Recovery and valorisation of lecithins in an industrial unit

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Abstract

This work focused on the study and technical-economical evaluation of the installation of a lecithins drying unit to produce feed-grade lecithins, in order to take advantage of its market value and to reduce the meals fat content.

The characteristics, specifications and applications of lecithins, as well as water-evaporating drying units were surveyed to select an efficient drying, resulting in a quality product within the specifications requested by the customers.

Several suppliers for this type of processes were contacted. The technical-economical evaluation of the four proposals received (A, B, C and D), was carried out, and it was concluded that the proposal C presented the best overall prospects.

From the economical analysis, a net present value (NPV) of 332 061 €, an internal rate of return (IRR) of 15% and a payback time of 8 years were obtained as for scenario 1 (GMO soybean and GMO rapeseed); and for scenario 2 (GMO soybean and non-GMO rapeseed) a NPV of 712 074 €, an IRR of 20% and a payback time of 6 years. Thus, both scenarios 1 and 2 are feasible, but the latter is preferable.

Keywords: clarification, filtration, lecithins, lecithins drying, rapeseed, soy, thin film evaporator

1. Introduction

1.1 Production process

The industrial unit under study produces oil and meal from rapeseed and soybean. The process consists of two stages, namely seed preparation and oil extraction.

The seed preparation is essential to ensure a high oil extraction yield and a good meal quality. Due to the differences of grain size and initial oil percentage in the soybean and rapeseed, the process steps sequence differs for the two seeds. For soybeans the sequence is as follows: cleaning, crushing, conditioning, rolling and expansion, whereas for rapeseed, the sequence is cleaning, preheating, rolling, conditioning and pressing.

The extraction process comprises three stages, namely oil extraction, solvent recovery and meal production. The oil extraction occurs inside the extractor, where the solids from the preparation are immersed in the miscella (hexane and oil) in counter-current at distinct compartments. The oil extraction takes place by the percolation method in which the solvent enters the seeds, mixes with their oil and transports it to the seeds outside due to oil the concentrations difference. This process should occur slightly below the atmospheric pressure to avoid hexane leaks but not too much to prevent air entrance.

The miscella obtained at the extractor outlet is treated by a multi-stage vacuum distillation process, to remove all hexane and obtain pure oil.

The solids are discharged from the extractor with a low oil content and impregnated in hexane. They are fed to the Desolventizer-Toaster-Dryer (DTD) in which hexane evaporation, meal toasting and drying take place. The hexane recovered from the DTD and from the distillation is recycled to the extraction process.

The oil is directed to a physical degumming process with water addition in a centrifuge, to eliminate the hydratable phosphatides (lecithins). This process produces the crude oil and a stream of hydrated lecithins (gums) that contain about 50% of moisture.

1.2 Objective

Currently, the lecithins resulting from the degumming are added to the meals in DTD, increasing their nutritional value but also their oil/fat. Nevertheless, lecithins have a high nutritional value and constitute a potential market niche, besides minimizing the residual oil in the meals. Thus, the lecithins stream can be recovered and sold according to the market specifications (feed-grade).

1.3 Lecithins

Commercial soya lecithin is a complex mixture of phosphatides, triglycerides, phytoglycolipids, phytosterols, tocopherols and fatty acids. Phosphatides are the main functional ingredient of lecithins. [1] [2]

The typical composition of crude lecithin is as follows:

- Oil: 30% to 50%;
- Phosphatidylcholine (PC): 15%;
- Phosphatidylethanolamine (PE): 13%;
- Phosphatidylinositol (PI): 9%;
- Phosphatidic acid (PA): 5%;
- Phosphatidylserine (PS): 2%;
- Other substances (glycolipids, carbohydrates, sterols and tocopherols): 5% to 25%;
- Moisture: 1%.

