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A NEW METHOD FOR PRODUCTION DEVELOPMENT

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Abstract: This paper introduces a new method for production development with the usage of process observation, fuzzy logic, and sensoring. In collaboration with experts in the field of food science, design, a program was developed that can simulate the behaviour of a semi-finished product during preparation. A factory producing bakery products applied sensors in order to gain real-time data that can be integrated into the program. Because of all the uncertainty of a preparation process, the optimal baking temperature and time are different in each package of the product. With the previously mentioned program, it is possible to provide the optimal values for each package.

Keywords: *Bakery product, production development, programming, fuzzy logic*

1. Introduction

This article is dealing with production development in the field of semi-finished bakery products. Several factors influence the dough quality. Bakeries sometimes achieve poor dough quality during mixing, which can be caused by biological (yeast), chemical (enzyme reactions, oxidation/reduction) and physical (water movement) process as well [1].

Because of the possibility of the variable semi-finished product, the goal of the system developed by us is to equalize the mistakes by the optimal baking temperature and time that will set by the user. If the production lines are fully examined by sensors, the exact values are known, and it is possible to conclude to other values. Similarly to an equation, if we know the perfect cake shape, taste, etc. as an output, and the input parameters (temperature, time and mass data of the ingredients) except for the final baking time and temperature, the missing parameters can be defined. For the background operation, a fuzzy logic-based system was developed that contains the rules between the input and output parameters. Fuzzy logic is one of the Artificial Intelligence (AI) tools [2]. By applying AI to model the process and develop the system is nowadays a viable solution in the baking sector [1] [3].

In this study, the goal is to create the best-prepared products with the help of sensors and mathematical programming. The hypothesis states that it is possible to model the behaviour of the preparation process with a mathematical method that could provide the required data – for the finishing phase – for end-users. With this data – optimal beaking temperature and time – the consumer is able to finish his product in the best way.

2. Material and method

During the test, products with different parameters were baked, and later the participants were rating the products in five categories (Shape, Shell, Inner structure, Smell, Taste) from 0–5, where zero meant "not appropriate at all", and five was considered "excellent". Some of the baked cakes (scones) are shown in *Figure 1*. These had to be evaluated by the participants.

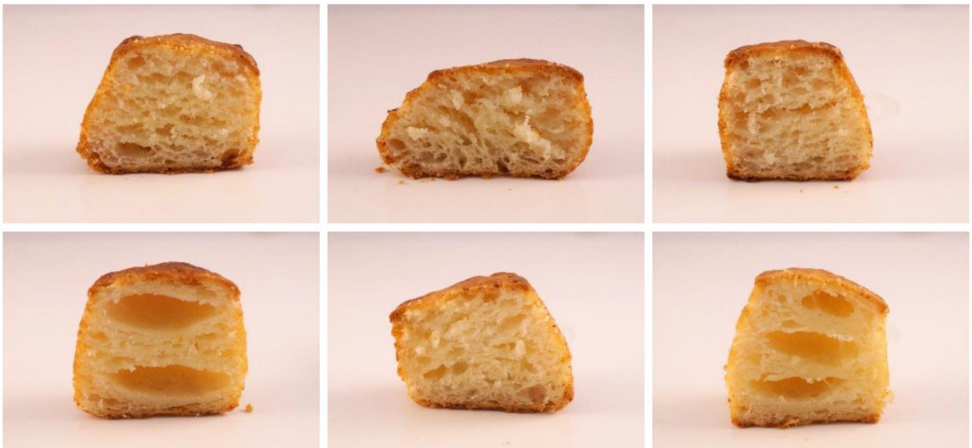

Figure 1
Different baked cakes

In total, 20 participants contributed to the examination as reviewers: 16 women, 4 men. The average age is 27.6 years old. From the members, 15% is a smoker, 85% is a non-smoker. The highest education level for 60% of the people is graduation, 30% have finished a university, and 10% have a Ph.D. degree. 65% of the participants are live in the countryside, 35% of them in the capital.

The program's validation happened by the valuation of test bakings results, which is presented in the "Results" section. With this test, it can be proved that the result of the baked product is predictable according to the input parameters (such as the temperature of the commodity, the mass of the product in different stages, and so on).

Figure 2 shows the detailed workflow of this research. This article is mainly dealing with the 1 and 2 tasks of the workflow. The 3 and 4 parts will be introduced in detail in the near future.

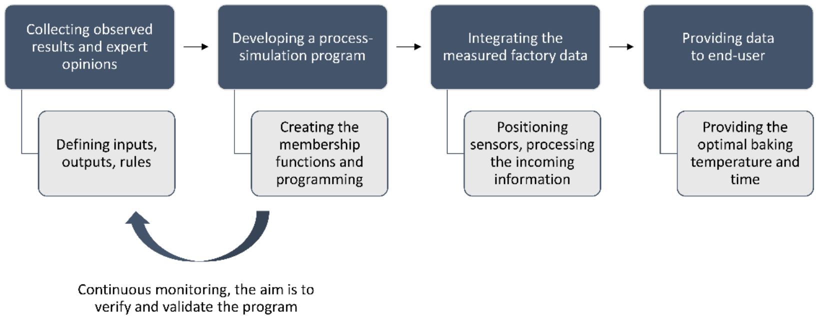

Figure 2
The workflow of the new method for production development

1. Collecting observed results and expert options:
   Continuous data gaining process was applied while the experts provide information about the input and output parameters, and also about the rules that define the effect of inputs or combination of inputs on the outputs.
2. Developing a process-simulation program:
   In the previous phases of this project, considerable mathematical methods were examined; for instance, neural network, genetic algorithm, and fuzzy logic. It turned out that fuzzy logic is the most suitable method for this task [4]. We used Matlab software in order to develop a fuzzy system.
3. Integrating the measured factory data:
   In collaboration, a semi-finished bakery product factory has applied sensors to all the important states of the production line. (For example to the storage area as visible on *Figure 3*.) The sensors are sending measured values that could be integrated into the program as inputs. Since the rules are already set, the software can automatically provide the required data regarding the baking temperature and time.
4. Providing data to end-user:
   The consumer will get this information on the package of the product.

