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Optimization Model for the Dairy Sector

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Abstract

This paper develops a proposed simulation and optimization model for the dairy industry overall, which is defined by using discrete simulation [1] and optimization [2], whose mathematical models have been solved by using simulation tools and optimization Promodel Gams [3], as well as the use of MS-Excel tool and building a graphical interface of MS-Excel Macros.

Keywords
Model, Simulation, Optimization

1. Introduction

As the global market becomes more competitive, techniques such as simulation and optimization have gained ground in the new theories of production: Lean Manufacturing, TOC or Theory of Constraints, Just in Time and Six-Sigma. One of the essential ways to manage and lead to survive today is the ability to identify and use resources optimally [2]. Then, the end of a simulation and optimization problem becomes an issue by trying to find optimal values in restrictive environments featuring multiple solutions.

In this sense, simulation and optimization are indispensable tools in decision-making in business, to find those sweet spots, which is why we have tried to address the case study of the dairy sector in the context of proposing a general model productivity and competitiveness in the agribusiness sector in Colombia. Initially the problem is addressed on the discrete simulation for a company in the sector, in two of its production lines defined as critical (Cheese and Yogurt), it is identified its flow of operations, from the receipt of raw materials to the delivery of finished product Next, is approached fieldwork by collecting times of operations, which are validated statistically using Stat-Fit tool Promodel software, to go to the construction of discrete simulation model and generate the results of the runs of respective simulation. After constructing the model based on MRP (Material Requirements Planning) and generic multi-objective optimization model for the sector, solved by GAMS software help [3]. Finally, the support tool is built by developing a macro in MS-Excel, for deployment in corporate sector in order to help improve their productivity and competitiveness through efficiency in planning their production process that contributes to maximizing profits and reducing costs and waste.

This article is organized as follows. Section 2 provides an analysis of the sector. Section 3 presents the discrete simulation model with two sub-models; the production model and the optimization model and analyze the results generated. Section 4 presents the tool support built. Finally, the conclusions and following work are presented in Section 5.

2. Sector Conditions

Colombia produces 1% of the world dairy production, a place that becomes important if the comparison is done only among Latin American countries, because the country is only surpassed by Brazil, Mexico and Argentina. Since 2005, dairy exports from Colombia were directed mainly to the U.S., Netherlands Antilles, Trinidad and Tobago, Ecuador and Venezuela as shown in the following chart.

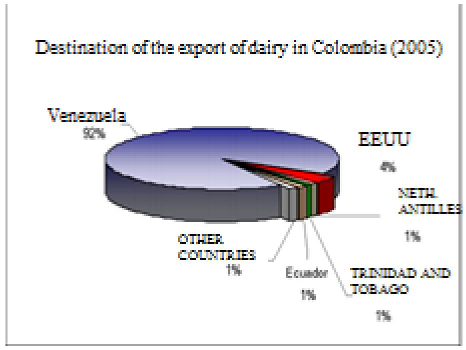

Figure 1: Percentages of dairy exports.

It is in this market and with the signing of free trade agreements where companies come to compete with companies such as Nestle, Unilever, Kraft Foods, Danone, among others, leaders not only in dairy production and marketing, but also in research and technological development. Now, the dairy sector in Colombia moves in the following production system: The first link in the chain, are stores that supply inputs farms and livestock. The second link is the producers that can be specialized herds in milk production or animal husbandry. The third link is made up of collection centers where it joins milk from herds and livestock. The fourth link in the chain that are processors, business pasteurize milk and transform it into products such as cheese, butter, yogurt, ice cream, milk caramel or different characteristics: whole, lactose-free, low fat, etc..

Now, according to a 2011 study, the agribusiness sector has increased about two percent (2%) in the past decade (2000-2010), of this growth is highlighted for the dairy sector, as aspects as:

- Colombia is the fourth largest milk producer in Latin America with an approximate volume of 6,500 million liters per year, surpassed only by Brazil, Mexico and Argentina.
- Quality of the milk produced in Colombia with protein and fat percentages higher than the world major producers, such as New Zealand, Germany, Switzerland, Canada and USA
- 2,600 million liters of fresh milk available for processing by new industries, amount that currently does not enter the formal channel transformation.
- Third dairy sales market in Latin America, with an annual value of U.S. $ 2,862 million.
- Existence of potential strategic partners, companies engaged in the production, processing and marketing of dairy consumption with great knowledge and national distribution networks.
- Since 2009, the whole country is free of disease with vaccination.
- Preferential access to markets including the CAN, Mercosur, Chile, Cuba, Canada, Mexico, EU.