The lecithins quality is assessed by various parameters, such as acetone insoluble content, hexane insoluble content, toluene insoluble content, acidity index, moisture, colour, peroxide index, pH and viscosity. The methodologies suggested by the American Oil Chemistry Society (AOCS) are often used to determine these parameters. [3]

Acetone insolubles represent approximately the phospholipids content in the lecithin. The matter insoluble in hexane corresponds to the polar insoluble impurities in the lecithin, which cause turbidity, bad aspect and sedimentation. This determination can also be made using toluene instead of hexane. The viscosity influences the ease to handle the product and it depends directly of the phospholipids concentration, moisture content and acidity index. The moisture content in the lecithin after the drying process is usually less than 1%. A low moisture content is extremely important to ensure microbiological stability. A high humidity content may lead to chemical variation and/or degradation. The acidity index represents the acidity of both the phospholipids and the free fatty acids. The peroxide index indicates the deterioration degree due to the phospholipids oxidation and the production of undesirable odours and flavours. The lecithins colour is a standard of aesthetic quality, relevant from the commercial point of view. It also reveals excessive temperature in the process or excessive drying, which can affect the lecithin functional properties. Moreover, it may indicate deterioration due to improper storage (exposure to light, for example). The lecithin colour stability requires exposures to temperatures lower than 60ºC.

Soy is by far the most important source of commercial lecithin. However, rapeseed lecithin has become increasingly popular and sought in the last decade. [4] The main differences between soybean and rapeseed lecithins is their compositions in fatty acids (***Table 1***) and phosphatides (***Table 2***).

Table 1 - Fatty acids composition in soybean and rapeseed lecithins, in percentage.[5]

Fatty acid	Soybean lecithin	Rapeseed lecithin
Palmitic (C16:0)	16	7
Stearic (C18:0)	4	1
Oleic (C18:1)	17	56
Linoleic (C18:2)	55	25
Linolenic (C18:3)	7	6
Others	1	5

Table 2 - Main phosphatides composition in soybean and rapeseed lecithins, in percentage.[5]

Phosphatide	Soybean lecithin	Rapeseed lecithin
Phosphatidylcholine	15	17
Phosphatidylethanolamine	13	9
Phosphatidylinositol	9	10
Phosphatidic acid	5	4

Companies producing commercial lecithins should fulfil certain requirements. ***Table 3*** presents a typical feed-grade lecithin specification.

Table 3 - Feed-grade lecithin specification.

Parameter	Content
Moisture	max. 1,0%
Insoluble in toluene	max. 1,0%
Insoluble in acetone	min. 60%
Acidity index	max. 30 mg KOH/g
Peroxide index	max 10 meq/kg

Lecithin is mainly used for its functional benefits in food. Of its main functional properties stand out: emulsifying agent; viscosity reducer of fatty emulsions; dispersing and wetting agent; stabilizer; antioxidant for organic compounds and crystallization inhibitor. [6] Its main applications are in the food industry (formulation of chocolates, cookies, milk powder, margarines, ice cream, pasta, bakery and instant products); cosmetics industry; chemical industry (paints, plastics, rubbers, soaps, lubricants and greases); and animal feed industry. [7]

2. Implementation of an industrial drying unit for lecithins

2.1 Drying technologies (by water evaporation)

The lecithins obtained after degumming contain a moisture content of nearly 50% which must be reduced to a maximum content of 1% to become commercial lecithins. Therefore, the physical degumming is followed by the lecithins drying (evaporation of water), which is a critical point in their production process, due to the gums tendency to darken by the heat action and to the viscosity variation as the humidity decreases. This variation of the lecithins viscosity with the moisture is shown in ***Figure 1***, in which the product viscosity starts to increase at a moisture content of 20% until reaching a maximum viscosity of approximately 9000 P (Poise) at a humidity of 7% to 8%. Thereafter, the moisture content decrease causes the viscosity drop to about 300 P at 4% of moisture. [8], [9]

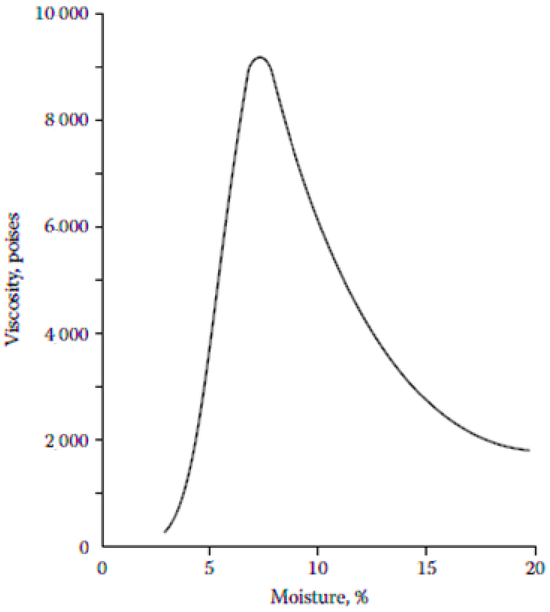

Figure 1 - Lecithins viscosity as a function of the moisture content (70ºC). [8]

