USING SIMULATION TO EVALUATE EXPANSION PLANS OF A MANUFACTURING PLANT OF LACTEAL PRODUCTS

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ABSTRACT

This research was developed for a manufacturing plant of lacteal products located in the Mezquital valley in the state of Hidalgo, Mexico. Its purpose was to evaluate if production times in the plant would improve by expanding its production lines with some new components. Since the new components were not available for an *in situ* experiment, a simulation model of the plant was built to evaluate the proposed expansions. The model was validated by the production staff of the plant, and was used to perform statistical experiments to compare production times of the actual and proposed plant configurations. Experiment results showed that the addition of the new components would considerably improve production times.

INTRODUCTION

Simulation is a quantitative technique widely used in industry. In the food industry, simulation techniques have been applied frequently since 1980 to model and analyze processes, to help to solve complex problems, and to propose new systems of operation (Barratt 1996). Turker (1997) developed the CTemp model for Campden & Chorleywood Food RA. CTemp models the heat behavior of a tinned food during a thermal process and predicts the temperature and the levels of sterilization of a product, as well as the effect of overcooking the product and its chemical composition. Flores *et al.* (1993) developed an administrative simulation model of a wheat flour milling facility. The model can be applied to facilitate the feasibility analysis of the company, to carry out the economic evaluations of the production of specific types of flour wheat, and to calculate the economic impact of the raw material types and the milling parameters. Syed *et al*. (1983), developed a simulation model for a plant that manufactures sausages and bologna to evaluate its processing system. The plant is a typical representation of multi-process with two semi-continuous batch systems connected in series. Syed *et al.* (1985) developed a second simulation model for another plant that has two processing systems (hams and sausages). The model was designed under the criterion of diminishing the total processing time and was used to monitor and to evaluate the use of the resources of the plant under five different production policies.

In this paper we present a simulation model developed for a manufacturing plant of lacteal products located in the valley of the Mezquital, in the State of Hidalgo, Mexico. The purpose of the model was to evaluate if production times in the plant would improve by expanding its production lines with some new components. The model was validated by the production staff of the plant and was used to perform statistical experiments that compared the production times of the actual and the proposed plant configurations.

MATERIALS AND METHODS

The basic materials used were data collected in the year 2000 about the equipment use and the production processes of the plant under study. This plant pasteurizes milk and manufactures lacteal products. The capital belongs to particular investors. The different products that are manufactured are sold in the market under a registered trademark. These products include different types of cheese, yogurt, cream and butter.

In addition to the basic materials, the simulation software Simact-VPR (Arjona and Perez 1999) and one workstation Hewlett Packard Kayak XM600 were used as auxiliary materials for the implementation and experimentation with the model.

With respect to the used methods these were two. The first was a method for the construction of activity models. The second was a classic statistical method for the comparison of two designs.

EQUIPMENT USED IN THE PLANT

Next, we describe the equipment of the plant and its uses.

Electrical boiler 1. It is used to cover the steam requirements of the coagulation tank.
Reception tanks. Tanks where milk is stored when arriving at the plant.
Worktables for analysis. Tables that have the equipment and material for the milk analysis (test tubes, grids and reagents (acid, cultures, curdling, salts, etc.)).
Preheating tank. Tank used to preheat the milk that is going to be skimmed to favor fat separation. It is connected to the reception tanks and to the skimmer. It works by means of a steam jacket.
Skimmer. Skimmer of plates. It is used to separate the fat in the milk that is destined for some cheeses. This fat is later standardized to obtain cream.

