Improving the Production Process of a Bakery: A Simulation Approach

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Abstract. The present study brings forward a simulation-based study of the production process of a Portuguese bakery. The main goal is to analyse different production processes and propose improvements, through the use of discrete event simulation. A relevant set of data was collected, and four productive processes were selected to be modelled using Simio software (Simulation Modelling based on Intelligent Objects). The analysis of the developed models highlighted the need for improvements and different scenarios were created to this purpose. Among the obtained results, it was found that the adoption of mixed production scenarios allowed the increase of the production level while maintaining the current existing resources. In conclusion, this study highlighted the ability of the simulation technique to analyse manufacturing processes, throughout the creation of different scenarios, providing insights on the production process optimising the companies' productive performance.

Keywords: Manufacturing · Simulation · Bakery · Case study

1 Introduction

Bakery industry has continuously changed over the past 150 years and the common artisan bakeries are being replaced by the technological bakery industry [1]. The constant changes on the market, with the increase of products variety, leded to automation and the need for new manufacturing environments [2].

In the middle 1980's the concept of par-baked frozen bakery expanded and in the early 1990's this technology was improved. A par-baked bread refers to a product fully baked, but without a crust [1]. There are many companies seeking the introduction and modernisation of their production processes, like the par-baked technique, without losing the flavour and tradition of their products.

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Simulation is a powerful technique in decision- making enabling the analysis and evaluation of a wide range of complex scenarios [3]. It can be defined as a method that imitates all the operations and processes of a system, during a time period, allowing to comprehend and analyse the system's behaviour [4]. A simulation model should be as similar as possible to the real system. Thus, it is important to define the problem to solve and collect all the information and required data. Concerning the model itself it is important to: (i) choose the type; (ii) evaluate; (iii) build in some computer language; (iv) validate; (v) perform a sensitive analysis; and (vi) verify if the results are consistent and representative [6].

Because of simulation versatility, many studies are being developed using this technique. This study presents the development of a simulation model to reproduce the manufacturing environment of a Portuguese industrial bakery. The aim is to analyse and improve some of the production processes. In particular, the analysis was performed in order to find alternatives to solve:

- the company is exceeding the production capacity of the daily working shift to meet the demand;
- due to the new production process implemented (par-baked process) and to the new production line configuration, the workers do not have standard times for their tasks;
- with the increasing number of orders it is increasingly difficult to meet the market's demands.

This work is organised into six main sections. The next section presents a brief literature review. Afterwards, in Sect. 3 we present the case study under analysis. A brief description of the company is presented, and the topic is contextualised and the production processes are described. In Sect. 4 we describe the methodology used to the development of the simulation models. Simulation results and a discussion are shown in Sect. 5 and, finally, conclusions are presented in Sect. 6.

2 Literature Review

The use of simulation technique is increasing due to its many benefits. As a result, managers are integrating simulation in their regular operations on an increasingly basis [7]. Simulation optimisation aims to identify the best input system' parameters considering all the possibilities. Its main objective is to minimise the consumed resources and, at the same time, maximise the obtained information in a simulation experiment [8]. Nowadays, computer simulation became a powerful tool for model and analysis of companies' performance [9]. Simulation technique allows to create mathematical and logical models to describe the behaviour of a system during a period of time [10].

Müller et. al [11] used the simulation software Arena to improve a productive real flow. According to the production phases two different scenarios were considered. Both scenarios were simulated and compared with the real system.

Results showed that it was possible to increase the productivity of the production line in both scenarios. Hassan and Abdelsalam [12] conducted a pioneer study using simulation. Using Simio software, the authors analysed the behaviour of a supply chain of the contraception methods for Egypt Ministry of Health. Loaiza, Sarmiento and Correa [13] developed a study using the simulation software ProModel aiming to increase production of an existing system. A flexible manufacturing cell was evaluated, in order to identify the best alternative to maximise the use of the available resources.

There are many possibilities when the subject is software packages and their popularity is increasing because of the many applications in reproducing engineering and management systems [14]. Nowadays, a wide variety of discrete simulation software are available. Among the most used softwares one can mention ARENA, ProModel, FlexSim, Simul8, WITNESS, ExtendSim, Plant Simulation, Simio, etc. [15].

In the next section a case study aiming to optimise the production process through discrete simulation, using real data is presented. The study was performed using Simio software. This simulation tool allows the creation of new objects with complex behaviour and it is possible to model discrete and continuous systems [16].