Among the drying technologies, by water evaporation, the following ones stand out:

- Batch evaporator **(A)**
- Natural-circulation tubular evaporator
  - Horizontal tube evaporator **(B)**
  - Short-tube vertical evaporator **(C)**
  - Rising-film evaporator **(D)**
- Forced-circulation tubular evaporator **(E)**
- Falling-film evaporator **(F)**
- Agitated thin film evaporator **(G)**

Batch Evaporator (A)

The batch evaporator (***Figure 2***) consists of a jacketed vessel which is heated with steam or other heating fluid. [10]

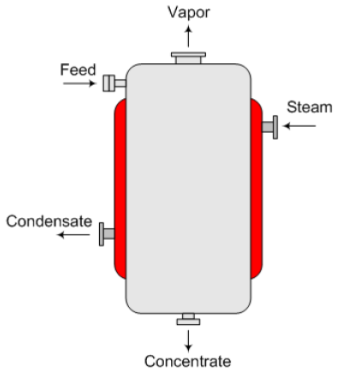

Figure 2 - Schematic drawing of a batch evaporator. [11]

This type of evaporator can operate under vacuum in order to lower the boiling point, but it is unsuitable for temperature sensitive products. Its residence time is high (3 to 4 hours) and the product movement is only by natural circulation, leading to fouling on the heating surface mainly when handling viscous, temperature-sensitive and solids-containing products. Furthermore, the heat flux is low as well as the heat transfer area per volume unit [10] with the heat transfer coefficients can be increased, and the fouling reduced by using an agitator in the evaporator (stirred batch). Yet, this type of evaporator is poorly flexible and efficient. [10], [12]

Natural-circulation tubular evaporator

Natural-circulation tubular evaporators are used for simple applications where the product is clean and not sensitive to the temperature.

- **Horizontal tube evaporator (B)**

The horizontal tube evaporator (***Figure 3***) is the only one in which the heating fluid circulates in the tubes. The main advantage of these evaporators is the small height necessary to install them. However, this evaporator is unsuitable for fouling fluids. [10], [11]

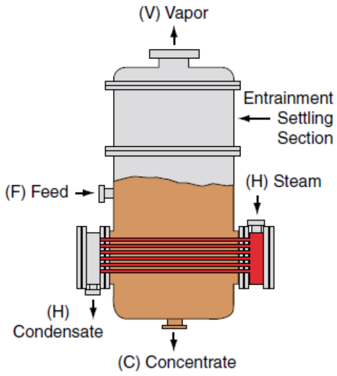

Figure 3 - Schematic drawing of a horizontal tube evaporator. [10]

- **Short-tube vertical evaporator (C)**

This evaporator consists of two sets of tubes and a central chute. The liquid feed circulates in the tubes and the heating fluid circulates outside them. As the liquid boils, it rises in the tubes and returns to the evaporator bottom through the central part. [10]

The main advantages of this equipment are, the small height required to install it, the ability to handle liquids with a moderate tendency to form scaling because the product circulates in the tubes (accessible for cleaning), the inexpensive manufacture and the rather high heat transfer coefficients for low viscous liquids (5 to 10 cP). On the other hand, the heat transfer in this type of evaporator depends very much on the temperature and viscosity, being unsuitable for materials sensitive to the temperature. [10], [11]

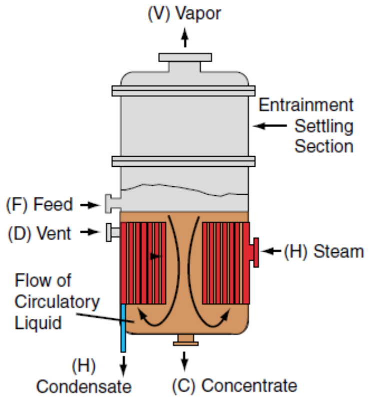

Figure 4 - Schematic drawing of a short-tube evaporator. [10]

- **Rising-film evaporator (D)**

The rising-film evaporator (***Figure 5***) consists of a shell and tube heat exchanger mounted on a liquid/vapour separator. It requires little floor space, but a high height to install the equipment.[10], [11]