3. Proposed Model

We have proposed a model for dairy production chain, more specifically in the two products considered critical: the production process of cheese and the production process of yogurt. These processes share operations as in the case of: receiving and discharge, sanitation, skim and standardized milk storage, last operation from which each process runs its own stream to package sterilization and aseptic filling, coding, packaging and palletizing and storage and delivery of the final product, as shown in the following figure:

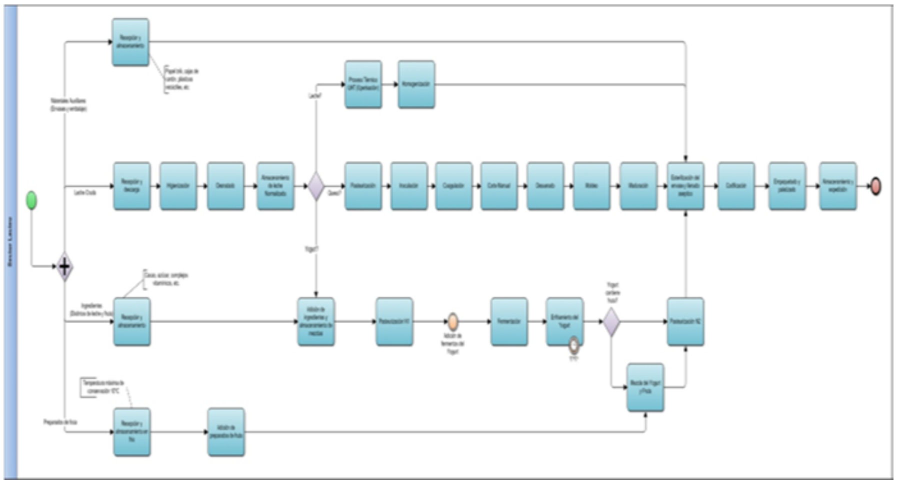

Figure 2: Dairy production process.

Then, the proposed model has been defined based on two sub-models: the cheeses sub-model process and yogurts sub-model process, as well as the production and optimization model.

3.1. Cheese submodel

For the Cheese submodel, is taken as reference the process from receipt of raw milk to the download in the hold of dispatch of finished goods. Once the process was documented with their respective operations, we proceeded to the respective decision-times for the case study and its statistical validation by using the software tool Promodel StatFit, as well as the establishment of model assumptions, such as: consider a work week of eight (8) days, with 24 hours per day and 60 minutes per hour, for a period of 15 days simulation under normal conditions, ie without the presence of peaks in orders due to stable demand. Then with the help of the tool Promodel, we proceeded to define the elements of the model as the locations (reception, pasteurization, reception tubs, ingredients and curd, cut and shredded, initial agitation, resting, draining, salting and heating, drainage, press molding and pressing, cooling, portioning and pressed, packaged and sealed, dated, storage, dig out, upload and download); entities (liters of milk, coagulated milk, cheese and cheese basket and prosecutions of the model as shown in the following figure:

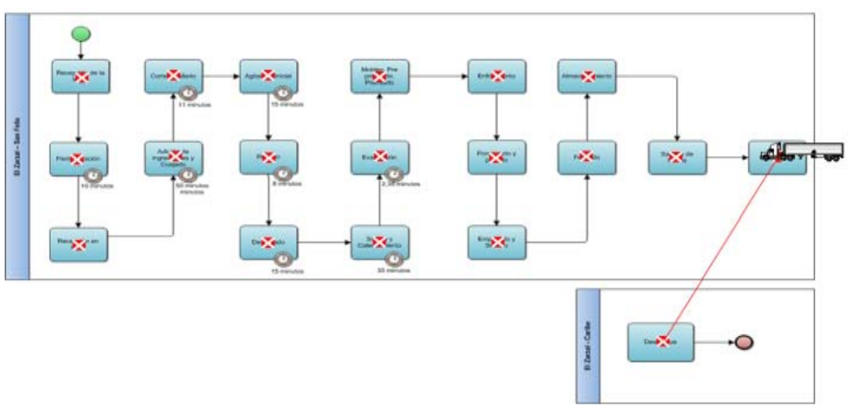

Figure 3: Cheese process simulation model

Finally, we proceeded to set the simulation model in order to determine the standard operating times throughout the cheese production process.

