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Design of an antioxidant supplement for the agricultural industry. Design of the process and the different equipment to create the production plant.

Diseño de un suplemento antioxidante para la industria agropecuaria. Diseño del proceso y de los diferentes equipos para la creación de la planta de producción

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“La ciencia no conoce país, porque el conocimiento pertenece a la humanidad, y es la antorcha que ilumina el mundo.”

Louis Pasteur

Me gustaría presentar mi gratitud a mis tutoras Dra. Esther Chamarro y Dra. Alicia Maestro, por ayudarme a elaborar un proyecto que ha ido variando a lo largo del tiempo en medio de la situación tan complicada que nos ha tocado vivir. Agradecer las videollamadas y las buenas palabras y ánimos para tirar para adelante.

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REPORT

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SUMMARY

Nowadays, meat industry has as one of its main objectives to optimise animal growth and its life quality, so that this has an effect on the quality of the meat and products that are commercialised.

The criteria considered by customers when it comes to choose among different meat products are the organoleptic properties: colour, taste and texture.

In order to improve the organoleptic properties of the different meat industry's products, investment and development must be centred on the farm animals' diet.

One of the last improvements that has been introduced in the production of animal fodder is the use of antioxidants.

This project will be centred in the poultry group and it will consist of designing an antioxidant supplement that can be added to the feed used in this industry in order to improve the quality of its meat. The design of the production process for this product will also be addressed.

Regarding the product's formula, vitamin E has been chosen as the active ingredient of the product due to its numerous advantages over the other possible antioxidants. Silica will be used as the solid carrier that adsorbs the liquid antioxidant and maltodextrin will be used as filler. Out of this formula, 38% in weight will be silica, 58% will be vitamin E and 4% will be maltodextrin. The concentration of tocopherol in the final product, using international units, is 575 IU.

It has been decided to work in campaigns. There will be 4 campaigns per year, each campaign will consist in 15 batches, and each of it will produce 130 kg of final product. This will allow to win about 10% of market share.

The process used to produce this product has been also designed. In order to do this, the operation conditions have been selected, and P&ID and Flowsheets have been attached to the project. An explanation to how the plant is going to work complements these documents.

Keywords: fodder, poultry industry, exogenous antioxidant, tocopherol, vitamin E

RESUMEN

Actualmente, en la industria cárnica se busca optimizar el crecimiento animal y la calidad de vida de estos, para que luego a su vez repercutan en la carne y los productos que se aportan y comercializan. Los criterios principales de los consumidores a la hora de seleccionar la carne y los productos cárnicos son las propiedades organolépticas; color, sabor y textura.

Para que las propiedades organolépticas de los distintos productos de la industria cárnica mejoren, se ha de invertir y mejorar en la alimentación de los animales de granja.

Una de las mejoras que se han introducido en los piensos animales en la actualidad es el empleo de antioxidantes en la dieta animal.

Este proyecto estará centrado en el grupo avícola y consistirá en diseñar un complemento antioxidante que se pueda agregar al pienso utilizado en esta industria con el fin de mejorar la calidad de su carne. También se abordará el diseño del proceso de producción de este producto.

En cuanto a la fórmula del producto, se ha elegido la vitamina E como principio activo del producto por sus numerosas ventajas sobre los demás posibles antioxidantes. Se utilizará sílice como vehículo sólido que adsorbe el antioxidante líquido y se utilizará maltodextrina como relleno. De esta fórmula, el 38% en peso será sílice, el 58% será vitamina E y el 4% será maltodextrina. La concentración de tocoferol en el producto final, utilizando unidades internacionales, es 575 UI.

Se ha decidido trabajar en campañas. Serán 4 campañas por año, cada campaña constará de 15 lotes, y cada una de ellas producirá 130 kg de producto final. Esto permitirá ganar alrededor del 10% de la cuota de mercado.

También se ha diseñado el proceso utilizado para producir este producto. Para ello, se han seleccionado las condiciones de operación y se han adjuntado P&ID y Flowsheets al proyecto. Una explicación de cómo va a funcionar la planta complementa estos documentos.

Palabras clave: pienso, sector avícola, antioxidantes exógenos, tocoferol, vitamina E

1. INTRODUCTION

1.1 ST MEAT OXIDATIVE PROCESSES

1.1.1st Origin and consequences of oxidative stress

Oxidation is a biochemical process that consists of electrons loss, always associated with another one consisting of electron gaining, called reduction. This oxidation process is fundamental for life as it participates in the process for the obtention of cell's energy (1).

However, this oxygen that is essential for life, can also be the source of cell damage due to an uncontrolled production of oxygen free radicals (OFR), which damage macromolecules (lipids, proteins and nucleic acids) and alter the cellular processes (membranes functionality, enzyme production, cellular breathing, genic induction, etc.).

On the other hand, antioxidants are able to oppose the oxygen and other oxidant species effects, independently of its mechanism. This will be further explained on later chapters of this project. When an unbalance between the OFR and the defence mechanism of antioxidants occur, the **oxidative stress** is originated .(2)

Effect over lipids

Lipids are the ones which take more damage due to oxidative stress, in a process called lipid peroxidation. This process affects polyunsaturated fatty acids (PUFA), which are part of the cellular membrane. Thus, lipid peroxidation has an effect over cellular structures, changing its adhesion, fluency, permeability and metabolic function (3).

Effect over proteins

Proteins are less affected than lipids due to the slow kinetics of the reactions. These reactions can cause fragmentation of the peptide chain, changes on specific amino acids, aggregation or intertwinement, alterations of the electrical charge or an increase of proteolysis susceptibility. In addition, irreversible changes that inhibit enzymatic function can occur (4)

Effect over nucleic acids

Mitochondrial DNA is especially susceptible to these reactions because it is exposed to a constant flow and a high reactive species that come from the breathing chain. Among all the alterations spectrum that DNA can suffer, the next ones, mainly, will be described: deoxyribose's oxidation, rupture and intertwinement of chains and modification of nitrogenous bases. Moreover, a loss of protein expression due to specific genes alterations can be caused (5)

This project will be centred on explaining with more detail the way in which lipid oxidation affects meat products, as it is where most of the oxidative damage occurs and it is also the one that can be reduced the most with the use of the supplemental diet that will be developed in further chapters.

1.1. 2nd Lipid oxidation in meat products

Lipid oxidation is the most important causes of deterioration in meat products and it affects unsaturated fatty acids particularly PUFA in membrane phospholipids as well as cholesterol, mainly low-density lipoprotein (LDL) cholesterol. The final end-products of this process can damage sensorial attributes of meat and reduce the nutritive value. Besides nutritional deterioration, lipid oxidation generates genotoxic and cytotoxic compounds which are deleterious for human's health. The oxidative damage to meat-based products results in problems like tissues damaging, rottenness, loss of nutrients, enhanced free radical generation and malonaldehydes production that reduce the antioxidant capacity of products (6)

1.1.3rd Lipid oxidation consequences:

The chicken meat contains higher percentage of PUFA that are susceptible to oxidative deterioration ultimately leading towards lower consumer acceptability for chicken meat products. For this reason food industries are looking for antioxidant to improve the oxidative stability (6).

As mentioned previously, due to degradation of unsaturated fatty acids, short-chained volatile components appear, such as aldehydes, ketones, alcohols, esters and acids which cause odours and flavours that reduce meat quality and its acceptability.

As consequence of lipid oxidation, the next processes, among others, are caused:

- Cholesterol oxidation: cholesterol is a component of the cellular membrane. The components produced due to cholesterol oxidation are detected at trace levels in raw meat during its storage, and its concentration increases due to a growth of free radical generation, caused by PUFA oxidation.
- Weight loss: oxidative processes can affect membrane's ability to serve as a semipermeable barrier and can contribute to lipid dripping.
- Muscle pigments oxidation: meat colour quality depends on muscle pigments (6).

2.2ND ANTIOXIDANTS AND ANTIOXIDANT SYSTEM

An antioxidant is any substance that delays, prevents or removes oxidative damage to a target molecule. Antioxidants are an inhibitor of the process of oxidation, even at relatively small concentration and thus have diverse physiological role in the body (7).

Living organisms can survive in an oxygen-rich environment only because of antioxidants presence. These mechanisms are described by the general term of **"antioxidant system"** and allow the organism to protect themselves front reactive species (8).

The antioxidant defence system is constituted by molecules from exogenous or endogenous origin and lipophilic or hydrophilic nature, and to have affect via processes carried on by enzymes or not (see Tables 1 – 3) (9).

Table 1. Classification of endogenous antioxidants (adapted from: www.portalantioxidantes.com)

Endogenous antioxidants	
Enzymatic antioxidants	**Non-enzymatic antioxidants**
Dismutase superoxide	Glutathione
Catalase	Uric acid
Peroxidase Glutathione	Dihydro-lipoic Acid
Transferase Glutathione	Ubiquinol (Q coenzyme)

Even though these are mainly bio-synthetized by the organism, it is also possible to provide them through diet. However, it must be clarified that the contribution that this antioxidant-containing diet would imply for the organism is not so meaningful because these antioxidants experience a prominent degradation/biotransformation throughout the gastrointestinal tract (9).