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Milk pump. Pump used for the transport of milk.
Slow pasteurizer. Pasteurizer that uses the method of discontinuous pasteurization LTLT (Low Temperature Long Time). It works by means of a steam jacket. An agitator is used to make the heat treatment homogenous.
Ice bank. Machine that forms ice blocks.
Vertical presses. Vertical presses of handles.
Homogenizer. It is used in several of the elaboration processes to break and to reduce fat globules. It can be used to elaborate the bases for yogurt or cheese.
Fast pasteurizer. Pasteurizer that uses the method of fast pasteurization by plates (72.7°C during 15 seconds) assuring the destruction of pathogenic organisms. The pasteurization is continuous or HTST (High Temperature Short Time).
Cooling unit. It lowers the temperature of the milk after passing through the fast pasteurizer.
Coagulation tank. Tank with a steam jacket.
Movable tank. Tank with wheels that allow moving it. It is used for the transport of small amounts of milk.
Work tables. Stainless steel tables used to aggregate curd, to mold, etc.
Mincer. It is used to prepare cheese aggregates.
Refrigeration chamber. It maintains the products in refrigeration to 6-12°C. Depending on his type, the cheese stays a time for his maturation within this camera before his sale.
Kettles. They are used for the formation of the curd in the elaboration of products.
Electrical boiler 2. Boiler for feeding steam to the kettles.
Boiler pumps. Pumps for feeding water to the boilers.
Water pump. Pump used for water transport.
Water tank. Tank used to store the water used to feed the boilers.
Churner. It is used for the formation of the emulsion in the non-continuous process of butter elaboration.
Molder. It gives the butter its final form.
Refrigerator of analysis and cultures. It is used to conserve cultures, reagents and samples of products.
Vacuum Packer. High vacuum programmable packer.

PRODUCTION PROCESSES IN THE PLANT

Five different products and two by-products are elaborated in the plant. The products are yogurt and cheeses panela, oaxaca, manchego, and manchego with chipotle chili. The panela and oaxaca cheeses are of the fresh type. The manchego cheeses are of the matured type. The by-products elaborated are cream and butter.

METHOD USED FOR THE CONSTRUCTION OF THE MODEL

The model was built using the activity approach. The idea in which the activity approach is based (Poole and Szymankiewicz 77; Spriet and Vansteenkiste 82) is that at any moment, any component of a system can only be active or inactive. In order to begin an activity, the required components must be inactive. As a result of the execution of the activity, some components can be generated, consumed or modified. When the activity ends, the components that were not consumed or that were generated become inactive. Inactive components are stored in waiting lines.

RESULTS AND DISCUSSION

THE SIMULATION MODEL

The simulation model comprised a total of 55 entities, 146 activities and 152 waiting lines.

The entities considered in the model correspond to the equipment in the plant, the raw materials, the products and the personnel. The production is organized in lots and each lot has specific characteristics that are determined beforehand like the type of product, the different subprocesses that the product requires for its elaboration, the place and type of pasteurization, the place where the curd will be made, the requirement that the skimming must be made before or after the curd, etc. All these characteristics were considered in the model as attributes of the respective entities. Other attributes considered were those that correspond to the state and use of the equipment, as are the total number of hours that the component has been in operation, the requirement that a component must be washed before the next process, the number of component when (as the case of the kettles) there are several of them that have the same characteristics, etc. Finally, for the personnel of the plant were considered the attributes that correspond to their identification, specialty, worked hours, assigned turns, etc.

With respect to the activities considered in the model, except for the pasteurization, that is common for all the processes, for each process, an independent set of activities was used. This was done to easy the monitoring of the model to the production staff of the plant, so they could collaborate in the validation of the model. A total of seven different production processes were considered in the model. Activities 1 to 30 correspond mainly to the milk pasteurization process and to the washing, cleaning, and preparation of some plant components. Activities 31 to 54 correspond to the manchego cheese production processes. Activities 55 to 74 correspond to the panela cheese production process. Activities 75 to 94 correspond to the oaxaca cheese production process. Activities 95 to 108 correspond to the yogurt production process. Activities 109 to 116 correspond to the cream production process. Activities 117 to 126 correspond to the butter production process.

The waiting lines considered in the model correspond to the deposits of the plant and to the intermediate states in the elaboration processes of the products. The deposits considered in the waiting lines are the reception tanks, the refrigeration chamber, the raw materials warehouse and the water tank.