TABLE 1: Real and simulated times of the production process of cheese

OPERATION	REAL TIMES	SIMULATED TIMES
Reception	**0,1066**	**0,1066**
Pasteurization	**0,0400**	**0,0400**
Add ingredients	**0,0033**	**0,0027**
Curd	**0,1399**	**0,1309**
Cut	**0,0440**	**0,0375**
Shredded	**0,0600**	**0,0600**
Resting	**0,0320**	**0,0320**
Draining	**0,1200**	**0,0600**
Initial agitation	**0,0080**	**0,0080**
Salting and heating	**0,2800**	**0,3415**
Drainage	**0,0191**	**0,007**
Pressed molding	**0,1183**	**0,1836**
Pre-pressed	**0,0453**	**0,0714**
Pressed	**0,0554**	**0,085**
Transport Cava	**0,0207**	**0,0207**
Cooling	**0,0014**	**0,0014**
Portioning	**0,2000**	**0,66**
Packaged and sealed	**0,6354**	**1,112**
Dated and, storage	**0,1270**	**0,1270**
Dig out	**0,0100**	**0,007**
Transport truck	**0,0104**	**0,0104**

Of which, it was determined that the actual average time for a cheese is 2.08 minutes versus a simulated average time of 3.10 minutes, so that in a day of 24 hours in normal conditions could been produced between 500 and 714 cheeses.

It was observed in addition to the model, that the most critical operations of the cheese production process are: molding, pre-pressing and pressing with an average occupancy rate of 37.37% of the total cycle time, Cooling with 23, 5% Cavas stumped with 52.7% and 90.7% bear. Data were statistically validated by applying the central limit theorem constructing confidence intervals for each of the 30 replicas simulated operations.

3.2. Yoghurt Submodel

For Yoghurt submodel has been taken as reference the general process described above.

Once the process was documented with their respective operations, we proceeded to the respective decision-times for the case study and its statistical validation by using the software tool Promodel StatFit, as well as the establishment of model assumptions, such as: choice of yogurt production line mark (Yogurt in 100cc bag) for the case study, the use of some behaviors times standardized process such as pasteurization, cooling, heating incubation and retention , and the other defined as above in the production process of cheeses. Then with the help of the tool Promodel, we proceeded to define the elements of the model as are the locations (Reception at the silo, Pasteurization, Flavoring Tub, packaging machine, Dated, Cava, multi-packing Area, Heating, Cooling, Heating on hold, Incubation, Upload, Download, Transport, Truck) entities (Milk, Yogurt and yogurt bag) and renders the model, as shown in the following figure:

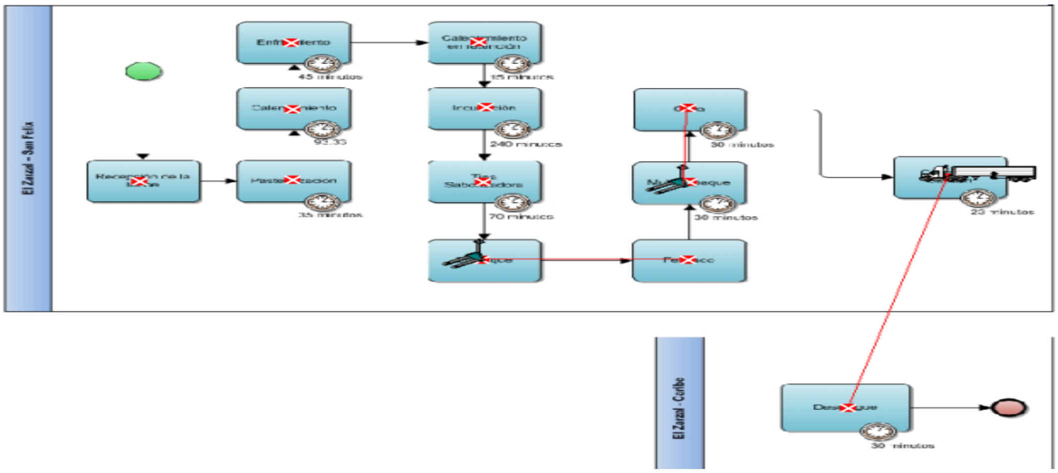

Figure 4: Yoghurt process simulation model.