Regarding the antioxidants that enter the organism only through diet (all of them, non-enzymatic), these are classified, essentially, as:

Table 2. Classification of exogenous antioxidants (adapted from: www.portalantioxidantes.com)

Antioxidants ingested through diet		
Vitamins – antioxidants	**Carotenoids**	**Polyphenols**
C Vitamin	Lutein	Flavonoids
E Vitamin	Zeaxanthin	Non-flavonoids
β-carotene	Lycopene	

Additionally, antioxidants can be classified according to its lipophilic or hydrophilic nature:

Table 3. Classification of antioxidants according to its nature (adapted from:www.portalantioxidantes.com)

Hydro-soluble antioxidants	Lipo-soluble antioxidants
C Vitamin	E Vitamin
Glutathione	β–carotene
Uric acid	Q coenzyme
Flavonoids	

3. OBJECTIVES

Once the oxidative stress effects on meat quality and how this can be countered with the addition of antioxidants have been addressed, the next step is to develop an antioxidant product that can be added to animal fodder.

Therefore, the objectives of this project will be:

1. To select the optimal antioxidant to the product respecting quality standards.
2. To choose which will be the best final condition to commercialise the product.
3. To formulate the product so that it can be added directly to common poultry fodder that can be found in market.
4. Design the working process and operation characteristics of the plant where the manufacturing of the product will take place.

4. BRIEFING

Main function of the food supplement:

As has been mentioned before, the objective of this project is to design an antioxidant food supplement for the poultry industry. Thus, the main function that is searched is to guarantee the enough placement of antioxidant to the muscle so to get protection against oxidation processes of meat, maintaining the optimal colour for longer periods of time, and therefore, increasing the lifespan of meat.

Expected benefits for the consumer:

• Effective antioxidant that prevents oxidation and improves meat quality: it will be important to focus on finding an antioxidant that is effective in small concentrations. To do this, it will be vitally important to look for and select those antioxidants that have a higher bioavailability and reach a higher concentration in the tissues where they perform the action.

• Do not modify the characteristics of the feed: consumers seek that the additives added to their feed do not modify excessively its organoleptic characteristics. Consequently, special attention will be paid to selecting antioxidants that do not interfere with the characteristics of the final product.

• Easy incorporation into feed: With the design of the product, the aim is to find the most appropriate way for consumers to easily incorporate the antioxidant into their feed.

Initial objective market at which the product is aimed

Big and small companies. It is expected to reach both big fodder production industries and small farmers, so that they can add the supplement in low amounts to their own fodder.

5. ANTIOXIDANTS SELECTION

In order to choose the antioxidant that will act as active ingredient in the product suitable to supplement fodder destined to poultry industry, a series of factor shall be considered:

- Its use must be safe. This can be assured using antioxidants that have been used and studied previously.
- Bioavailability must be high once ingested. As seen in the last section, there are antioxidants ingested through diet and endogenous. While the later are mainly bio-synthetized by the organism, it is also possible to provide them through diet. However, the contribution that this would imply to the organism is not very meaningful because they experience degradation/biotransformation throughout the gastrointestinal tract.
- Its bioavailability. This depends on its nature. Hydrophilic antioxidants are located mainly in cellular fluids and lipophilic antioxidants are located in cellular membranes having a decisive role in the interruption of lipid peroxidation, which affects PUFA's membranes.
- It must be effective in low concentrations.
- It must not give odour, flavour nor colour to the fodder. It is important that it does not modify the characteristics of fodder that supplements.
- Its addition to the product must be easy, it must be soluble and easy-dispersed in it. The fodder will be in solid phase and so the antioxidant, so that it can be used by small farmers, even though this would not be its main purpose.
- It must be stable during the food processing and capable of stabilizing the final product. It must not deposit nor separate from the fodder because it would not be functional.
- It must be available at low cost. Its price is one of the most important factors to the customer.
- The final choice will be a natural and genetically non-modified antioxidant, as they cause less mutagenic effects and have more acceptability in the market.

Justification of the antioxidant choice:

Taking into account the considerations mentioned above, one of the most important characteristics when you have to select an antioxidant is bioavailability.

It is observed that exogenous antioxidants have a higher availability than endogenous antioxidants, because these last ones present biodegradation processes throughout the gastrointestinal tract. This makes exogenous antioxidants the chosen option. The place of action of antioxidants is also of vital importance. As it has mentioned above in section 3.1.2nd, lipid oxidation represents the major cause of deterioration in meat products affecting the PUFAs of the cell membrane.

This leads directly to choose an antioxidant that is located and has its place of action in cell membranes. Therefore, an exogenous antioxidant of a lipophilic nature will be selected, since they are the ones that are mostly located in these structures and will have a decisive role in PUFAs, interrupting lipid oxidation.

Among the lipophilic exogenous antioxidants, the choice is between the use of vitamin E or the ß-carotenes. Looking at the characteristics of the ß-carotenes it is appreciated that they do not comply with the previous specifications since this type of antioxidants adds colour and this can modify the characteristics of the final feed. This make us to rule out the carotenes and choose Vitamin E as the ideal antioxidant for the project.

Finally, once the Vitamin E has been chosen, to improve and comply with the last of the product specifications, it must be taken into account that chosen vitamin E must be NO GMO to cause less mutagenic effects and have more acceptability in the market.

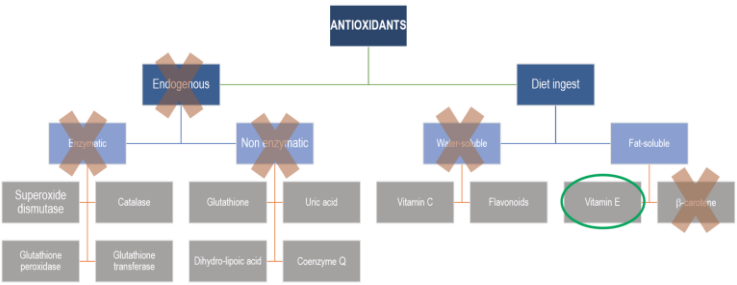

Figure 1. Conceptual diagram for the choosing process of the optimal active component (vitamin E). Own elaboration.

Compliance with all these factors brings to choose **natural and no GMO Vitamin E** as the optimal antioxidant.

5.1ST VITAMIN E

Vitamin E is the generic term that includes a series of liposoluble antioxidants compounds present in the cells of every tissue of the body and it is considered as the first defence line against lipid peroxidation. It is constituted by four isomers: α, β, γ and δ, which differ in the number and position of the methyl tied to the phenolic ring. They are also constituted by a chromanol ring and a isoprenoid chain that can be saturated (tocol) or unsaturated (tocotrienol) (10). Figure 2.1 shows the chemical structure for the tocopherol and Figure 2.2 show the chemical structure for tocotrienol.

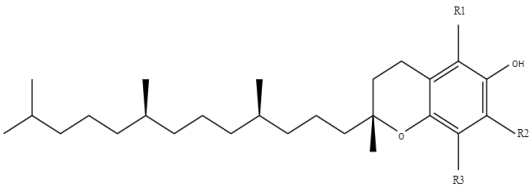

Figure 2.1 Chemical structure for tocopherols (generated with ChemDraw)

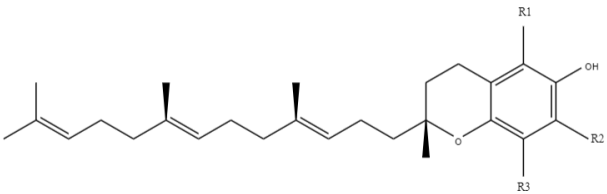

Figure 2.2 Chemical structure for tocotrienols (generated with ChemDraw)

The hydroxy group contained in its structure is essential for the antioxidant activity of Vitamin E, as well as the presence of a methyl group and an aromatic ring, minimum. α-Tocopherol, with three methyl groups, is the predominant in most species as well as the most biologically active one. The other equivalents (β, γ, δ) differ in the position of the methyl groups in the ring (Table 3-4) (10).

Table 3. Position of the methyl groups in the aromatic ring. Own elaboration

	R1	R2	R3
α– tocopherol **α -tocotrienol**	CH3	CH3	CH3
β- tocopherol **β- tocopherol**	CH3	H	CH3
γ–tocopherol **γ–tocotrienol**	H	CH3	CH3
δ-tocopherol **δ-tocotrienol**	H	H	CH3

Table 4. Biological activity of the difernt isoforms of tocopherol (10)

Tocopherols	Biological activity
α	+
β	
δ	
γ	-

For this reason, the project focuses on using α-tocopherol since it is the isoform that stands out for its great biological activity compared to the rest.

5.1.1st Physicochemical characteristics of Vitamin E

In pure state, vitamin E is a yellow viscous liquid that decomposes easily in presence of light, oxygen, alkaline pH of metallic ions traces. Moreover, it is insoluble in water and soluble in alcohol, organic solvents and vegetal oils. It has a UV absorbance intensity quite low, though moderate fluorescence (11).

. 5.1.2nd Metabolic function of vitamin E

Vitamin E is an antioxidant that cannot be synthetized by animals and its concentration in animal tissue shows that it is ingested through diet. It a vitamin with lipophilic nature, thus, its absorption depends on the animal capacity to absorb and digest fat through diet.

Vitamin E is absorbed in the proximal intestine, where it is incorporated to the chylomicron, where it is stored and, subsequently, secreted to the bloodstream. Once in the bloodstream, the lipase lipoprotein of the endothelium cells hydrolyses these chylomicrons into remnant chylomicrons which hand over vitamin E to hepatic cells.

Vitamin E is transferred from the hepatic cells to the VLDL (very low density lipoproteins) by the α-TTP (α-tocopherol transferred protein) action. Inmediatly, the VLDL hand over a part of the vitamin E to the peripheric tissues, the other to the HDL (high density lipoproteins) and the most part, after VLDL metabolism, ends up associated to the LDL (low density lipoproteins): the most important transport vehicle to the peripheric tissues (Figure 3). There, it uses its protective effect against phospholipids peroxidation (see next section) (11,12).