3 Case Study

The company "Pão de Gimonde" is located in the village of Gimonde, Bragança, Portugal. The company's mission is to recreate the tradition of artisan breads like in the old days. Among the different products of the company it is possible to highlight: wheat bread, rye bread, fig bread, and "bijou" bread.

Nowadays the company works in two working shifts. The first working shift works during the night and produce fresh products (breads) ready for distribution in the early morning. The second working shift starts at 8 a.m. and produces bread according to the new production process of par-baked breads. Nevertheless, on this study only the day shift will be analysed, since it is the one in expansion and with more needs to be improved.

After the introduction of the new par-baked products on the market, the demand have increased substantially, and often the eight-hours workday is not enough to complete the required production. As production cannot be stopped, due to the specific production process, the company use overtime production, resulting in extra hours to be paid.

Taking into consideration the actual production context, a simulation of the production system was performed. First illustrating the current reality, and then, different scenarios were tested with the main focus on adapt the actual production level to one shift of work. If this is not feasible, due to the configuration of the production, finding a solution to maximise production level that may reduce extra hours of work will be required. The four production processes included in this study will be described in the next section.

4 Modelling and Simulation

The development of the simulation model was divided into four main steps:

- Step 1: Evaluation of the manufacturing processes for the different products. The processes were studied and the manufacturing process workflows (flowcharts) were created to detail the activity-level steps that must be completed to produce finished products.
- Step 2: Data collection. Necessary data was collected during some visits to the company, and/or was available in the company.
- Step 3: Development of the simulation model. Taking into account the collected data, and using the developed simulation model, each production process was represented and evaluated.
- Step 4: Validation of the simulation model. The developed model was tested to confirm if it correctly represents the reality of the manufacturing processes. For that purpose outputs were produced and compared with the real activity of the company.

Then, for each product, alternative scenarios have been created in order to identify possible improvements in the current manufacturing process. The scenarios that have been studied will be described in Sect. 5.

4.1 Fig Bread Manufacturing Process and Model

To better understand the production process of the fig bread, a flowchart has been created to identify all the necessary manufacturing steps. Data collection was obtained by observing all the production steps and using the fly back method of a stopwatch time study. Then, processing times have been placed on the respective model equipment's and the entity movement logic was created. The production process of the fig bread was modelled and validated in order to check if the model is functional, and represents the production reality. Model's validation was performed checking all the entity paths, the processes times and sequences, and the entity behaviour during a time period of a working day. Then, it was verified if the created model matched with the observed reality during the data collection time period. After the verification phase the developed simulation model was validated. The production of the fig bread was simulated and the output produced by the model was compared with real production level of 477 units. Multiple replications were carried out and the maximum percentage of error obtained was 0.75%. So, it is possible to conclude that the simulation model may be considered valid and correctly represents the fig bread production process.

4.2 Wheat Bread Manufacturing Process and Model

The wheat bread manufacturing process was also illustrated in a workflow to better describe the production process. For this process, the data for the different processing times were provided by the company. For this reason, they were considered reliable and representative of the reality of the company. The verification of the model was also performed to attest its functionality. During this step it was possible to certify if the process is being performed according to the reality and if the model works properly. To verify the simulation model, all the entity paths, the processes times and the entity behaviour were checked during a working day period. After that, it was possible to confirm that the model presented the expected behaviour, similar with the reality of the production line. After the verification of the model, the next step was the model validation. The model was simulated and multiple replications were carried out. Again, the model's output was compared with the quantity of wheat bread produced by the bakery. The higher verified percentage error was of 0.74%. Therefore, it is possible to conclude that the model may be considered valid and correspond to a correct representation of the wheat bread production.

4.3 Rye Bread Manufacturing Process and Model

The production process of the rye bread is very similar to the production of the wheat bread. Also, the data processing times for the rye bread were provided by the company. As such, they were considered reliable. The verification of the rye bread model was also performed to certify that the processes is according with the reality and if the model works properly. The model was ran and all the entity paths, the processes times and the entity behaviour were checked during a working day period. It was possible to confirm that the model presented a behaviour similar with the real production level. Due to validation purposes, the model was simulated and multiple replications were carried out. Again the model's output was compared with the real production level. In this case the higher percentage of error achieved was 0.184%. Therefore, it is possible to conclude that the model is valid and correspond to a correct representation of the rye bread production.

4.4 Bijou Bread Manufacturing Process and Model

The bijou bread is a typical bread consumed in Portugal. The production process of the bijou bread is slightly different from the production processes of the wheat and rye breads, since this variety of bread is always packed and shipped fresh. As for the wheat and rye breads the data of the processing times was provided by the company. Consequently, they were considered reliable. This production process was simulated and the verification of the model was performed to verify if the model works properly, and if the process is being modelled according to the reality. It was possible to verify that the developed model has a similar behaviour to that of the real production line. Model's validation was made simulating a daily working shift. In all the performed replications the production level of 1080 units of bijou bread was reached. Thus, the developed model may be considered valid and representative.

