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# ANALYSIS OF PROFITABILITY OF INTEGRATED PRODUCTION PROTEIN CONCENTRATE, LACTOSE POWDER WHEY

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***Abstract***

*Whey is the main by-product of the dairy industry, which is formed during the enzymatic or acid treatment of milk, during the cheese production process. Due to its composition, whey is a good substrate for use in various biotechnological processes, which include the production of lactose, protein concentrates and hydrolysates, functional fermented beverages, enzymes, etc. Due to the numerous useful properties of whey, the aim is to establish new procedures in order to obtain products from it that would have daily application. In article according to performed research, proposes the possibility of applying the „SuperPro Designer software package" for modeling and analysis of technical and economic variability, including risk analysis and analysis of the impact of pollution reduction through the whey processing unit with integrated production of concentrated protein (WPC 80) and lactose powder (LAC 80). Based on the results of the economic assessment of the factories for the production of WPC 80 protein concentrate and whey lactose LAC 80 and the internal rate of return (IRR) after deducting all costs, it was determined that the production is economically justified and can be accepted.*

***Key words***: *whey, protein concentrate, lactose powder, technical and economic analysis*

## INTRODUCTION

When considering obtaining any new product, attention is paid not only to its placement, stimulating interest among consumers and its consumption, but also to the cost-effectiveness itself, ie. sustainability of production of such a product. A very important role in assessing the sustainability of production of a product has a techno-economic analysis that includes all possible investments and costs that may arise during production [5, 10]. Therefore, when it comes to whey utilization, economic indicators are crucial in It is profitable to process it and use it in the production of certain products.

The presented research proposes modeling and analysis of technical and economic variability, including risk analysis and analysis of the impact of environmental pollution reduction through a whey processing unit with integrated production of concentrated protein WPC 80 and lactose powder LAC 80 [1].

Simulation as a methodology is used to analyze and predict production costs in many industrial processes [2].

It has the ability to easily, quickly and without much money to estimate the total costs and effects of variables, such as rising raw material costs, utilities, changes in the composition of products and the introduction of new technologies. Based on request, through the development of a model for simulating certain conditions, it is possible to create different variants based on changes in information, which would check the sensitivity of the given parameters. Also, with the help of modeling it is possible to get information about how the process takes place, which contributes to a better understanding of the process [8, 11, 6].

The "*SuperPro Designer*" software package was used in these researches [9]. The selected simulator for presenting the analyzed process was previously successfully used in scientific and technical activities. He and co-workers cite "*SuperPro Designer*" as a powerful tool for performing the economic evaluation process, which offers the possibility of shortening the time required to design a production process, which allows comparison of alternative processes based on consistency, so that many designed processes can be synthesized and interactively analyzed in a short timelines deadline [4].

Lima et al. used the "*SuperPro Designer*" software package during the analysis of the production costs of carbon activation from waste in poultry production [7, 3].

## MATERIALS AND METHODS

The paper uses a methodology for techno-economic analysis of the cost-effectiveness of obtaining whey protein concentrate and lactose production, using the most modern computer program SuperPro Designer, which offers the possibility of shortening the time required to design the production process.

Also, in order to better explain theoretically the process of obtaining whey protein concentrate and lactose production, the paper uses the knowledge of domestic and foreign authors dealing with this issue, which are listed in the literature.

## RESULTS AND DISCUSSIONS

### Raw material and description of the process for obtaining whey and lactose proteins

***Raw material***

The paper discusses whey that remains after the production of cheese and sterile skimmed milk with a fat content of 0.5%, which is obtained from the domestic dairy industry Imlek a.d.“ (join-stock company Belgrade, Serbia). After collection, whey can be stored at a temperature of - 18$^{o}$C for a maximum of one week. The chemical composition of whey consists of: proteins 2.6 ± 0.012% (w/v); fat 1.05 ± 0.08% (w/v) and lactose 5.6 ± 0.114% (w/v).

The price of whey used as a raw material for the production of WPC 80 and LAC 80 can be considered negligible because it is a waste product of the mentioned dairy industry.

***Description of the process of obtaining whey protein concentrate and lactose***

The process of obtaining whey protein concentrate and lactose, according to Figure 1, begins with pre-processing, which represents the preparation of raw materials for the next stage of protein modification. Excluded possibilities of external contamination of the raw material were performed in a heat exchanger in the sub-unit marked P-2/HX-101 by pasteurization at + 60$^{o}$C for 60 minutes. After pasteurization, the mixture is cooled to + 37$^{o}$C via a heat exchanger marked P-6/HX-102 and passes into the ultrafiltration phase into the sub-unit marked P-19/UF-1, after which a retentate is produced in the sub-unit marked P-20/V -102. Drying the retentate in subunit P-21/SDR-101 yields whey protein concentrate in subunit P-23/FL-101 in the next step.