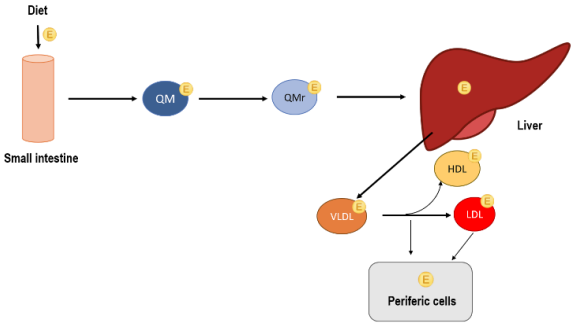

Figure 3. Representation of the distribution of vitamin E. Adapted from (11).

5.1.3rd Antioxidant properties of vitamin E

Vitamin E is the main liposoluble antioxidant capable of breaking the propagation chain of lipid oxidation, protecting PUFA from phospholipids of the membranes and from the plasmatic lipoproteins. The reaction of α-tocopherol is non-enzymatic and fast, catching peroxyl radicals before they attack a lipid substrate target and propagate lipid peroxidation.

In particular, vitamin E acts transferring the hydrogen from the hydroxyl group of the sixth carbon to the peroxyl radical and α-tocopheroxyl radical is formed, which is quite stable as the unpaired electron can delocalize in the aromatic ring, avoiding its reaction with the PUFA of membrane phospholipids and blocking the chain reaction (see Figure 4).

Membranes have about one molecule of α-tocopherol out of two thousand phospholipids, but despite this, it is extraordinarily effective since peroxyl radical reacts about ten thousand times faster with vitamin E than with PUFA. (11).

Antioxidant efficiency of Vitamin E is increased by the regeneration of the vitamin from its oxidized product. α-tocopherol radical can be reduced to vitamin E by ascorbic acid and the glutathione or it can generate a quinone radical and react with another vitamin E radical generating a dimer (13).

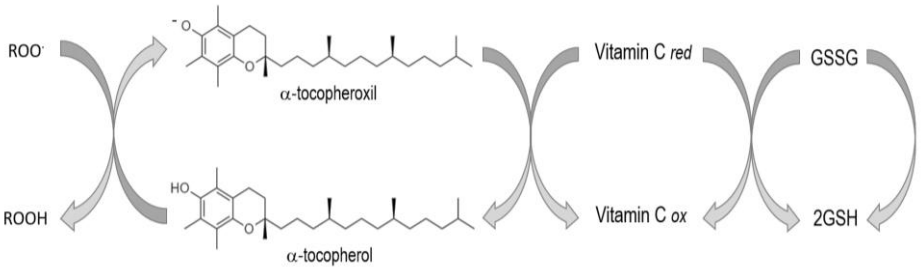

Figure 4. Antioxidant function of vitamin E. Adapted from (13).

5.1.4TH Differences between the natural form and the synthetic form of α-tocopherol.

One of the aspects to consider when choosing the antioxidant is its form. Even though, α-tocopherol has been chosen as the referential antioxidant to the product design, the next step is to decide which form is more convenient, its natural form or its synthetical one.

The plant-produced α-tocopherol has only one RRR configuration in 2, 4' and 8' position of the α-tocopherol molecule.

However, synthetical Vitamin E (called DL- α-tocopherol) is a mix of 8 stereoisomers of α-tocopherol that are originated from the three chiral carbons in positions 2, 4' and 8': RRR-, RSR-, RRS-, RSS-, SRR-, SSR-, SRS- and SSS- α-tocopherol (in equivalent quantities) (see Figure 5). The chemical structure of these while all stereoisomers have an in vitro antioxidant activity equivalent, only the R-conformation forms in the position 2, satisfy requirements of vitamin E. Thus, synthetic form contains only a 12.5% of RRR α-tocopherol, analogous to the natural form (also called D-tocopherol) (14).

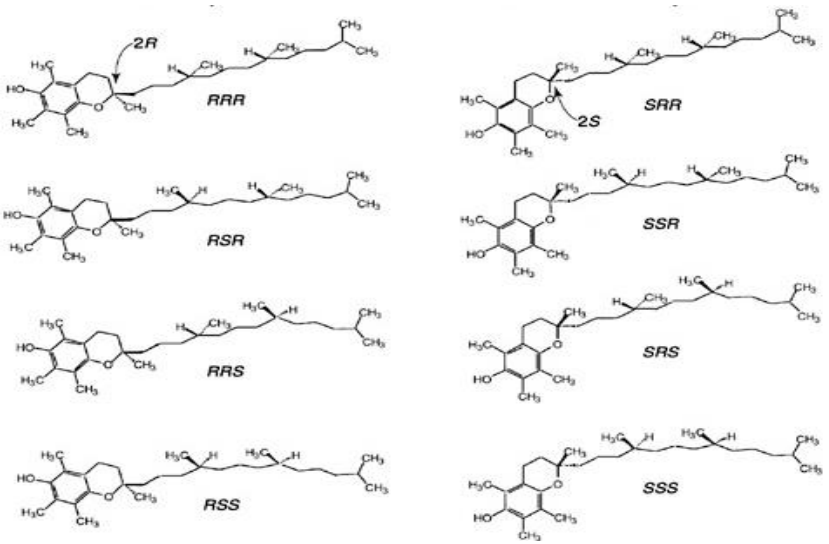

Figura 5. Chemical structures of 8 steroisomers of DL-α-Tocopherol.
https://www.nap.edu/openbook/0309069351/html/189.html

Both forms are absorbed by the intestine and transported by chylomicrons to the liver, without discrimination among them. However, once it reaches the liver, there is a significative discrimination in the transport from the liver to the body tissues. The α-TTP is only specific to the natural RRR form of α-tocopherol; that is, it can transport the RRR form but very little, or rather nothing, from the others. This way, natural vitamin E provides to the tissues from 2 to 3 times the α-tocopherol from the synthetic vitamin E due to the fact that 4 out of the 8 stereoisomers from the vitamin E can be transported by α-TTP (though 3 out of them with a much lower efficiency), while the other remaining 4 stereoisomers are not transported by αTTP, they are metabolised within the liver, and then they are excreted (15, 16)

In conclusion, natural α-tocopherol (100% RRR) is totally transported from the liver to the body tissues, while synthetic vitamin E is transferred in a much lower grade, with a great proportion simply being metabolised and excreted.

Thus, in this project it has been decided that the natural form of α-tocopherol (D- α-tocopherol).

6. TECHNICAL PRODUCT DESING

As it has mentioned in section 3.1.3, chicken meat is susceptible to oxidation processes since they contain a high percentage of PUFA, which generate odours and flavours that reduce the meat quality and its acceptance. Faced with this problem, there are many meat industries looking for natural antioxidants to improve oxidative stability and consumer's acceptability of meat-based products.

For this reason, and as it has been discussing, the intention of the project will be to create a product that contains natural non-GMO vitamin E as an antioxidant for use in supplementation of poultry diets.

6.1ST BENEFITS OF SUPLEMENTATION WITH VITAMIN E IN POULTRY

Vitamin E supplementation in the diet of animals destined to the production of meat, aims to ensure enough deposition of α–tocopherol in the muscle to get its protection against oxidative degradation. In this sense, numerous works demonstrate the efficacy of vitamin E supplementation in the animal diet.

6.2ND FINAL STATE OF THE PRODUCT

One of the most important choices for product design is to select the state in which it is going to be marketed, since it has to bear in mind that it will be a product which will serve to supplement solid feed.

For this, these two situations must be considered:

- **Final liquid product**: liquid tocopherol can present many technical and commercial problems due to its viscous nature. Design the product in a liquid state could entail problems when handling and dosing it.
- **Final solid product**: highly viscous and sticky liquids become easier to handle and to dose, when converted into powders. Moreover, powder can easily be mixed with other powder components and homogeneously distributed in powder formulations.

The goal is that the product will be able to mix homogeneously with the common feeds, which will be in a solid state. For this, it will be more favourable that the two components have the same

physical state, in this way they will mix more easily and more homogeneously. Also, it's necessary that product can be sold in bags, because this can be safely stored and that its mix can be optimal with any type of common poultry feed.

Therefore, the product, due to its function and viability, must be in a solid state.

To produce the final product in a solid state, it's necessary to convey the liquid antioxidant. This implies choosing a suitable carrier that allows it to comply with technical and aesthetic specifications and come up with the concentrations of vitamin E powder that market can demand.

6.3RD CARRIER CHOICE

For choice a carrier, the following aspects must be considered:

- The carrier must be FOOD grade, of high quality and fully studied and known. It seeks to ensure the quality of the final supplement through a formulation where all products are known and safe
- The liquid antioxidant mixed with the carrier must adopt the state of powder non-mud. The carrier adsorption limit must not be exceeded to avoid having a wet product
- The selected carrier must be able to adsorb a large amount of liquid antioxidant to achieve high product concentrations with a ratio liquid optimal-solid.
- Another very important aspect is that the product can flow easily and that it will be able to mix homogeneously with the feed that has to be supplemented, is for this reason that it's necessary a carrier that provides a high fluidity to the product.

As it has reflected in the previous points, by the choosing of the carrier, the essential parameters of the product can be modified. A correct choice of the carrier will provide great fluidity to the product, ensure the absence of dust, and create an adequate aesthetic.

Specifically, for this product, silica has been chosen as carrier. Silica acts like a sponge adsorbing liquids and converting them into a free-flowing powder. With this carrier, it can be obtained free-flowing and almost dust-free adsorbate.