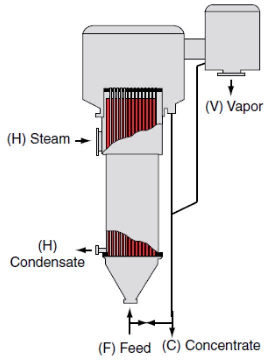

Figure 5 – Rising-film or long vertical tube evaporator. [10]

This type of evaporator can handle products that tend to form foams and it is a good solution for liquids moderately heat sensitive.[13] The main advantages of this equipment are the small space required for its installation and the relatively high heat transfer coefficients. However, there is a high pressure drop along the tubes and the hydrostatic pressure at the tubes bottom can increase the product temperature and jeopardize its quality. [10], [11]

Forced-circulation tubular evaporator (E)

This equipment (***Figure 6***) consists of a shell and tubes heat exchanger, a liquid/vapour separator and a liquid recirculation pump. [11]

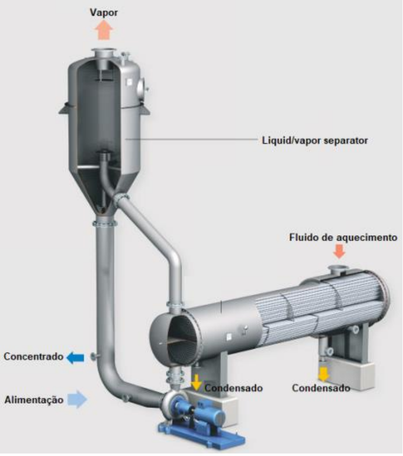

Figure 6 - Schematic drawing of a forced-circulation tubular evaporator. [14]

The concentrate partial recirculation to the concentrate to the feed stream significantly increases the heat transfer and the evaporator size can be reduced considerably, resulting in lower overall costs. The high velocity at which the liquid flows through the tubes reduces the likelihood of scaling and in turn reduces the unit downtimes. [10]

One of the disadvantages of this evaporator, in addition to its high cost and energy consumption of the circulation pump, is the high retention time of the product in the heating zone which may lead to its degradation and deterioration. [10]

Falling-film evaporator (F)

The falling-film evaporators (***Figure 7***) are a variant of the rising film evaporator, but the heat exchanger is at the top and the liquid/vapour separator at the bottom. [10], [11]

The main advantages of this type of evaporator are relatively low cost, large heat transfer surface, small space for its installation, high heat transfer coefficients, short residence times, low load losses and suitability to operate under vacuum. However, enough height is required to install the evaporator. Usually, it is unsuitable for materials with tendency to form scaling and recirculation is often required. [10], [11], [15]

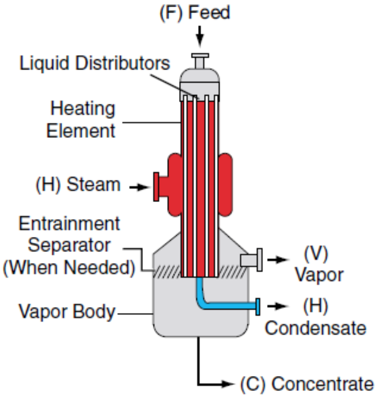

Figure 7 - Schematic drawing of a falling-film evaporator. [10]

Agitated thin film evaporator vertical or horizontal (G)

This type of evaporator (***Figure 8***) is characterized by easily overcoming the problems with products hard to handle, rapidly separating the volatile components from the less volatile compounds by indirect heat transfer and having mechanical agitation of the product film under controlled conditions. This separation is carried out under vacuum to maximize the temperature between the fluids while maintaining the product moderate temperature, as well as to maximize the removal and recovery of volatiles. [10]

Due to its short residence time (1 to 2 minutes), high turbulence and rapid renewal of the product film along its internal surface, the film evaporator can handle heat sensitive and high viscosity materials (such as lecithins). [10]

This type of evaporator involves low costs and maintenance works due to its robust design and the continuous washing of the heat exchange surface by the rotor blades, which minimizes scaling formation.

