are shown as well as the stock of each month and the final stock for each product. In these tables are also implemented the expected sales per month, calculated by taking the whole production and dividing it between 12.

Table 30: Proposal of a annual planning for soy milk production.

SOY									
	Stock (St) in kg and batches per campaign					**Stock (St) in SQU and batches per campaign**			
Month	**Initial Stock [kg]**	**Batch/ Campaign**	**Production [kg]**	**Sales [kg]**	**Final stock [kg]**	**Initial Stock [packs]**	**Production [packs]**	**Sales [packs]**	**Final Stock [packs]**
1	0	4	24000	**18000**	6000	0	4000	**3000**	1000
2	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
3	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
4	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
5	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
6	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
7	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
8	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
9	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
10	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
11	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
12	6000	3	18000	**18000**	6000	1000	3000	**3000**	1000
TOTAL		*37*	*222000*	*216000*			*37000*	*36000*	

Table 31: Proposal of an annual planning for almond milk production.

ALMOND									
	Stock (St) in kg and batches per campaign					**Stock (St) in SQU and batches per campaign**			
Month	**Initial Stock [kg]**	**Batch/ Campaign**	**Production [kg]**	**Sales [kg]**	**Final stock [kg]**	**Initial Stock [packs]**	**Production [packs]**	**Sales [packs]**	**Final Stock [packs]**
1	0	3	18000	**14400**	3600	0	3000	**2400**	600
2	3600	2	12000	**14400**	1200	600	2000	**2400**	200
3	1200	3	18000	**14400**	4800	200	3000	**2400**	800
4	4800	2	12000	**14400**	2400	800	2000	**2400**	400
5	2400	3	18000	**14400**	6000	400	3000	**2400**	1000
6	6000	2	12000	**14400**	3600	1000	2000	**2400**	600
7	3600	2	12000	**14400**	1200	600	2000	**2400**	200
8	1200	3	18000	**14400**	4800	200	3000	**2400**	800
9	4800	2	12000	**14400**	2400	800	2000	**2400**	400
10	2400	3	18000	**14400**	6000	400	3000	**2400**	1000
11	6000	2	12000	**14400**	3600	1000	2000	**2400**	600
12	3600	2	12000	**14400**	1200	600	2000	**2400**	200
TOTAL		*29*	*174000*	*172800*			*29000*	*28800*	

Table 32: Proposal of an annual planning for oat milk production.

OAT									
	Stock (St) in kg and batches per campaign					**Stock (St) in SQU and batches per campaign**			
Month	**Initial Stock [kg]**	**Batch/ Campaign**	**Production [kg]**	**Sales [kg]**	**Final stock [kg]**	**Initial Stock [packs]**	**Production [packs]**	**Sales [packs]**	**Final Stock [packs]**
1	0	3	18000	**13200**	4800	0	3000	**2200**	800
2	4800	2	12000	**13200**	3600	800	2000	**2200**	600
3	3600	2	12000	**13200**	2400	600	2000	**2200**	400
4	2400	2	12000	**13200**	1200	400	2000	**2200**	200
5	1200	3	18000	**13200**	6000	200	3000	**2200**	1000
6	6000	2	12000	**13200**	4800	1000	2000	**2200**	800
7	4800	2	12000	**13200**	3600	800	2000	**2200**	600
8	3600	2	12000	**13200**	2400	600	2000	**2200**	400
9	2400	2	12000	**13200**	1200	400	2000	**2200**	200
10	1200	3	18000	**13200**	6000	200	3000	**2200**	1000
11	6000	2	12000	**13200**	4800	1000	2000	**2200**	800
12	4800	2	12000	**13200**	3600	800	2000	**2200**	600
TOTAL		*27*	*162000*	*158400*			*27000*	*26400*	

9. CONCLUSIONS

The following conclusions can be extracted from the work developed:

- When designing the product, it is concluded that the main factors for which plant-based milks are not fully accepted by the western cultures is their traditional flavor and their nutritional value. To solve the problem of milk's taste, the enzyme lipoxygenase must be deactivated by heating the product and avoiding the contact with oxygen that enables the lipid oxidation reactions. To solve the problem of nutrients, addition of vitamin D in a previous-prepared nanoemulsion and addition of calcium via calcium carbonate is made.
- The general process to produce plant-based milks is composed of an initial soaking of the raw material to consequently separate the liquid phase by centrifugation, taking the solid phase and carrying out a wet milling. Afterwards, the slurry is filtered to obtain, in this case, the liquid phase composed of oils and water. Then, a UHT process is carried out and after this the product is homogenized. Finally, the beverage is dosed in cardboards and packaged. This traditional process must be modified to improve the final flavor and make the product more appealing for people. Apart from all the modifications made to deactivate lipoxygenase in the three processes, in almond milk production a roasting step is added and in oat milk production a degradation of starch is added. All these changes are made to improve the organoleptic properties and the final taste of the product. In addition, in all three processes calcium and vitamin D are added to improve the nutritional value.
- The batch size decided is 6000 kg, considering the total production and the delivering in packs of 6 cardboards of one liter each.
- Time required for a soymilk batch is of 21 hours, for almond milk is of 18 hours and for oat milk is of 23 hours. Although there is plenty of time throughout a year to meet the requirements of an annual production, there must be pointed out factors such as the time to deliver the product and the shelf life of the product, when planning and designing the scheduling. Therefore, a campaign per month is defined for each beverage. In addition, the plant is designed to assume a higher production in the future if necessary or produce other types of milk due to changes in the market.
- The soaking operations controls the soymilk and oat milk production process whereas the filtration is the operation that controls almond milk production process. Both operations are the longest ones in their corresponding processes and not until they are over can a new batch begin when overlapping is used.

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