The alternative to silica that is usually proposed is maltodextrin. It is used in those cases in which a powder product suitable for use in organic production is required, since technologically suitable silica (E551a) is not allowed at this level. Obviously, its technological properties are worse, since it has an adsorption capacity of 30% of its mass with respect to silica, of 60%, which

would always require manufacturing with more concentrated tocopherol extracts. Since in this case organic production is not required, maltodextrin won't be used as the main carrier.

Into the world of food silicas there is a great variety. After analysing various types of them, it opted for a range from the supplier EVONIK, a company that works with carriers for different uses.

In particular, from the wide line of products that it presents, it interested in the EVONIK SPIERNAT range. This type of silica carrier consists of primary particles which are linked together in aggregates and subsequently to larger agglomerates. This form has a highly porous structure into which liquid can be adsorbed.

Within this range, it's finds several types of silicas with different characteristics (see table 5 and 6):

Table 5. Table that shows the particle size, adsorption, practical liquid content, ratio and DOA of the different types of SIPERNAT silica.

SIPERNAT-grade	**Average particle size (μm)**	**Adsorption capacity**	**Practical liquid content (%)**	**Ratio Silica: Liquid Density=1g/ml**	**DOA [ml/100g]**
SIPERNAT 22000	320	1.5X	60	40 g: 60 g (ml)	225
SIPERNAT 22	110	1.8X	65	35 g: 65 g (ml)	235
SIPERNAT 50	40	3X	75	25 g: 75g (ml)	305

When it has to choose the food silica offered by the supplier, you must opt for the product specifications. So, it will mainly look at the following characteristics: **dust free, flowability and adsorption capacity.**

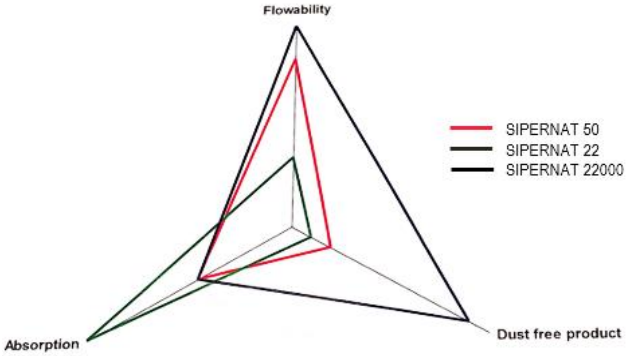

Figure 6. Graphic that shows the parameters of the different silicas from the SIPERNAT range.

Table 6. Table that shows the differences between flowability, dust free and adsorption of silicas from the SIPERNAT range

SIPERNAT-grade	FLOWABILITY	DUST FREE	ADSORTION
SIPERNAT 22000	++	++	+
SIPERNAT 22	+	+	+
SIPERNAT 50	-	-	++

Looking at the graphics and tables, it's choose silica SIPERNAT 22000 as it is the one that complies in the best measure with all the specifications that its requested before:

It has an adsorption capacity very similar with SIPERNAT22 and SIPERNAT50. It is the one with a lower adsorption value, however, the difference is low and acceptable.

It has the largest particle size (320 μm) and this improves the dust free effect and, greatly, fluency and flowability.

6.4 TH QUALITATIVE COMPOSITION OF THE PRODUCT

The final product formula will be composed of the principal active, the silica carrier, and if it were necessary, and excipient can be added for technical purposes (see table 7).

Formula will not contain aromas or colorants since this product will be used for the subsequent mixed with feed, which already contains aromas. The intention is to modify the minimum the organoleptic characteristics of the feed to which it will be added.

Active Ingredient:

- OXABIOL E 1000 IU (73,5% D-α-Tocopherol): natural vitamin E in liquid state obtained from soybean GMO.

Carrier:

- SIPERNAT 2200: micro pearl food silica

Excipients:

- Glucodry G210: Maltodextrin can be used to reduce the concentration of the final product to lessen the use of silica, since it has a higher cost than the excipient.

Table 7. Composition of the product to be designed

Formulation			
Supplier	**Brand name**	**Component**	**Function**
EVONIK	SIPERNAT 2200	MICROPEARL food silica	Carrier
BTSA	OXABIOL E 1000	D-α-Tocopherol-acetate	Principal antioxidant active
Tedros Synal	Glucodry G210	Maltodextrin	Filling to dilute the concentration

6.5TH QUANTITATIVE COMPOSITION OF THE PRODUCT

Once the qualitative composition has been decided, the quantitative composition is next. The quantitative compositions will be defined once the percentage of each component is set. The percentage of tocopherol in the final formula is also an important parameter, as it will be of great use once the quantity of product added to the fodder is required. All this said, a few considerations must be taken first in order to define this quantitative composition.

First of all, as shown in Table 5, the mass ratio between liquid (Oxabiol E 1000) and silica (Sipernat 2200) must be 1.5. A lower ratio would imply that silica is not able to adsorb all the liquid tocopherol, and a greater ratio would imply that there is silica that is being wasted (it is not an efficient ratio, economically).

In second place, it must be considered that the active ingredient, Oxabiol 1000 IU, has a tocopherol concentration of 73%.

And finally, the carrier percentage in the formula should be decided. Once this parameter and the others above are chosen, then the tocopherol concentration in the formula gets determined (it is no longer a degree of freedom). The carrier percentage chosen is 4%; even though it may seem a low concentration, it will allow to low the quantity of the other two components in the formula, and thus, low the product cost as well.

As said before, once these three design parameters for the product have been decided, the concentration of tocopherol in the formula is determined, which in this case is 42% of tocopherol. The calculations are shown below:

Equations:

$$\boldsymbol{F = 0.04} \qquad (\boldsymbol{eq.1})$$

$$\frac{\boldsymbol{A}}{\boldsymbol{C}} = \boldsymbol{1.5} \qquad (\boldsymbol{eq.2})$$

$$\boldsymbol{F + C + A = 1} \qquad (\boldsymbol{eq.3})$$

F stands for filler mass percentage; A stands for active ingredient mass percentage and C stands for carrier mass percentage. Equation 1 is the percentage of filler in the formula which is 4% as said before. Equation 2 is the ratio Active Ingredient: Carrier, which is 1.5, as said before, too. And Equation 3 stands for the fact that all components sum 100% of the mass.

There are then, two equations and two unknowns (equation 1 and F could be counted or not). Solving them, A and C are found:

$$\boldsymbol{C = \frac{1 - 0.04}{1 + 1.5} = 0.384}$$

$$\boldsymbol{A = 1.5 \cdot \frac{1 - 0,04}{1 + 1.5} = 0.576}$$

That is, the formula consists in: 57.6% of Oxabiol E 1000 IU, 38.4% of Sipernat 2200 and 4% of Maltodextrin.

Once at this point, the tocopherol concentration in the final product can also be calculated:

$$\%\mathbf{tocopherol = 0.735 \cdot A = 0.735 \cdot 1.5 \cdot \frac{1 - 0.04}{1 + 1.5} = 0.423}$$

That is, the concentration of tocopherol in the final product is 42.3%

At this point, it is important to introduce the concept of International Units, IU. In pharmacology, an IU is a unit of measurement for the amount of a substance. The mass or volume that constitutes one international unit varies based on which substance is being measured, and the variance is based on the biological activity or effect.

When talking about vitamins, the quantity of IU per milligram or gram of vitamin varies depending on whether the vitamin has synthetic origin or natural origin. Typically, the same amount of vitamin has more IU when it is natural-originated than when it synthetic-originated.

In the specific case of natural-originated vitamin E, 1 IU is equivalent to 0.735 mg of vitamin E. Therefore, the product that has been designed in this project will have the next amount of IU:

$$\frac{\mathbf{42.3\ g\ tocopherol}}{\mathbf{100\ g\ final\ product}} \cdot \frac{\mathbf{1000\ mg}}{\mathbf{1\ g}} \cdot \frac{\mathbf{1\ IU}}{\mathbf{0.735\ mg\ tocopherol}} = \frac{\mathbf{575\ IU}}{\mathbf{g\ final\ product}}$$

Therefore, this product will have a concentration of 575 IU. This nomenclature is much more used in pharma and food industry.

6.6TH TECHNICAL CHARACTERISTICS AND APPEARANCE OF THE FINAL PRODUCT.

In Table 8, showed below, there are schematically pointed the most important specifications of the product. Below this table, the operations instructions as well as the storage instructions are described.

Table 8. TOCPHEROX UB-40 Product Technical Specifications

Product name	**TOCOPHEROXUB-40**
Application	Natural premix for use in the feed industry
Product state	Dust not mud
Concentration of tocopherol	42.3% (575 IU)
Density	0.5-0.7 kg/L
Appearance	Creamy white powder
Packaging	Polyethylene bags
Solubility	Can be dissolved in water Soluble in oils and fats

Operating instructions: dose the recommended amount in a mixer or machinery suitable for mixing with the feed that you want to enrich, you can also do manual mixing of the quantities are small and allow it.

Storage: Product will be stored in polyethylene bags contained in boxes of cardboard. The standard format will have a capacity of 15 kilograms per container.

The chose polyethylene as storage material it's due to it is one of the safest containers, they practically do not transfer chemicals, and this will avoid problems in subsequent migrations test that the costumer may require or maybe the quality certifiers. It is also very remarkable its thermal and chemical resistance and its ability to be fully recyclable. Thanks to the airless system, air is prevented to come into contact with the components of the product, avoiding aging and oxidation in order that the consumers can use it with total guarantee for more time.