The film evaporator also has a high processing flexibility, especially when operating horizontally. [10] When it operates vertically it is less flexible and more sensitive because the lecithins film can break more easily within the apparatus, decreasing the drying efficiency. [16]

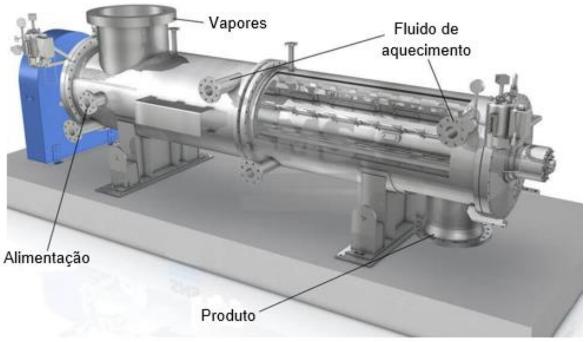

Figure 8 - Schematic drawing of an agitated thin film evaporator. [17]

2.2 Selection of the evaporator type

After analysing the characteristics of the various evaporators presented on ***Table*** 4, which compares their suitability ("Yes" if suitable, "No" if unsuitable) to the lecithins characteristics (high viscosity, tendency for scaling, suspended solids, highly temperature sensitive product), the conclusion drawn was that tubular evaporators are less successful with temperature sensitive, high viscosity, contaminated or high boiling point products. The agitated thin film evaporation easily solves all these problems.

Table 4 - Evaporators suitability to the lecithins characteristics

Evaporator	**High viscosity**	**Fouling**	**Suspended solids**	**Temperature sensitive product**
A	Yes	Yes	Yes	No
B	No	No	No	No
C	No	Yes	Yes	No
D	No	No	No	Yes
E	No	Yes	No	No
F	No	No	No	Yes
G	Yes	Yes	Yes	Yes

Thus, the batch evaporator and the horizontal or vertical agitated thin film evaporator (ATFE) were selected for the lecithins drying. Bearing in mind the characteristics of these evaporators, a more detailed analysis was carried out to select the best option for the lecithins drying, based on the following criteria:

1. investment and installation costs;
2. energy consumption;
3. process continuity;
4. residence time;
5. robustness;
6. flexibility;
7. ease of cleaning/maintenance;
8. suitability for viscous and temperature sensitive products;
9. product quality;
10. effective agitation (good mixing and turbulent flow);
11. fouling;
12. preservation of the film inside the evaporator;
13. vacuum;
14. evaporation rate;
15. heat transfer coefficient;
16. heat transfer area.

A weighting factor of 1 to 10 was assigned to each criterion (***Table 5***). The criteria with higher weighting factors have a greater weight in the hierarchy of the evaporators analysed. The three equipments were compared to each other and a classification was assigned on a scale of 0 to 10, where 10 corresponded to the best ranking and 0 to the worst. ***Table 5*** shows the values assigned to each criterion in each equipment. The final classification of each evaporator corresponded to the sum of the products of the weighting factor by the classification to assigned to each criterion.

Table 5 - Weighting factors assigned to each criterion for ranking the drying technologies under study.

Criterion	Weighting factor	Batch	Vertical ATFE	Horizontal ATFE
1	9	10	8	8
2	6	10	8	8
3	6	0	10	10
4	5	2	10	10
5	7	8	9	9
6	9	2	8	10
7	7	4	6	8
8	10	2	10	10
9	10	5	10	10
10	8	3	10	10
11	7	4	9	9
12	7	0	6	9
13	6	9	8	8
14	8	7	9	9
15	8	6	9	9
16	5	6	9	9
Classification		**572**	**1029**	**1082**

From the analysis of ***Table 5,*** it was concluded that the most suitable technology for the lecithins drying is the agitated thin film evaporation operating horizontally.

2.3 Filtration/clarification of miscella/oil

To produce lecithins, all solid impurities inevitably entrained throughout the process, must be removed prior to degumming such that the lecithins at the outlet of the drying process have the desired colour and quality.

In the current process, there is a hydrocyclone (in the extractor) that removes a small fraction of the miscella solids, which carry with them a small amount of miscella, and return to the extractor. In most cases, the miscella from a properly operated hydrocyclone is sufficiently clear to keep distillation equipment clean. [18]

However, the company’s hydrocyclone is not enough to guarantee the lecithins quality, and it is mandatory to remove as many solids as possible. Thus, in addition to the drying process, the suppliers were also requested to propose the best hypothesis for the solids removal. (filtration/clarification of miscella/oil).

2.4 Technical analysis

2.4.1. Suppliers proposals

Several suppliers of drying technologies and lecithins production process were requested for turn-key proposals concerning the lecithins drying process and the miscella/oil filtration/clarification. Four proposals from distinct suppliers (A, B, C and D) were received.