Finally, we proceeded to set the simulation model, with the aim of determining the standard operation time in the whole process

TABLE 2: Times of the production process of real and simulated Yoghurt

OPERATION	REAL TIMES	SIMULATED TIMES
Reception at the silo	0,1066	0,1066
Pasteurization	0,015	0,015
Heating	0,04	0,04
Cooling	0,019	0,019
Heating on hold	0,0064	0,0064
Incubation	0,1028	0,1028
Flavoring Tub	0,029	0,029
Packaging machine	0,012	0,0108
Dated	0,010	0,0167
Multi-packing	0,25	0,1818
Cava	0,25	0,1685
Upload	0,19	0,7962
Download	0,1695	0,1695

From this it was determined that the real average time average for a yogurt is 1.20 minutes versus a simulated average time of 1.66 minutes, so that in a day of 24 hours in normal could been produced between 900 and 1200 Yoghurts in 100cc bag. It was observed also that the most critical operations in the production process of the yogurts in 100cc bag are: Pasteurization, Heating, and Cooling, Heating on hold and Incubation with utilization rates above 90%. Data were statistically validated by applying the central limit theorem constructing confidence intervals for each of the 30 replicas simulated operations.

3.3. Production model

For the production model it has been taken as reference the MRP methodology, according to which initially is taken a production line, that in this case study was the cheese, which according to the historical performance of sales has had a weekly demand of 876 units, for an expected daily production of 146 units, then we have defined a master production plan for the production and packaging operations, based on real and simulated times previously we proceed to the planning of material requirements (MRP). Since the company wants to produce 350 cheeses, every other day (1-3-6), and have assumed some initial inventories with their delivery times, then we proceed to make the explosion of such materials to obtain the requirements of which were generated the purchase orders and the production orders. Then, with the labor available for the cheese production process, that in this case study, is qualified 2 semi-skilled 14. It can be determined the productivity indicators of the process, so we can get a productivity of 21.87 Cheese / Operator and 14.28 liters of milk / cheese for a weekly efficiency of the production process of the order of 83.43%.

3.4. Optimization model

In the case of the optimization model, we have proposed a multi-objective model, in which the company has prioritized the sale of yoghurts of three different flavors: strawberry, blackberry and peach, the company has two machines: the packing 1 and the packing 2, for flavoring and packaging of three references. According to market research, for the next quarter will be an increase in demand that exceeds the quarterly capacity of the balers, as follows: 830 strawberry units, 1100 blackberry units and 520 peach units. To meet the additional demand, overtime should be implemented during the quarter on the machines, with a value of $ 15,410 (packing 1) and $ 5550 (packing 2). The value of this overtime takes into account the value of: Extra Labor, water consumption, energy consumption, and Raw Materials. There is a percentage of waste associated with each machine and product, and it varies, because for each yogurt was used a different packaging material from different suppliers. Namely: what is the ideal composition for scheduling overtime in the packing in the next quarter, seeking to minimize waste and costs, taking into account that there is a more marked interest in minimizing the costs in the trash. It should be noted that the values of Xij must be integers.

In this vein, the proposed model is of the form:

Min = $15.410X_{1j} + 5.500X_{2j}$ *(Min. Coste)*

Min =$3.1X_{11} + 2.2X_{21} + 2.5X_{12} + 3.2X_{22} + 3.5X_{13} + 1.8X_{23}$ *(Min. waste)*

S.A

$9X_{11} + 3X_{21} >= 830$ (*Demand yoghurt of strawberry).*
$9X_{12} + 6X_{22} >= 1100$ (*Demand yoghurt of blackberry).*
$6X_{13} + 3X_{23} >= 520$ (*Demand yoghurt of peach).*
$X_{ij} >= 0$
X_{ij} Integer
Where:
Xij: Overtime programming in the next three months to produce yogurt j on machine i.
i = 1, 2. (Baler 1, Baler 2)
j = 1, 2, 3. (Strawberry Yogurt, Blackberry yogurt, Peach Yogurt)

This problem is characterized by being a multi-objective problem and which has two different purposes, which must be resolved as individual problems, i.e, optimize for cost and then for waste, as independent problems. Now, the first thing you do to solve this problem is to solve each of the objectives independently. One can see that for the minimization of Overtime Costs, wastes are very high with a value of 1189.4 kg and in the opposite case when minimizing waste, overtime costs increase with a value of \$ 4,659 .320. This indicates that the multi-objective optimization needs a step further than the mere independent optimization of each of the objectives, and then the solutions are uneven.

Therefore, to solve this problem is needed the implementation of the method MINIMAX, in which is used goal programming. This method seeks to minimize the percentage deviations of the value achieved with respect to the target. The goals or ideals are the values obtained in single minimization, and are as follows.

Goal 1: Minimize waste to about 899.4 kg.

Goal 2: Minimize costs to approximately \$ 3,392,220.