It's recommends storing the product in the original container, closed, at a room temperature, in a dry place and protected from oxygen, light and heat. Once the container is opened, it will advise its immediate use.

Best-before date: 18 months under the above conditions.

Figure 6**.** Design of the polyethylene bags 15 kg where the product TOCOPHEROXUB-40 will be stored.

7. PRODUCTION PLANT DESIGN

To fabricate the product, its must design and select the equipment that will be part of a plant capable of achieving the production that its will propose.

The intention is to produce under customer demand as the product features a short expiration. In this way its can deliver a new elaboration product to the customers so that they can take advantage of the entire life of the product.

To get the most out of the installation, it will consider that the best option is to create a multiproduct plant, that is an installation able to work with several raw materials to give rise to a different and wide product.

7.1 ST OPERATION CONDITIONS

The first step in designing the plant is to know how it will operate and the operating conditions. It has been decided that the plant will operate on loads.

For the installation, it must design it considering that it will produce pulverulent solids originated as a result of the mixtures of solids and liquids. That is why it is important to know the characteristics of the products it will work with (Table 9).

Table 9. State and density of raw materials and final product obtained.

Product	State	Density (Kg/L)
SIPERNAT 22000	Pulverulent solid	0.18-0.25
TOCOPHEROL 70%	Oily liquid	0.9-1
MALTODEXTRIN	Pulverulent solid	0.5-0.6
TOCOPHEROXUB 40	Pulverulent solid	0.5-0.7

As can be seen, the table specifies the desired characteristics of the different components that will take part in the process.

Moreover, it will be vital to know the operating conditions of the plant (Table 10), in order to adjust parameters and later define the production.

Table 10. Specify which operations will be worked on during the production process

Operating temperature	25-35ºC
Operating pressure	1 atm

No special conditions are required for this process, so atmospheric pressure and room temperature are chosen.

7.1.1 st Define the bacth:

Once operation conditions have been defined, the production needed for each batch must be decided. This will enable further dimensioning of the plant's equipment. The batch production must be based on the expected market demand and the desired market share.

However, it is not normal to talk about demand of vitamin E aimed at poultry fodder, rather, it would be fitter to talk about demand of poultry fodder and then, knowing a reference quantity of vitamin E per kg of poultry fodder, the "demand" of this vitamin E can be calculated.

The reference value that will be used is 50 IU of vitamin E per kg of fodder. This value comes from a recommendation found in bibliography, however, it is important to say that each poultry industry will use different values depending on the aim of the fodder (that is, to feed baby poultry, adult poultry, etc.), thus, this is only a reference value to get a quick estimation of the demand of vitamin E that can exist in the market.

The next key parameter that is needed is the poultry fodder demand. Because of the difficulty of finding or setting out a possible expected demand and because this project is only for academical purposes, it will be supposed an annual demand of 900.000 tonnes in the market.

With these two values, the amount of the product that could supply all this demand can be calculated:

$$\frac{\mathbf{50}\ \boldsymbol{IU}}{\boldsymbol{kg\ fodder}} \cdot \frac{\mathbf{1}\ \boldsymbol{g\ final\ product}}{\mathbf{575}\ \boldsymbol{IU}} \cdot \frac{\mathbf{1000}\ \boldsymbol{mg}}{\mathbf{1}\ \boldsymbol{g}} = \frac{\mathbf{87}\ \boldsymbol{mg\ final\ product}}{\boldsymbol{kg\ fodder}}$$

Therefore, these 900 000 tonnes of annual fodder demand would require about 78 260 kg of vitamin E. This value can be taken as a quick estimation for the demand of vitamin E aimed at poultry fodder in the market.

It is also decided that the desired market share will be 10%, that is, it is necessary to sell (and thus, to produce) 7826 kg each year.

In order to reduce the amount of stock (and thus, its associated cost), the production will be distributed on four campaigns (one each trimester). This will also allow the production of other different products between these campaigns and therefore, the plant will fulfil its purpose (multiproduct plant).

As said, the total production must be distributed in 4 campaigns, thus, each campaign must produce 1.956 kg.

When operating in campaigns, these typically range from 5 to 15 batches each one. Moreover, as the product obtained has a high add value, each batch may not surpass 200 kg. All of these are only illustrative ranges, but they can help when deciding.

Having said all this, in this project is proposed the next planning: a total number of 4 campaigns, two of them consisting in 15 batches. In each batch, 130 kg of final product will be produced.

It is very important to notice that this is only one of the many alternatives that could have been set out. However, it is the duty of an engineer to decide among all alternatives. This choice has not to be the most optimal one, just choosing something feasible could be considered good enough.

7.2ND QUANTITATIVE COMPOSITION OF EACH BATCH:

Once the composition of the product (the percentages of each ingredient in the formula) and the size of each batch have been defined, the composition of each batch can be easily done. This, together with the characteristics of the raw materials, will allow to calculate the volume of each batch and, thus, it will be possible to dimension the equipment.

Table 11. Quantitative composition of TOCOPHEROL UB40

RAW MATERIAL	Composition	Mass (Kg)	Volume (L)
OXABIOL 1000 IU (tocopherol 73 %)	58%	75	75
SIPERNAT 22000	38%	50	250

RAW MATERIAL	Composition	Mass (Kg)	Volume (L)
Maltodextrina	4%	5	10
Producte conc > 40%	100%	130	335

To be able to design the necessary equipment it will be important to know in which state and quantity raw materials come to the plant.

Table 12. Presentation and amount of support for primary materials at the production plant

BRAND NAME RAW MATERIALS	PRESENTATION	QUANTITY PER EACH CONTAINER
OXABIOL E 1000 IU	Flexitank	300 L
SIPERNAT 22000	Bags	25 kg
Glucodry G210	Bags	25 kg

7.3 RD PRODUCTION OPERATIONS:

Knowing the above technical data, a first diagram can be made with all production operations that will be produced (Figure 7):

1. The liquid antioxidant (73.5% Tocopherol) is added to the mixer using an injection system. The process of adding the liquid is detailed below.
2. The solid carrier is loaded (SIPERNAT 22000) into the mixer through an unload hopper for unloads and prepared for bags.

For the mixture of the two phases inside the mixer, it is contemplated that a third solid product may be added (Maltodextrin) if it is necessary. It is important that the mixer ensure the final homogenization.

3. After a certain time inside the mixer in operation is proceeded to unload the product through a sieve.
4. There will be a semi-automatic bagging machine always controlled by an operator.

7.3.1st General operating time and operating time for each equipment/operator:

The plant must operate to be able to give rise to a planned production. So, the properly establishment of a plan in order to meet production requirements, is vital to know operating times and final production time.

To establish the time for each operation, a few quick calculations will be done.

For the liquid injection time, it will be considered that the pipe through which tocopherol is added to the mixer has a diameter of 1 inch (typical values are 1 or 2 inches) and circulation velocity of the liquid is 1 m/s (another typical value for liquid circulation).

With this circulation flowrate can be calculated and knowing the total volume to add (50 L), the required time is easily determined. This gives an addition time of 1,64 minutes (let's say 3 minutes as the pump needs to be switched on and valves must be opened).

The addition of solid raw materials may take a bit more since it requires a greater manual intervention. In case of SPIRENAT 22000, 75 kg must be added. They are stored in bags of 25 kg each, therefore, 3 bags must be added. It is supposed that the manual addition of one bag takes 5 minutes, thus, a total 15 minutes are required for the SPIRENAT 22000 addition. Five more kilograms of Maltodextrin must be added, this manual addition is supposed to take another 5 minutes. Therefore, the solids addition operation will take a total of 20 minutes.

In the mixer's case, the supplier reported that the typical operation time is 150 minutes.

In the last two operations (semi-automatic bagging and sack palletising) it will be considered that each bag takes about 2 minutes. Therefore, as the product is placed in bags of 15 kg each, and in each batch 130 kg of final product is produced, 9 bags must be filled. Thus, each of these two operations will take 18 minutes.

Table 13. Times dedicated to each of the product operations

Time (min)	Operation
20	Solid carrier loading at mixer
3	Liquid antioxidant injection
150	Mixer. Homogenization phase

Time (min)	Operation
18	Semi-automatic bagging
18	Sack palletizing
209	**TOTAL OPERATING TIME**

7.3.2nd Description of the equipments used:

To describe the characteristics of the equipment used, they will be divided into two groups:

A. **Production equipment**: which includes the mixer and its auxiliary parts

B. **Storage equipment:** includes the bagging machine and its auxiliary parts

A) MIXER

The mixer used is mainly chosen based on the carrier used. The choice of silica as a carrier directly affects the choice of the type of mixing and the teams that are going to carry it out. To get a homogeneous mixture between the silica carrier and the liquid antioxidant, a number of conditions must be accomplished:

- Selecting a low shear mixer and also need to switch off any fast-moving tools before starting to mix
- Choose a mixer that allows us place the silica into the mixer first before the liquids.
- The mixer filling volume should not exceed de 50-75%
- Need to distribute the liquid as finely divided as possible
- The mixing time should be as short as possible

Therefore, and considering the recommendations it has found by the manufacturer of the solid carrier, a horizontal blade mixer has been choosen. This type of mixer is economical and allows the injection of liquids in a distributed way, that is, to not allow the antioxidant to be incorporated in large quantities.