Proposal A

Regarding the lecithins drying, this supplier proposed a vertical film evaporator operating under vacuum. The vacuum system generates a vacuum of 80 to 93 mbar and consists of multi-stage steam ejectors with inter-condensers.

For the solids removal, the supplier A recommended the oil clarification prior to degumming using a clarifying centrifuge.

Proposal B

The supplier B proposed a film evaporator operating horizontally under vacuum. The vacuum system is a one-stage liquid ring vacuum pump and generates a vacuum of 60 to 70 mbar. This supplier did not send a proposal for the solids removal.

Proposal C

The supplier C proposed a horizontal film evaporator operating under vacuum (very similar to supplier B). The proposed vacuum system comprises a liquid ring vacuum pump and generates a vacuum of 40 to 70 mbar. This supplier did not send a proposal for the solids removal.

Proposal D

The proposal D comprises a film evaporator operating vertically under vacuum. The hybrid vacuum system consists of a steam ejector and a liquid ring pump and it generates a vacuum of about 55 mbar.

For the solids removal, the supplier D proposed the oil filtration before degumming with the use of two vertical leaf filters operating continuously and a filter aid (diatomaceous earth) that acts as a pre-coating of the medium filter.

After the lecithins drying, they should be cooled to a temperature in between 55ºC and 60ºC to maintain their quality and colour during the storage. For such aim, the suppliers A, B and C proposed a scraped surface heat exchanger, whereas supplier D proposed a plate heat exchanger.

Suppliers A and D also proposed two storage tanks for the lecithins, which should be conical bottom, heated and agitated.

2.4.2. Technical comparison of the proposals

To rank the proposals hierarchically from the most to the least suitable, they were analysed based on the following criteria:

1. Drying technology;
2. Type of vacuum system;
3. Type of heat exchanger for cooling the lecithins;
4. Storage tanks;
5. Utilities consumption;
6. Piping within defined limits for implementation
7. Piping connections between the unit and the existing process;
8. Connection of the electrical cables from the unit to the electrical cabinet in the electrical cabinets room;
9. Instrumentation;
10. Final product within the intended specifications;
11. Tracing in pipelines where lecithins flow;
12. Insulation of pipes and equipments;
13. Equipments ready to be installed in ATEX zone;
14. Materials of equipments and piping;
15. Local electrical cabinet;
16. Electrical cabinet in the electrical cabinets room;
17. Installed power;
18. Integration of the control system into the existing system at the plant;
19. Positive displacement pumps for the lecithins;
20. Unit assembly and installation on the ground
21. Equipments delivery in the industrial unit facilities;
22. Pre-commissioning, commissioning and start-up activities;
23. Staff training activities;
24. Type of technology for solids removal upstream of the degumming.

As previously, a weighting factor between 1 and 10 was assigned to each criterion. For each proposal a classification between 0 and 10 was assigned for each criterion, and a final classification for each proposal was obtained (***Table 6***).

Analysing the results presented in ***Table 6***, it was concluded that the proposal B is the best suited to the project. However, this proposal does not include the solids removal technology, meaning that another supplier should be requested.

Table 6 - Weighting factors and classification assigned to each criterion for each proposal and its final classification.

Criteria	Weighting factor	A	B	C	D
1	10	9	10	10	9
2	9	6.6	10	10	0
3	10	10	10	10	6
4	10	10	0	0	10
5	7	0	10	3.3	0
6	6	0	10	10	10
7	5	0	0	0	0
8	5	0	0	0	0
9	7	0	10	10	10
10	10	10	10	10	10
11	8	0	10	10	0
12	8	0	10	10	0
13	10	10	10	10	10
14	8	10	10	10	10
15	8	0	10	10	10
16	8	0	10	10	10
17	7	0	9.6	10	0
18	6	0	10	10	10
19	10	10	10	10	10
20	7	0	10	10	0
21	7	0	10	10	10
22	5	0	10	10	10
23	5	0	10	10	10
24	10	10	0	0	5
Classification		**739**	**1467**	**1423**	**1110**

2.5 Economical analysis

The economical feasibility of each proposal was analysed for two scenarios:

- 1st scenario: both raw materials, soybean and rapeseed, are genetically modified organisms (GMO), i.e., equal selling prices for soybean and rapeseed lecithins.

- 2nd scenario: as often the rapeseed is non-GMO, it was considered a scenario in which the GMO soybean and the non-GMO rapeseed are processed, i.e., the selling price of rapeseed lecithin is higher than the selling price of soybean lecithin, the ratio of the first by the second being 1.28.