In order to create a MINIMAX model, it must be created a variable Q which is as follows:

$$Q = \mathrm{Max}\,\{\mathrm{vp.coste}, \mathrm{vp.waste}\}$$

$$\mathrm{vp.coste} = w_1\left(\frac{15.410x_{1j} + 5.500x_{2j} - 3.392.220}{3.392.220}\right)$$

$$\mathrm{vp.waste} = w_2\left(\frac{3.1x_{11} + 2.2x_{21} + 2.5x_{12} + 3.2x_{22} + 3.5x_{13} + 1.8x_{23} - 899}{899}\right)$$

With this criterion, we can proceed to solve the problem is left, as follows:

Min Q

$9X_{11} + 3X_{21} >= 830$ (*Demand yoghurt of strawberry).*

$9X_{12} + 6X_{22} >= 1100$ (*Demand yoghurt of blackberry).*

$6X_{13} + 3X_{23} >= 520$ (*Demand yoghurt of peach).*

vp.coste <= Q (Goal 1 Restriction MINIMAX)

vp.waste <= Q (Goal 2 Restriction MINIMAX)

Xij>=0

Xij Integer

Since it has placed a weight w1 = 3 to cost, and w2 = 1 to waste. We proceed to solve the problem in GAMS tool, whose code is shown in the following figure:

```
set i Maquina / Emp1,Emp2/;

set j Yogur / Fresa,Mora,Melocoton/;

Table C(i,j) Capacidad de máquina i para yogur j
             Fresa   Mora   Melocoton
  Emp1         9       9        6
  Emp2         3       6        3;

Table D(i,j) Desperdicios de máquina i para yogur j
         Fresa    Mora     Melocoton
  Emp1   3.1      2.5        3.5
  Emp2   2.2      3.2        1.8;


Parameters
B(j) Demanda para cada tipo de yogur
 /   Fresa        830
     Mora         1100
     Melocoton    520/

Variables
X(i,j) Cantidad de horas extras programadas en la máquina i para yogur j
Z   Objetivo
Q   MINIMAX;

INTEGER variables X;

X.up(i,j)=200
```

```
equations
OBJ Función MINIMAX
R1  Restriccion fresa
R2  Restricción Mora
R3  Restricción Melocoton
R4  Meta 1
R5  Meta 2;

OBJ.. Z=E=Q;

R1.. Sum(i, C(i,'Fresa')*X(i,'Fresa')) =G= B('Fresa');
R2.. Sum(i, C(i,'Mora')*X(i,'Mora')) =G= B('Mora');
R3.. Sum(i, C(i,'Melocoton')*X(i,'Melocoton')) =G= B('Melocoton');
R4..(sum(j, 15410*X('Emp1',j))+ sum(j, 5500*X('Emp2',j))-3392220)=L=3392220*Q/3;
R5..(sum((i,j),X(i,j)*D(i,j))-899.4)=L=899.4*Q ;


MODEL yogur /ALL/
SOLVE yogur USING MIP MINIMIZING Z;
```

Figure 5: GAMS Model Scheme.

Solving this problem with the Excel Solver tool and also GAMS model, the solution is as follows:

```
---- VAR X  Cantidad de horas extras programadas en la máquina i para yo

                 LOWER     LEVEL     UPPER    MARGINAL

Emp1.Fresa         .       93.000   200.000     0.014
Emp1.Mora          .       37.000   200.000     0.014
Emp1.Melocoton     .         .      200.000     0.014
Emp2.Fresa         .         .      200.000     0.005
Emp2.Mora          .      129.000   200.000     0.005
Emp2.Melocoton     .      174.000   200.000     0.005

                      LOWER     LEVEL     UPPER    MARGINAL

---- VAR Z             -INF      0.245     +INF        .
---- VAR Q             -INF      0.245     +INF        .

  Z  Objetivo
  Q  MINIMAX
```

Figure 6: Solution of the model in GAMS.

Is taken as the best solution, the one thrown for the tool Solver, since it achieves greater minimization of the objective function: taking a value of 23.12% versus 24.5% GAMS. This means that as a final answer to the problem, you must assign overtime for the next quarter as follows: 92 hours for strawberry yogurt, 35 for blackberry yogurt, and 0 for peach yogurt in the baler 1. And 1 hour for strawberry yogurt, 131 for blackberry yogurt, and 174 for peach yogurt in the baler 2. Thus, waste and costs can be minimized in accordance with the assumptions made.