From the ergonomic point of view, so that the mixer can be loaded by the operator efficiently, it is important that you have a raw material input that allows incorporate the bags easily and without harming the health of the operator. The chosen solution is to add a sack discharge station to the mixer, which includes a hopper with lid attached to the mixer, plus a small shelf for the

operator, in this way he can support the bags while he opens them to insert the content. Moreover, when you are working with powder, it is important that the entrance of the mixer is equipped with a suction system so that when the operator breaks a bag and proceeds to load it, small particles that can escape are wretched by the aspiration and do not harm the health of the operator. To continue taking care of the operator's health, a security grille inside the hopper is added in order to prevent elements from falling into the interior of the mixing equipment and ensure that the operator cannot have contact of any way with the moving elements of the mixer.

The mixer must also have side gates that allow access to inside the equipment for inspection and cleaning purposes. Treated products can create cleaning problems. It is vital that the equipment is easily accessible so that you can access for special cleaning and / or maintenance. After specifying the type of mixer and how the materials will be introduced raw in it, it is also necessary to specify the following technical design and particular conditions of operation (Table 14):

Table 14. Mixer design characteristics

Volume	450 L
Useful volume	360 L
Construction material parts in contact with product	AISI -316L
Construction material auxiliary parts	AISI -304L
Operating temperature	20-25ºC
Operating pressure	1 atm

As seen previously a total volume of 360 L of raw material must be added. For safety purposes, only 80% will be used in operation, therefore, the total volume of the mixer will be 450L.

Operation description:

The operation of the chosen mixer is very simple, the solid raw materials will be manually loaded into the equipment through a hopper located in the loading mouth.

For the addition of liquids to the mixer you must have a liquid injection system as well as an additional blade agitation system for the correct deagglomeration of the product. To be able to

ensure a good injection of liquid raw materials is expected to connect a mobile tank to a centrifugal pump which will deliver the liquid raw material to the mixer through a delivery pipe.

Mixer and hopper layout:

The discharge opening of the 450L mixer must be high enough to allow the installation of the sieve and bagger in the unloading. That is, the equipment must be installed immediately under the mixer and connected directly.

Sieve

The characteristics of the sieve depend mainly on the particle size that is needed. Looking at other already existing vitamin E products, typical mesh sizes are not bigger that mesh 30, that is, they all pass through mesh 30.

Just as a reminder, mesh 30 is equivalent as to say a sieve opening of 0.6 mm.

B) BAGGER

The final products will be presented in 15 kg capacity polyethylene bags, by mouth open with a heat-shield closure and will be arranged inside standard boxes.

When designing the bagger, it must keep in mind several concepts:

- In order to ensure the homogeneity of the final product, the installation of a sieve between the mixer discharge port and the bagger.
- It is planned to unload the production volume of the mixer to the semi-automatic bagger, by coupling this bagger to the discharge port of the sieve.
- The bagger must be able to dose the weight automatically and accurately, this will make it necessary to install a discharge weight detector.
- To facilitate the manoeuvre to the operator it is decided to add a pedal to control the clamps for holding the sacks. The bag will cross a thermo-sealing machine subsequently.

Description of central dust suction equipment

As it will be necessary to work with bags of powdery solids that can be harmful and annoying when handling it, decisions can be made in advance to avoid occupational safety issues

and comply with all required regulations. For this reason, it is contemplated the installation of a dust collection system for all that equipment where there is a risk of dust coming out.

The equipment will be connected by a direct connection to a suction system which aims to capture dust that may have escaped into the environment. The points where a leak can occur are marked on the flowsheet (showed later) and all of them will have the same suction system.

7.4TH CHARACTERISTICS OF AUXILIARY INSTALLATIONS

The equipment has great volumes and heights, in order to be able to get to the equipment and to the charge hopper is necessary to have an access structure.

The structure must be constructed in AISI-304L. This is a criterion from both design and market. It would convenient that the maximum safety is assured at a competitive price.

The installation of an elevator platform next to the structure will be needed to take the raw materials and the other necessary elements to the working height. Thanks to this platform, workers won't need to carry great weight on their own and many labour accidents will be avoided.

In the following pages you will find different plans represented in AUTOCAD with a small approximation of what the room would be like and the equipment that would be implemented. The attached documents correspond to a FLOWSHEET and a preliminary project P&ID (Figure 8, Figure 9 and Figure 10). They are useful to see the process flow and machinery; this serves as an aid to organize the idea of the future plant that you want to build. In the P&ID document it can find the control elements represented; as this is the first representation, this document will probably undergo important modifications as it gets closer to the detail, almost certainly it will be necessary to modify, eliminate or add control elements.

Regarding the flowsheet, there are some equipment tagged. The first equipment that comes chronologically in the process would be the hopper (3), this is where the solids are charged manually by an operator. Then it comes the mixer (5). The addition of the liquid raw material to the mixer is done thanks to a centrifugal pump (10), which aspirates the liquid from a container (11) and carries it to the mixer through a pipe (9). After the mixer, it comes the sieve (6), which ensures a correct particle size, and then finally the product is packaged with the bagger (7). The whole system is vented with a vent machine (1). A compressor (12) is used to inject compressed air in the liquid addition line and help the pumping system.

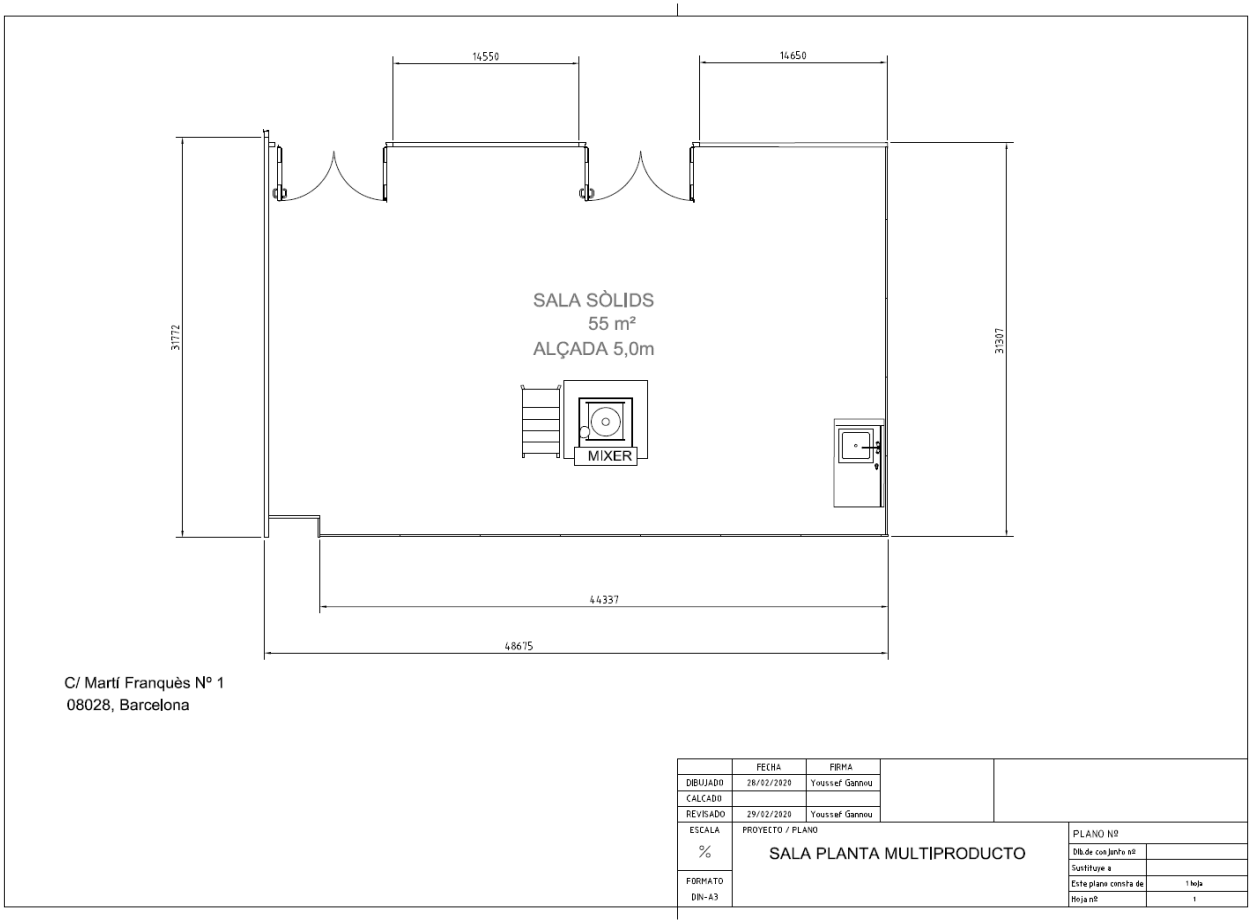

Figure 8. Diagram that shows possible measurements of the room where the production will take place.