In the described manner, 17% of retentate was obtained from whey, and the rest was permeate. The powder may contain 35-85% protein in the dry matter. The process of isolating dry protein concentrates using ultrafiltration is shown in Fig 1.

In the same process, lactose isolation occurs after ultrafiltration via reverse osmosis (RO) in subunit designation P-3/RO-101. After RO isolating lactose is transferred to the evaporator in the sub unit marked P-4/ EV101, then taken to the tank where the crystallization process begins in the sub unit marked P-5/CR-101. After crystallization, the suspension passes into the spray dryer in the sub-unit marked P-7/SDR-102 where the crystals are dried at a temperature of + 92$^{o}$C (drying time is 15-20 minutes), then passes into the sub-unit marked P-8/FL-102 where the final lactose product in powder form is isolated.

The whey protein concentrate and lactose powder obtained in this way are lighter, easier to transfer and can be stored for a longer period of time.

**Capital expenditures**

The money needed to pay for equipment and auxiliary units, procurement and preparation of soil, civilian structures, facilities and control systems is a fixed capital investment. Based on the total selling price of the equipment (PC), the share capital was estimated, i.e. fixed capital. In the studies performed, the capacity/size ratio and the correction using cost indices are used as a method for estimating the cost of capital built into the „SuperPro Designer" software. Direct fixed capital represents fixed capital investment and is calculated for the complete process as the sum of direct, indirect and other costs associated with the complete capital investment in the plant.