4. Prototype Construction

With this case study resolved, we proceeded to build a tool to support the decision making in the sector. This tool has been implemented with the case study and is actually in a assessment phase, achieving the expected results. Upon entering the application, there is a first menu which allows you to enter the various component modules: Display the process, import data from simulation, Optimize the yogurt packaging machine, Calculate the master production plan and generate a report. As shown in the following figure:

Figure 7: Tool Menu Interface.

Upon entering the display module of the process, the application will allow to observe and analyze the production process for different products with its workflow, facilitating the understanding and analysis of the process. Upon entering the module Import simulation, there is necessary Promodel tool for the simulation, and the results should be exported from this to Excel. After this, simulation results are selected to be imported for each product in terms of entities, locations and resources. Upon entering the option: Optimize Baler Yogurt, you can optimize the amount of Yogurt Peach, Strawberry and blackberry to be packed into two packing machines in order to ensure a minimum cost of hours and / or a minimum amount of waste, according to the parameters introduced into the module. This shows the results of the optimization algorithm.

Upon entering the option of calculating the master plan, it displays a form allowing the analyst to enter the data necessary to calculate the master production plan for the product of the cheese, on a time horizon of six days (1 week). Once all the data is entered, simply click to see the master plan, to see how the spreadsheet has done all the necessary operations and automatically delivers the Master Production Plan. Finally, when entering the module “to generate report”, is validated that all previous modules have been executed in order to generate a summed report, where the process can be viewed, the results of simulation, optimization and product indicators master plan, as shown below:

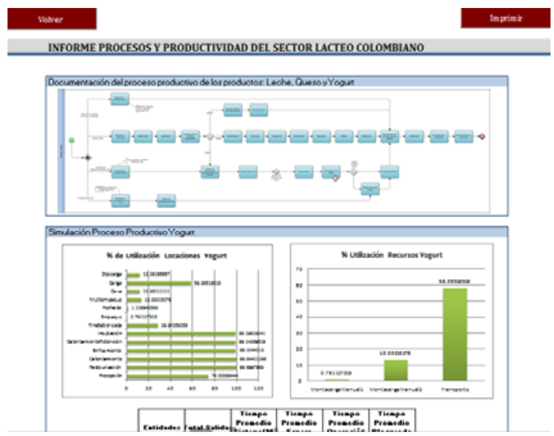

Figure 8: General report interface

5. Conclusion

The proposed model for the dairy sector has been developed from two sub-models: the cheeses simulation submodel and the yogurts simulation submodel, as well as a production model and an optimization model, the two sub-models have been solved with discrete simulation, the production model with MS-Excel tool and the optimization model has been developed as a multi-objective model with the help of GAMS tools and MS-Excel, which have been adapted to the needs presented in the development of project. Facing the model itself, it was established a standard average time thread for cheese and yogurt production, in order to ensure adequate amounts of inputs to the production model and optimization, from it was concluded that the measurement period for the production of a cheese is 3.10 minutes, and the production time for a yogurt is 1.66 minutes.

Now, for a total estimated volume of weekly production of 876 units, i.e., for an expected daily production of 146 units of cheese, it will take 452.6 minutes, i.e. the assumptions of 24 hours of work, this production could be achieved at 0.31 days of work, productivity indicators of 21.87: Cheese / Operator and 14.28 liters of milk / cheese, for a weekly efficiency of the production process of the order of 83.43%. In the case of yogurt, concerning the decision on efficiency packing machines to model assumptions for cost reduction and waste, based on an expected increase in demand for strawberry yoghurt 830 units, 1100 blackberry yogurt units, and 520 units of peach yogurt, for a total of 2450 units, these will be produced in 4067 minutes and with the same assumptions as in the case of cheese it would take 1.70 days of work, if we add the assumptions that must be implemented overtime during the quarter, on machines with a value of $ 15,410 (packing 1) and $ 5,550 (packing 2), and with capacities and waste proposed in the model, it is necessary to have a plan to allocate overtime for the next quarter as follows: 92 hours for strawberry yogurt, 35 for blackberry yogurt and 0 for peach yogurt in the baler 1, and 1 hour for strawberry, blackberry 131 for and 174 for peach, in the packing 2; achieving minimize waste and costs.

This has allowed the construction of a tool to support decision making in the sector, which will contribute as an inexpensive tool and easy to use, to the improvement of the productivity and competitiveness of the sector.
As future work it is been carried out researches for the optimization of other productive sectors, at the level of general models, which provide clear evidence against the new schemes of productivity and competitiveness for the country.

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Biography

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