The economical analysis performed was based on the following assumptions:

- annual flow rates of soybean and rapeseed processed in 2017;
- ratio between the selling prices of soy lecithin and soybean meal of 2.34;
- ratio between the selling prices of GMO rapeseed lecithin and rapeseed meal of 3.95;
- ratio between the selling prices of non-GMO rapeseed lecithin and rapeseed meal of 5.04;
- 10 years depreciation of tangible fixed assets and 3 years for intangible fixed assets;
- discount rate of 10.5%;
- interest rate of 0,5%;
- income tax rate of 25%.

The project's profitability was assessed based on economical indicators calculated from updated cash-flows, such as NPV (net present value), which consists of the monetary return from the investment; IRR (internal rate of return), which consists of the update rate for which NPV is null; PB (payback time) that is the required operating time to recover the whole money invested.

Table 7 and ***Table*** 8 present the economical indicators of each proposal for scenarios 1 and 2, respectively.

Table 7 - Economical indicators resulting from the 10-years economical analysis for scenario 1 of each proposal.

Proposal	**A**	**B**	**C**	**D**
NPV (€)	3 792	-19 815	332 061	-159 434
IRR (%)	11	10	15	8
PB (year)	10	-	8	-

Table 8 - Economical indicators resulting from the 10-years economical analysis for scenario 2 of each proposal.

Proposal	**A**	**B**	**C**	**D**
NPV (€)	383 805	360 198	712 075	220 580
IRR (%)	16	14	20	13
PB (year)	8	8	6	9

Analysing the results for scenario 1 (***Table 7***), the proposals B and D were immediately excluded, as they have a negative NPV and an IRR lower than the 10.5% discount rate, meaning that it would be impossible to recover the investment in less than 10 years. Both proposals A and C have a positive NPV, an IRR above the discount rate and a PB of 10 years or less, meaning that they could be cost-effective (long term). The proposal C is the best-performing one for scenario 1.

Analysing the results for scenario 2 (***Table*** 8), all the proposals have a positive NPV, an IRR higher than the discount rate and an investment recovery period of less than 10 years, i.e., all proposals would be profitable. Likewise, proposal C has the best results.

According to the technical analysis of the proposals in ***2.4.2. Technical comparison of the proposals***, proposal B has the best classification. Nevertheless, proposal C is more profitable than B. Since proposals B and C are quite similar technically and the profit of proposal C is the double of the profit of B for scenario 2 (B was unfeasible for scenario 1), the proposal C was selected for the implementation of the lecithins drying unit.

3. Conclusions

This work had as main objective the technical-economical assessment of the implementation of a lecithins drying process in an industrial unit. Currently, the lecithins from the oil degumming process are added to the meal in DTT and sold together with it, at a price lower than the selling price of the dried lecithin. To produce feed-grade lecithins within customer specifications, it was concluded that the thin film evaporator is the technology that best suits this product characteristics. Lecithins after physical degumming have a maximum moisture content of 50% and must be dried to a maximum humidity content of 1%. Due to the lecithins high viscosity and sensitivity to high temperatures, their drying must operate under vacuum.

Besides the moisture content, there are other customer specifications that must be fulfilled, e.g. the solid impurities content. Lecithins drag solid particles along the process which, unless removed, can jeopardize the final product quality. Meaning that, the oil or the miscella must be purified upstream of the degumming.

Suppliers of this type of processes were contacted and four proposals were received, two of them comprising the solids removal.

After the technical assessment of the proposals (based on several criteria), it was concluded that the proposal B, including a thin film evaporator operating horizontally, is the most adequate for the lecithins drying.

According to the economical assessment, two scenarios were envisaged, the 1st one in which both soybean and rapeseed were GMOs; and the 2nd one in which soybean is GMO and rapeseed is non-GMO.

From the economical analysis, for 10 years of project span, in scenario 1, proposals B and D are unfeasible, whereas proposal C is the most feasible with the following economical indicators: NPV of 332 062 €, IRR of 15% and PB of 8 years. For scenario 2, all proposals are economically feasible (long term) and, once again, proposal C is the most profitable, with a NPV of 712 075 €, IRR of 20% and PB of 6 years.

Comparing of proposals B (best classification in the technical analysis) and C (the most profitable) it was concluded that the latter would be selected for the implementation of the lecithins drying process.

4. References

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