Figure 1 depicts the part of the model that corresponds to the elaboration of manchego cheese. The rectangles represent activities, the circles waiting lines and the arrows flows of entities. The letter A stands for activity and the letters LE stand for waiting line. The green waiting lines communicate with other parts of the model. The activities included in the figure are the following:

A31. Adding aggregates
A32. Resting 1
A33. Curdling
A34. Resting 2
A35. Cutting
A36. Adding water
A37. Resting 3
A38. Eliminating serum
A39. Cheddar processing
A40. Preparing chipotle chili
A41. Mixing chipotle chili
A42. Salting
A43. Molding
A44. Pressing 1
A45. Turning
A46. Pressing 2
A47. Unpressing
A48. Arranging
A49. Maturing
A50. Washing
A51. Packing 1
A52. Packing 2
A53. Weighting
A54. Loading

EVALUATION OF THE EXPANSION PLANS

Once that the model was validated by the production staff of the plant, some experiments were carried out with the model to evaluate several expansion plans. Next we present the results of an experiment conducted to compare two configurations of the production processes. The first configuration, which we will call configuration A, corresponded to the actual configuration of the production processes. The second configuration, that we will call configuration B, corresponded to an extended configuration of the production processes. These extensions include the use of new kettles and an additional milk pump. The second boiler of the plant would feed this group of kettles.

The main variable to estimate was the expected production time under a typical production scheme of the plant. This scheme includes the elaboration of several types of cheeses and yogurt using two consecutive 8-hour shifts.

The experiment consisted of a mean-difference test for the estimated production times under each one of the configurations. 30 independent runs of each configuration were made and confidence intervals for the differences of the estimated production times were calculated. Table 1 shows the results obtained. The used unit of time is the minute. In the table, it can be observed that none of the calculated confidence intervals for the differences of the estimated production times contains the zero, so we conclude that there is a significant difference in the production times of the two configurations. As a matter of fact, configuration B improves considerably the production times.

CONCLUSIONS

Several expansion plans of a manufacturing plant of lacteal products were evaluated. To do this, a simulation model that describes the general behavior of the plant was built and implemented. The model includes the elaboration processes of different types of cheese, yogurt, cream and butter. To develop the model it was used the activity approach, so the model resembles structurally the real physical conditions of the plant, and was easily understood and validated by the production staff of the plant. The evaluation of the expansion plans was done using different configurations in the model and making statistical experiments to measure differences in the expected production times. In each experiment were compared two configurations. The first configuration corresponded to the actual configuration of the plant and the second to an extended configuration of the production processes. In all the experiments made, the confidence intervals obtained excluded the zero, providing evidence that the extended configurations were better than the actual. The improvements in the expected production times for several of the extended configurations were of the order of 25%.

As the model includes several generic processes for the elaboration of lacteal products and by-products, it can be considered as a general representation of the manufacturing industry of lacteal products, and can be easily adapted to other plants by changing the data about the raw materials and equipment used in the plant.