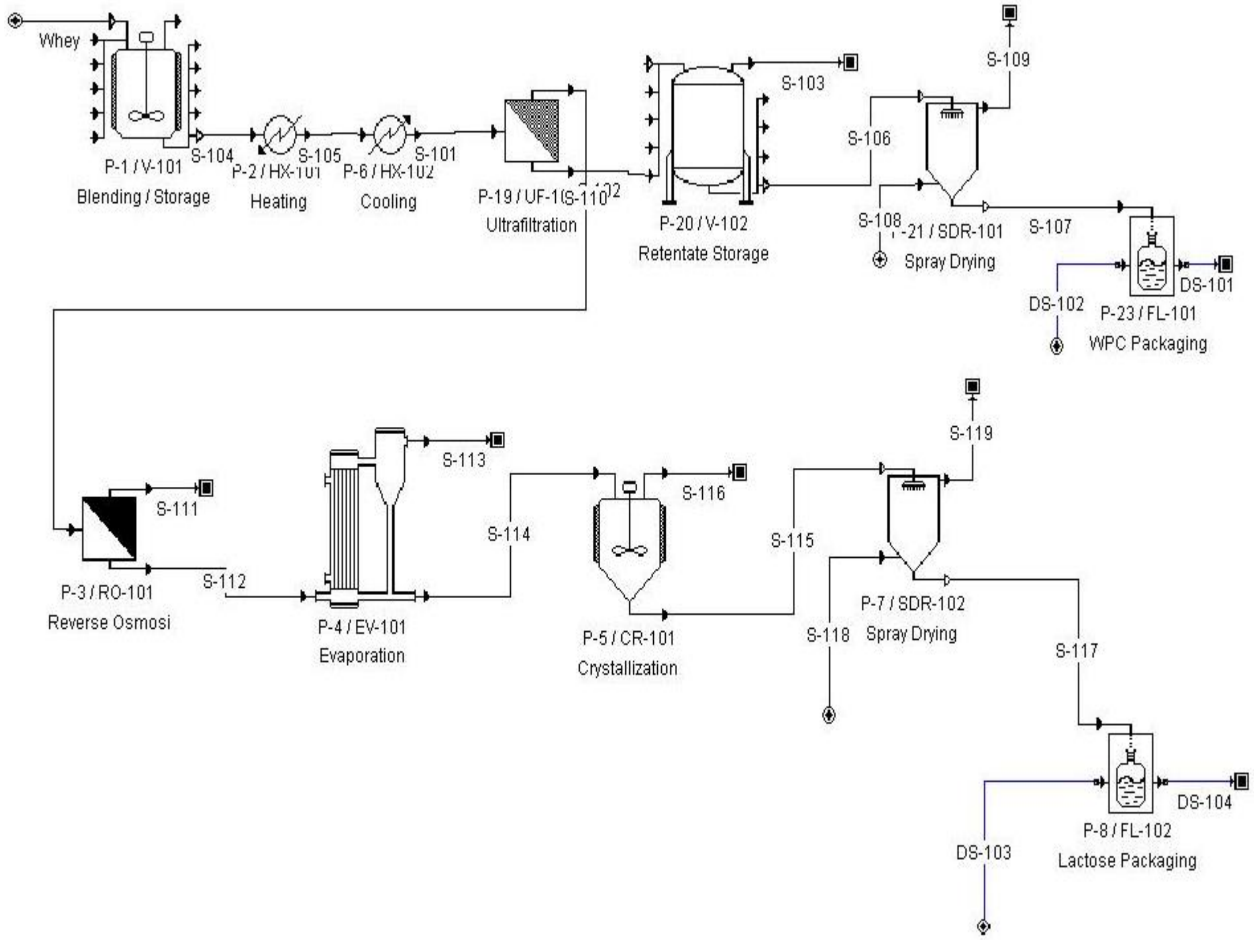


Fig. 1. Process of production of WPC 80 protein concentrate and LAC 80 lactose.
Source: Slavica Arsić (2018), Analysis of techno-economic justification of whey use in Serbia, Doctoral dissertation, Belgrade, 2018., University of Belgrade, p.63 [3].

Table 1, shows the total direct cost of fixed capital (DFC) of $ 19,634,000 and the individual cost items that contribute to direct fixed capital. Total capital investments include working capital as the cost of initiating validation, which totals $ 20,985,000 in the total capital investment costs of the WPC 80 concentrated protein and lactose powder production plant.

**Operating costs**

Table 2, which shows the basic operating costs of the WPC 80 and LAC 80 production plants, notes that the factory with a processing capacity of 1,000 kg h-1 in production has a total annual operating cost of $ 8,614,932. Unit production costs of WPC 80 are $ 15.84 per kg -1 and LAC 80 is $ 1.83 per kg -1.

The biggest item of operating costs in the production of WPC 80 and LAC 80 whey are equipment maintenance costs of 42.75%, labor costs of 40.60%, utility costs involved with 6.28% and laboratory equipment costs with 6.10%.

Based on the calculated costs, it can be stated that the most expensive point of the production process in the factory production WPC 80 and LAC 80 are the costs of equipment maintenance and labor costs.

Based on the total economic parameters of the WPC 80 and LAC 80 production plant, shown in Table 3, it can be concluded that the project is very favorable for the repayment period of all costs of 1.59 years, because in a very short time they can release funds for other purposes.

Table 1. Capital costs of factory production of WPC 80 protein and lactose LAC 80.

| COSTS | Price per unit in ($) | Costs in ($) |
|---|---|---|
| **Direct cost of fixed capital (DCF Capital )** | | **19,634,000** |
| Equipment procurement costs | | **3,093,000** |
| Mixing tank | 755,000 | 755,000 |
| Heat exchanger | 4,000 | 4,000 |
| Ultrafiltration unit | 149,000 | 745,000 |
| Vertical tank | 30,000 | 30,000 |
| Spray dryer, SDR-101 | 147,000 | 147,000 |
| Reverse osmosis unit | 52,000 | 52,000 |
| Evaporator | 128,000 | 128,000 |
| Crystallizer | 441,000 | 441,000 |
| Spray dryer, SDR-102 | 174,000 | 174,000 |
| Equipment not on the list | | 619,000 |
| Installation | | 1,762,000 |
| Process pipelines | | 1,083,000 |
| Measuring equipment | | 1,237,000 |
| Insulation | | 93,000 |
| Electrical equipment | | 309,000 |
| Facilities (objects) | | 1,392,000 |
| Landscaping | | 464,000 |
| Auxiliary facilities | | 1,237,000 |
| Designing | | 2,668,000 |
| Construction | | 3,735,000 |
| Fee for performing works | | 854,000 |
| Contingency costs | | 1,707,000 |
| **Reversible capital** | | 370,000 |
| **Start-up and validation costs** | | 982,000 |
| **Funds (assets) allocated to research and development** | | 0 |
| **Funds (assets) allocated for licenses and franchises** | | 0 |
| **Total capital investment** | | **20,985,000** |

Source: Results obtained by computer simulation in „*SuperPro Desinger*“ (3)

Table 2. Basic operating costs of the factory for production WPC 80 protein and lactose LAC 80.