5 Simulation Results and Discussion

In this section the results of the developed simulation models are presented and discussed. Our aim is to analyse the production system behaviour and identify new production strategies. First single productions of all the four products were tested (fig bread, wheat bread, rye bred, and bijou bread). Then, simulation models were developed regarding mixed-production scenarios, where more than one product were produced in a daily shift. Six distinct scenarios were considered: (i) bijou and wheat bread; (ii) bijou and rye bread; (iii) bijou and fig bread; (iv) rye and wheat bread; (v) rye and fig bread; and (vi) wheat and fig bread.

The company's working shift is 8 h long. Nevertheless, it can be of 9 h if we consider the lunch break hour. During this time the employees are not working. Nevertheless, this time is useful in the production process, because the products are on the cold chambers. For this reason, in productions scenarios where the final product is frozen (fig bread, wheat bread and rye bread) the working shift is considered to have 9 h and in what concerns fresh products (i.e. bijou bread) the working shift has 8 h long. For the scenarios involving wheat bread we will consider that the shift begins at 3a.m. resulting in a 14 h shift. This is possible because a "fermentation" activity occurs during six hours and without the workers intervention.

The obtained results are shown in Table 1. It is possible to mention that, with exception of Scenario 5, if the company starts using a mixed-production strategy it is possible to, at least, duplicate the daily production in all the considered scenarios without exceed the working shift. Actually, and considering the production of single products, the company produces 500 units of fig, wheat or rye breads, and for the bijou bread 1080 units.

Table 1. Mixed Scenarios Production Level.

Scenario	Description	Production level
Scenario 1	Bijou + Wheat Bread	1580 units
Scenario 2	Bijou + Rye Bread	1580 units
Scenario 3	Bijou + Fig Bread	1580 units
Scenario 4	Rye + Wheat Bread	1000 units
Scenario 5	Rye + Fig Bread	973 units
Scenario 6	Wheat + Fig Bread	1000 units

In an attempt to increase the production level the dough's proportion was increased. Using this approach, six new scenarios (see Table 2) were created, where the dough proportion for each product was incremented. For example, in Scenario 8 it was considered an increment of 40% on the bijou dough and of 20% on the rye bread dough. Simulation's results highlighted the increase of the production level. Scenario 7 is the one with higher production level (2512 units) being produced 1512 units of bijou bread and 1000 units of wheat bread.

Table 2. Mixed Scenarios Production Level: After Increasing the Recipe.

Scenario	Description	Production level
Scenario 7	1.4xBijou + 2xWheat Bread	2512 units
Scenario 8	1.4xBijou + 1.2xRye Bread	2112 units
Scenario 9	1.2xBijou + 1.1xFig Bread	1850 units
Scenario 10	1xRye + 1.4xWheat Bread	1200 units
Scenario 11	0.96xRye + 1.02xFig Bread	990 units
Scenario 12	1.6xWheat + 1.09xFig Bread	1345 units

Note that scenarios where the bijou bread is involved have a final production bigger then the others. This happens due to the fact that bijou is a fresh product and it does not passes through the cold chambers, and also because the recipe of the bijou bread generate more units. Scenarios 10, 11 and 12 have reached lower production levels. This happens due to the fact that both products use the cooling chambers. This process narrows production level because of the smaller capacity of the cooling chambers. Finally, it is possible to highlight that even in Scenario 7, the maximum percentage of the processing time do not exceed 42.74%, which may be considered a low percentage.

6 Conclusions

This work aimed to analyse the production processes of an industrial bakery. The main goal was to study possibilities of increasing the production level to face the external increasing demand. Using Simio software, simulation models were developed to reproduce the production process of four product types: fig bread, wheat bread, rye bread and bijou bread.

A total of twelve scenarios were considered. The outputs of all scenarios showed that it its possible to face the increase of the external demand with the company's actual resources. In fact, it is possible to, at least, double the production level if the company adopts a strategy of mixed-production instead of a single item production.

In summary, the gathered results showed that changing the production strategy, it will be possible to increase the production level to face the external demand using the current existing resources.

As future works, it is possible to expand the developed simulation model, considering mixed-production of new product types, and explore different scenarios. Also new simulation models involving new production processes and or new production layouts may be developed and analysed.

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