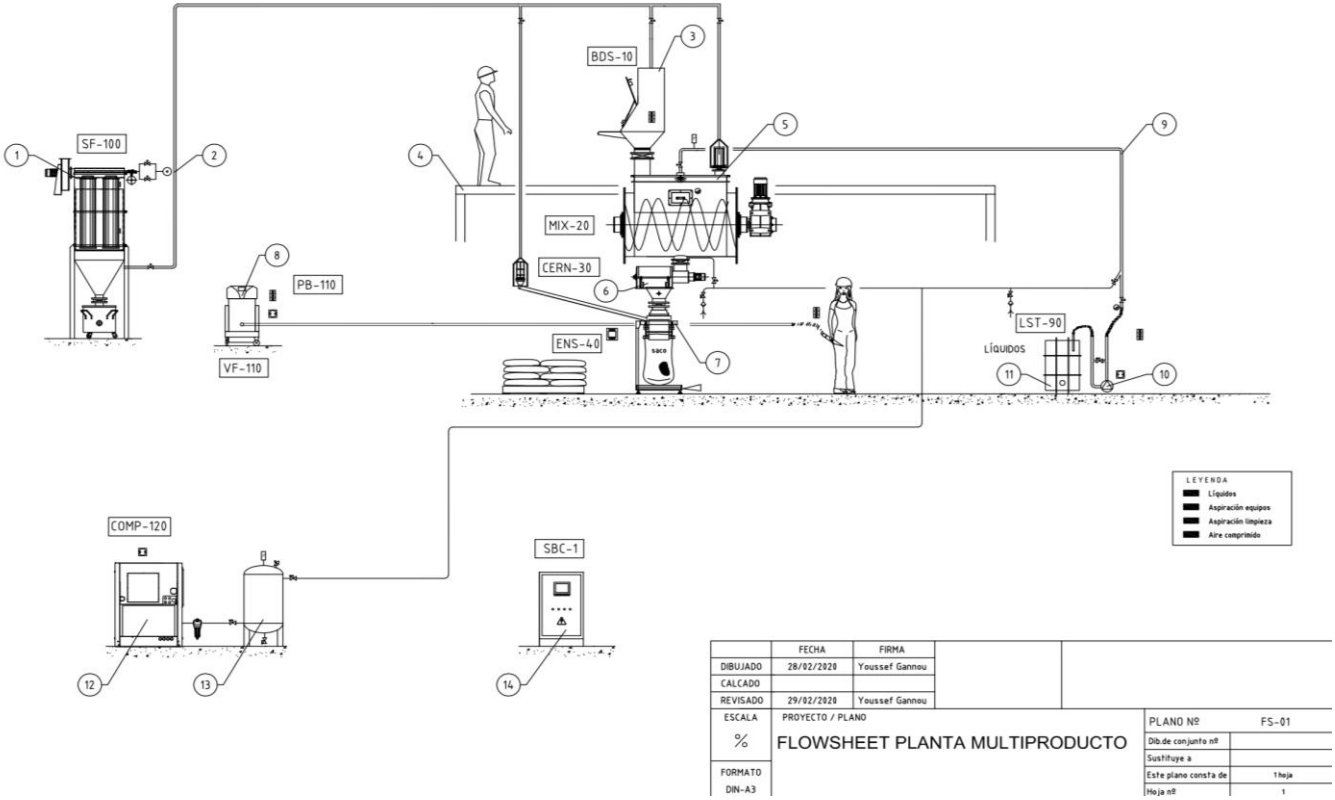

Figure 9. Flowsheet of the plant.

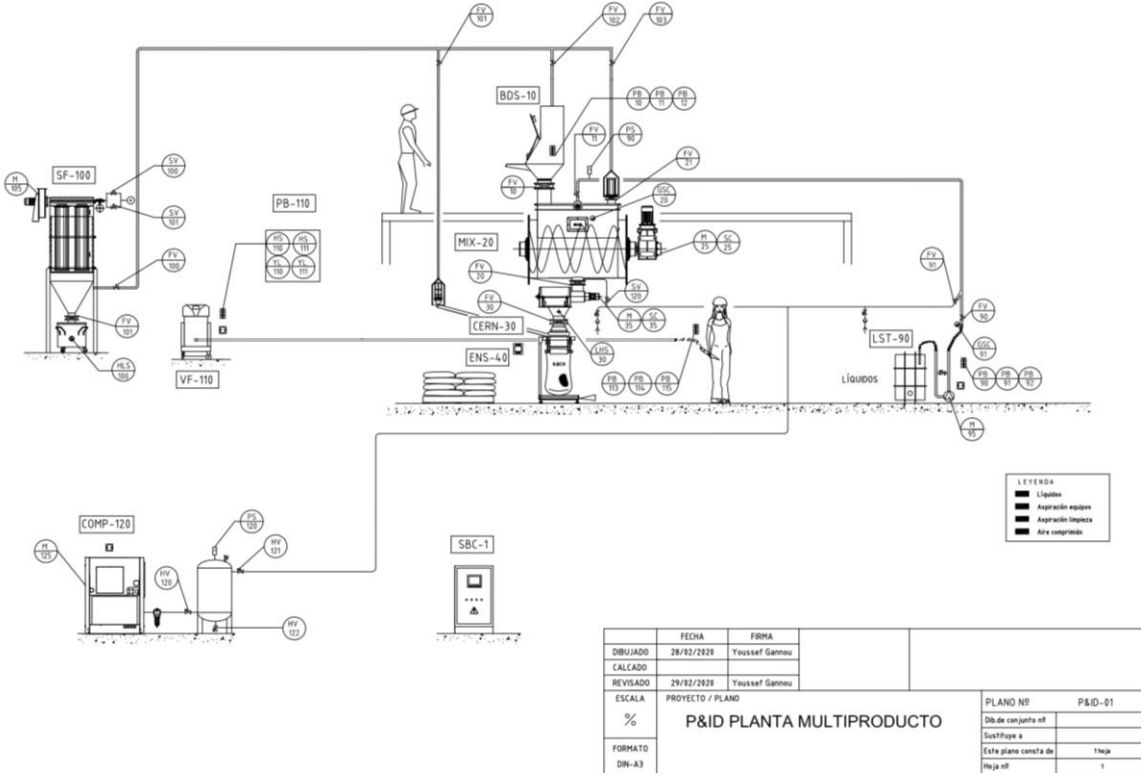

Figure 10. P&ID PLANT

Table 15. Equipment choice.

EQUIPMENT CHOICE	
CENTRALIZED ASPIRATION	**P&ID PLAN**
Vent	M-105
Aspiration filter	SF-100
Membrane electro valve	SV-100 / SV-101
Butterfly valve	FV-100
Drum filling level gauge	HLS-100
HOPPER	**P&ID PLAN**
Receiver hopper	BDS-10
Butterfly valve	FV-10
Button panel	PB-10
MIXER	**P&ID PLAN**
Mixer	MIX-20
Position detector (gate 1/0)	GSC-20
Butterfly valve	FV-20
SIEVE	**P&ID PLAN**
Static sieve	CERN-30
Static sieve level	LHS-30
Rotative butterfly valve	FV-30

BAGGER	P&ID PLAN
Bagger	ENS-40

COMPRESSED AIR	P&ID PLAN
Compressor	COMP-120
Pressure switch	PS-120
Manual valves	HV
Automatic valves	SV-120 / SV-121

LIQUID INJECTION MIXER	P&ID PLAN
Liquid injector	VIL-90
Pressure switch	PS-90

LIQUID INJECTION MIXER	P&ID PLAN
Ball valve	FV-90 / FV-91
Centrifugal pump	M-95
Liquid tank	IBC-90

SPILLAGE ASPIRATION	P&ID PLAN
Industrial aspiration equipment and complete accessories	VF-110

Below there is the flow chart of the manufacturing process that would be followed to obtain the designed product. In the flow chart, the process to generate the powdered product is represented by symbols. Two tables are also attached where it is specified which points are critical and points to control. The tables specify each control point, how it is controlled, when, who has the responsibility of each control point and how any incident with any of these reference points is resolved.

The first check point (1) is about the sieve, this will be a critical point to control. The next point is the metal detector that has been called check point 2, that is a control point, in turn it can be seen in the second table the specifications and instructions to be followed at this point.

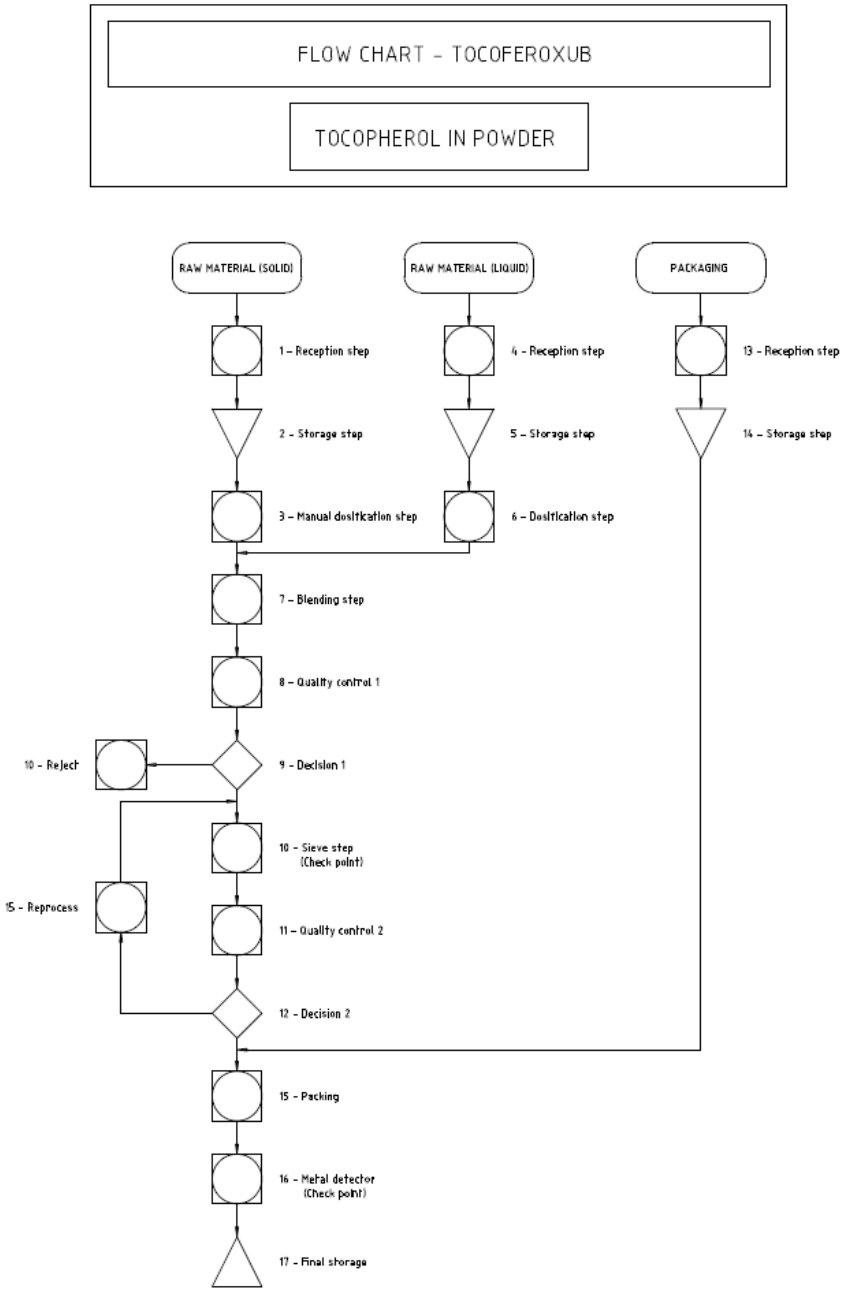
FLOW CHART – TOCOFEROXUB
TOCOPHEROL IN POWDER
RAW MATERIAL (SOLID)
RAW MATERIAL (LIQUID)
PACKAGING
1 – Reception step
4 – Reception step
13 – Reception step
2 – Storage step
5 – Storage step
14 – Storage step
3 – Manual dosification step
6 – Dosification step
7 – Blending step
8 – Quality control 1
10 – Reject
9 – Decision 1
10 – Sieve step
(Check point)
15 – Reprocess
11 – Quality control 2
12 – Decision 2
15 – Packing
16 – Metal detector
(Check point)
17 – Final storage