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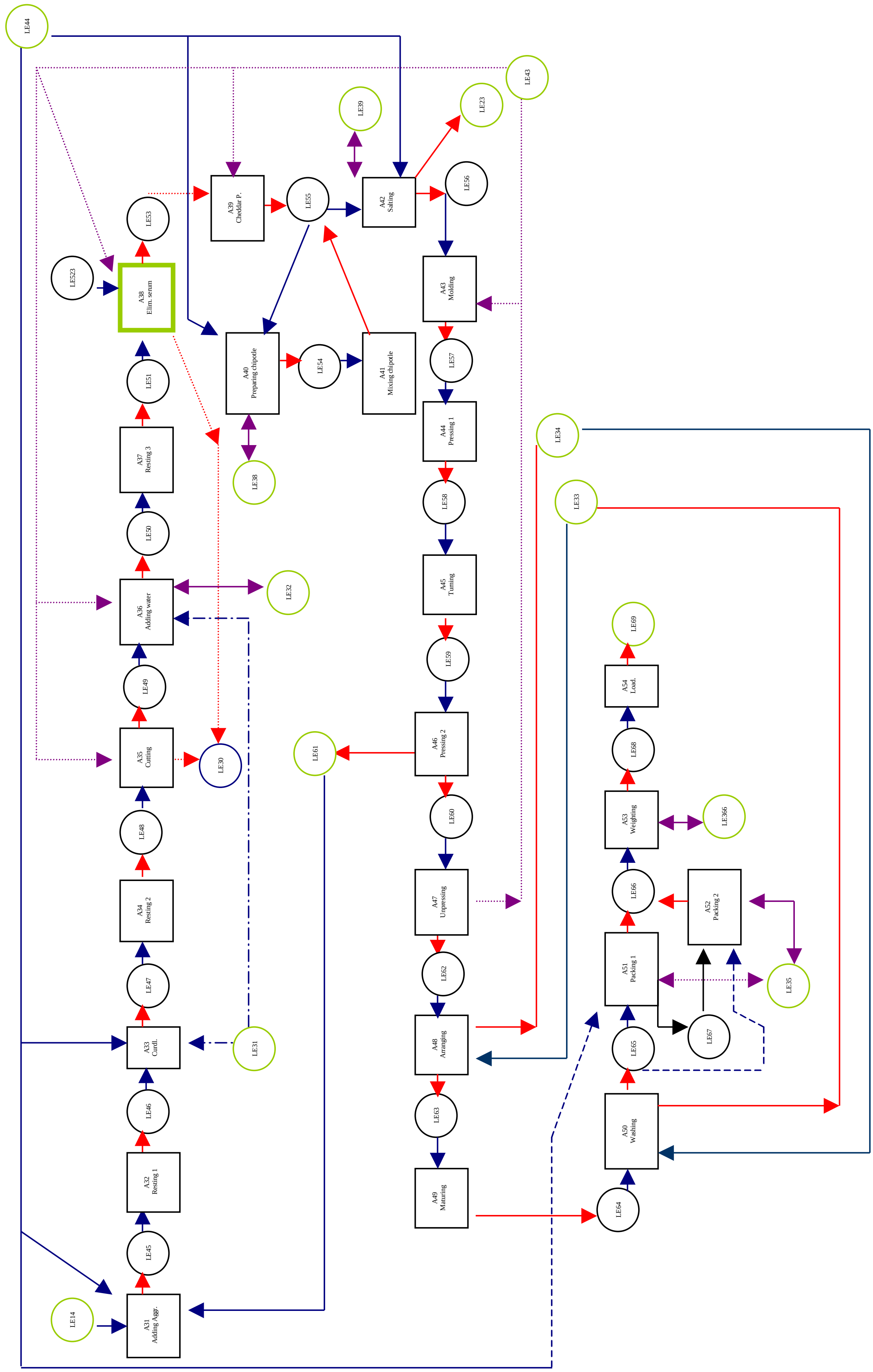

Figure 1. Part of the simulation model that corresponds to the manchego cheese elaboration process

Table 1. Confidence intervals for the differences in processing times of two plant configurations

Run	Configuration A*	Configuration B**	Difference
1	780.201	574.003	206.198
2	777.381	570.472	206.909
3	786.953	598.806	188.147
4	777.57	584.97	192.6
5	782.808	580.068	202.74
6	773.998	603.429	170.569
7	791.082	574.94	216.142
8	780.447	600.797	179.65
9	765.756	598.396	167.36
10	758.364	610.727	147.637
11	779.321	586.504	192.817
12	775.831	567.134	208.697
13	786.543	574.932	211.611
14	781.143	567.987	213.156
15	776.122	604.38	171.742
16	785.295	565.033	220.262
17	777.235	560.472	216.763
18	783.388	574.816	208.572
19	780.525	581.297	199.228
20	774.15	582.048	192.102
21	783.523	605.329	178.194
22	772.557	563.344	209.213
23	782.308	603.327	178.981
24	781.225	594.296	186.929
25	773.145	609.327	163.818
26	776.953	586.304	190.649
27	773.35	583.134	190.216
28	782.456	563.234	219.222
29	780.451	572.332	208.119
30	773.432	579.765	193.667
		Sample mean	194.397
		Sample standard deviation	18.4743213
		80% confidence interval	190.08-198.71
		90% confidence interval	188.81-199.94
		95% confidence interval	187.79-201.01

* Configuration A corresponds to the actual configuration of the plant..
** Configuration B corresponds to an extended configuration of the plant.