| COSTS | Annual costs ($ year $^{-1}$) | Unit costs ($ kg$^{-1}$ WPC-a) | Unit costs ($ kg$^{-1}$ Lactose) | Total operating costs (%) |
|---|---|---|---|---|
| Raw material costs | 32,000 | 0.058 | 0.011 | 0.37 |
| Labor costs | 3,497,000 | 6.429 | 0.156 | 40.60 |
| Equipment maintenance costs | 3,683,000 | 6.771 | 1.203 | 42.75 |
| Costs of laboratory equipment | 525,000 | 0.965 | 0.174 | 6.10 |
| Communal services | 541,000 | 0.995 | 0.179 | 6.28 |
| Water vapor | 106,402 | 0.196 | 0.035 | 1.23 |
| Cold water | 160,298 | 0.295 | 0.053 | 1.86 |
| Glycol | 70,232 | 0.129 | 0.023 | 0.81 |
| Other | 0 | 0 | 0 | |
| Advertising / sales | 0 | 0 | 0 | |
| **Total operating costs** | **8,614,932** | **15.84** | **1.83** | **100** |

Source: Results obtained by computer simulation in „*SuperPro Desinger*“ (3).

**Techno-economic analysis of profitability of protein and lactose production**

The results of the economic assessment of the WPC 80 and LAC 80 whey production plant are shown in Table 10. For a plant with a basic capacity of 1,000 kg $^{h-1}$, the total capital investment is $ 20,985,000, the direct fixed capital cost is $ 19,634,000, and the operating cost is $ 8,614. .932 $ per year $^{-1}$, gross margin is 68.53% and return on investment is 62.70%.

The repayment period (number of years) required to recoup the funds invested in this research is 1.59 years. The shorter the repayment period, the more acceptable the project.

The maximum allowed repayment period in relation to which all investments of the company are compared is 6 years. Existing research has shown that with a repayment period of 1.59 years, a project for releasing funds for other purposes is much more suitable.

The internal rate of return (IRR) is compared to the minimum acceptable rate of return (MARR) or to the cost of capital of the enterprise. In this case, the IRR after tax is 45.86%, and the criterion for making a decision on accepting the project is that the IRR is higher or at least equal.

The net present value (NPV) with 7% tax is $ 68,118,000 -10$^{6}$ which is an indicator of the added value of the investment in the industry. In this case, the NPV is positive, which means that the investment should add value to the industry and thus indicate a production that is economically justified and can be accepted.

Table 3. Summary of economic parameters of the factory for the production of protein WPC 80 and lactose LAC 80

| COSTS | AMOUNT |
|---|---|
| Total investment ($) | 20,985,000 |
| Direct costs of fixed capital ($) | 19,634,000 |
| Operating costs ($ year $^{-1}$) | 8,614,932 |
| Gross margin (%) | 68.53 |
| Return on investment (%) | 62.70 |
| Repayment period (year) | 1.59 |
| IRR after tax (%) | 45.859 |
| NPV at 7% ($ · 10$^{6}$) | 68,118,000 |

Source: Results obtained by computer simulation in „*SuperPro Desinger*“ (3).

**Analysis of investment sensitivity**

For the production of WPC 80 protein concentrate and whey lactose LAC 80, using the SuperPro Desinger program that allows simultaneous design and production evaluation, the capital and operating costs of factory production are shown, to be successfully marketed as commercial products and their use in further research.

The two basic costs that are the criterion for making decisions on the economic feasibility of the production process are total capital costs and operating costs.

The basis for estimating these costs are: capital (fixed, labor and total), equipment, labor costs and total annual production costs (Table 1).

All costs arising from the regular activities of the industry (labor costs, utilities, laboratory costs, advertising), except for production costs, products and product sales prices, represent operating costs (Table 2).

Capital costs include the purchase of fixed assets, ie costs that contribute to increasing the value of fixed assets (costs of purchasing a new fermenter, storage tank, auxiliary building). Operating costs contribute to the reduction of the base for calculating income tax, while capital costs do not have a direct impact on the profit tax, (income) that the factory has to pay, but have an indirect impact.

## CONCLUSIONS

Based on the results of the economic assessment of the factories for the production of WPC 80 protein concentrate and whey lactose LAC 80, according to Table 3, it can be concluded that if the total capital investment in the factory is $ 20,985,000, direct fixed capital costs $ 19,634,000, operating costs $ 8,614,932 per year $^{-1,}$ gross margin 68.53%, return on investment 62.70% and repayment period is 1.59 years, as well as if the internal rate of return (IRR) after deduction (payment) is 45.86% while NPV (net present value) with a 7% tax amounting to 68,118,000 $ -10 6 that production is economically justified and can be accepted.

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