Table 16. Specifications that need to be considered in the SIEVE

CHECK POINT 1		**SIEVE**
Step		Sieving
Potential hazard		Foreign materials
Preventive measures		Sieving control - Preventive maintenance plan
Critical limit		Sieving of 4 mm of mesh size in perfect conditions and free of improper elements
Monitoring	**Control**	Check sieve after operation
	Responsible	Packaging Operator
	Frequency	Once per shift
	Record	Weekly record of Sieving control
Corrective measures	**Corrective measures**	Stop the process and segregate affected product that should be held in quarantine Inspect the product to find all the improper elements Change the Sieve and reprocess the product
	Responsibilities	Factory Manager
	Record	Weekly record of Sieving control Production sheet Data Base of Non-Conformities
Verification	**Verification**	Checking the sieving record
	Responsible	Factory Manager
	Frequency	Every week
	Record	Weekly record of sieving control
Surveillance		Internal audits

Table 17. Specifications that need to be considered in METAL DETECTOR

CHECK POINT 2		**Metal Detector**
Step		Metal detector
Potential hazard		Foreign materials
Preventive measures		Metal detector control - Calibration
Critical limit		Metal Detector Sensitivity: 3 mm Fe, 4mm SS, 5mm Al – Not detect metallic elements
Monitoring	**Control**	Check Metal detector
	Responsible	Packaging Operator
	Frequency	Every 4 hours
	Record	Weekly record of Metal detector control
Corrective measures	**Corrective measures**	Stop the process and segregate affected product that should be held in quarantine Inspect the product to find all the improper elements Calibrate the Metal detector Management of Non-Conformities
	Responsibilities	Factory Manager
	Record	Weekly record of Metal Detector control/ Production sheet Data Base of Non-Conformities
Verification	**Verification**	Checking the Metal detector record
	Responsible	Factory Manager
	Frequency	Every week
	Record	Weekly record of Metal detector control
Surveillance		Annual calibration Internal audits

8. SWOT ANALYSIS

Finally, a SWOT analysis has been carried out, reflecting on what would be the weaknesses and strengths of the product and what would be the threats and opportunities that would arise when commercializing TOCOPHEROX UB-40.

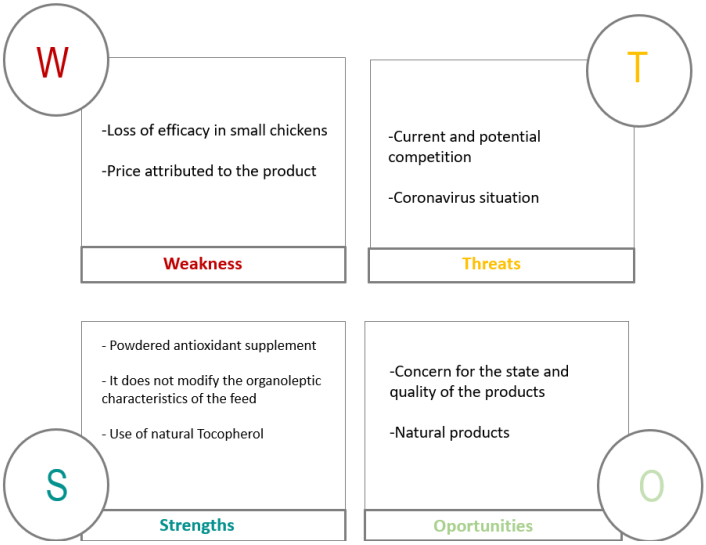

Figure 11. Shows the SWOT analysis of the product.

INTERNAL ANALYSIS

S. STRENGTHS:

1.-Powdered antioxidant supplement. The powdered product is presented so that it can be mixed directly with the feed without the need for consumers to use any additional carrier. In this way, the addition method is simpler.

2.- It does not modify the organoleptic characteristics of the feed. The designed product will not modify the organoleptic characteristics of the final product. Unlike other antioxidants, vitamin E will not add coloration or modify the appearance of the feed.

3.- Use of natural Tocopherol. Tocopheroxub-40 has been designed using naturally occurring Tocopherol. At the absorption level, it is almost completely absorbed, almost 100% being deposited in the muscle. Unlike if the synthetic forms are absorbed where less than 50% is absorbed.

W. WEAKNESSES:

1.- Loss of efficiency in small chickens. The product is marketed in the form D-alpha-tocopherol acetate. This implies a step prior to absorption in which pancreatic esterases intervene, which act by rapidly releasing the original α-tocopherol, which will be absorbed and incorporated into the muscle tissue. This can be a problem in young chickens, which have less bile acids, less pancreatic esters and, as a consequence, less alpha-tocopherol will be absorbed. Therefore, the designed product will be thought to be incorporated in the feed of broilers.

2.- Price attributed to the product. The fact of using natural and non-GMO vitamin E could make the price more expensive compared to other synthetic presentations on the market.

EXTERNAL ANALYSIS:

O. OPPORTUNITIES

1.- Concern for the state and quality of the products. Increasingly, consumers when selecting meat products, have as acceptance criteria their organoleptic properties: colour, flavour and texture. However, it is the compounds that are generated from lipid oxidation that produce undesirable odours and flavours, thus reducing the acceptance of the product.

With TocopheroxUB-40 all the consequences derived from lipid oxidation are avoided, thus increasing the acceptance of the meat product by the consumer, thus creating an opportunity for growth in the sector.

2.-Natural products: Nowadays, antioxidants of natural origin are perceived as safe and their use in food is expanding to potential levels. Therefore, the fact of designing an antioxidant product using natural vitamin E could represent an opportunity for expansion in the agri-food market.

T. THREATS:

1.- Current and potential competition: There are many presentations of antioxidants with vitamin E on the market. Therefore, it will be necessary to differentiate from the competition and present competitive products.

2.- Current situation with the Coronavirus. With the current situation, many production processes have been stopped. Therefore, the production and market launch of the product can be altered.

9. CONCLUSIONS

The conclusions reached throughout the project are the following:

- Considering aspects such as bioavailability and place of, it has been decided that the best option for an antioxidant supplement is an exogenous and with lipophilic nature antioxidant. Among these, vitamin E has been chosen since it is the one that modifies the less the characteristics of the meat. Subsequently, it has been decided to use natural vitamin E instead of synthetic as body absorption efficiency is superior.
- The carrier chosen is silica, as it is food grade, it mixes with the liquid in powder form, it has high liquid absorption capacity and it provides high fluidity to the product.
- The formula of the product will be: OXABIOL 1000 IU (58%), SIPERNAT 22000 (38%) and Maltodextrina (4%). The concentration of tocopherol, expressed in international units, will be 575 IU.
- In order to get a 10% of the market share, it is necessary to produce 7.826 kg each year. This production will be distributed in 4 campaigns of 15 batch each. Each batch will produce 130 kg and will have a lifespan of 209 minutes.
- The main equipment of the process will be: a hopper, a 450 L mixer, a sieve and a bagger.
- The conclusions of the SWOT analysis are the following:
    - Strengths: the product is presented as a powder and it does not modify the organoleptic characteristics of the meat.
    - Weaknesses: high price and the loss of efficiency of the product when used in small chickens.
    - Opportunities: the product is natural-originated and there is also a growing concern in society for the state and quality of the products.
    - Threats: current and potential competition and current situation with the coronavirus.

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Documents for internal use of EVONIK, ITPSA, BTSA and IDP Concept Design.

11. ACRONYMS

GMO: genetically modified

IU: international units

LDL: low-density lipoprotein

OFR: oxygen free radicals

PUFA: polyunsaturated fatty acids

TBARS: substances reactive to thiobarbituric acid

VLDL: very low density lipoproteins

α-TTP: α-tocopherol transferred protein