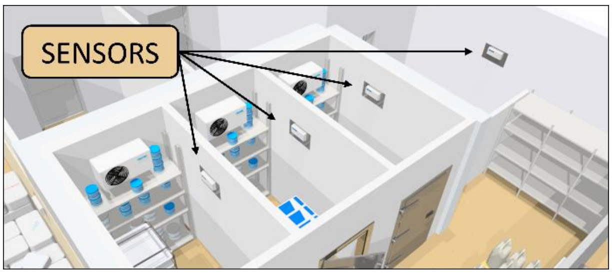

Figure 3
Model of a storage part with sensors

The input parameters are all of those parameters that have an impact on the quality of the final product. All parameters can have low, medium, and high values, that were defined according to measurements in the factory and also by the opinion of experts. The input parameters were already published in a paper by the authors [4]. Defining the output values is a much more complicated task because there is no exact data that can help. Since in "scoring sensory judgment and rating" [5] the researchers use five groups: Shape, Shell, Inner structure, Smell, Taste, we distinguished these categories as well. Since the evaluation of these categories ranges from 0–5 during the study the same ranking was also applied in the mathematical model, as shown in *Table 1*.

Table 1
Output data

	Parameters on 0–5 scale		
Shape	0–1 Flat	3–4 Deformed	5 Correct
Shell	0–1 Burned / Raw	2–3 Vesicular	4–5 Correct
Inner structure	0–1 Hollowed / Solid	2–3 Friable	4–5 Correct
Smell	0–1 Not appropriate	4–5 Correct	
Taste	0–1 Raw / Foreign taste / Salty	4–5 Correct	

The membership functions were created by *Table 1*. As an example of that, *Figure 4*. presents the membership functions of Shape, where the blue function represents the parameter of flat, red is the deformed and yellow represents the correct value.

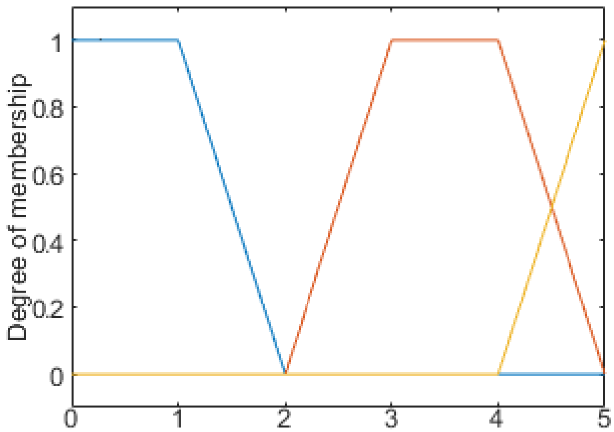

Figure 4
Membership functions of Shape

3. RESULTS

The validation of the program happened by the valuation of test bakings results. The following input parameters were defined as variables, while the others were fixed in the measurement:

– Rising Temperature [°C]
– Time of Rising [min]
– Baking temperature [°C]
– Baking time [min]

Table 2

Introduction of one of the test results

Shape						**Shell**						**Inner structure**						**Smell**						**Taste**						**Cumulative value**	**Evaluation**
0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5	0–20	*
					15						15	1			6		8						15						15	18.64	Excel-lent

Table 2 shows the table that helped to collect the data, and there is an example as well. At this specific example, the following variable inputs were used:

– Rising Temperature 40 [°C]
– Time of Rising 20 [min]
– Baking temperature 215 [°C]
– Baking time 6 [min]

During the testing procedure, the following weighting factors were applied. These factors were defined by the expert of this project.

– Shape 0.6
– Shell 0.6
– Inner structure 1.2
– Smell 0.6
– Taste 1.0

The calculation procedure:

1. A given score multiplied by the corresponding number of pieces.
2. E.g., at Inner structure:

$$0 \cdot 1 + 3 \cdot 6 + 5 \cdot 8 \quad (1)$$

3. A given category multiplied by a weighting factor. E.g., at Inner structure:

$$(0 \cdot 1 + 3 \cdot 6 + 5 \cdot 8) \cdot 1.2 \quad (2)$$

4. Sum up of the numbers above.
5. Divide by the number of samples (here 15) due to averaging.

The number in the cumulative value column is used to compare the results of the mathematical model, where we also weighted the values with the same weighting factors.
The evaluation section used the following states. (*Table 2* * sign)

- 0–11 Not appropriate at all
- 11–13 Not appropriate
- 13–15 Medium
- 15–18 Good
- 18–20 Excellent

The mathematical model was built up with the input parameters, with the output parameters *(Table 1)* and with the rules that define the behaviour of the product in different levels of the preparation process. During the validation process, the mathematical model and the actual test had the same input parameters, and if the cumulative values were mainly close, we could say that our hypothesis is correct.
In total, 16 input parameters (12 fixes and 4 variable), 5 output parameters, and 34 rules were defined in this experiment. In the baking process, 15 cakes were baked at a time, all in all on 13 occasions. The cakes were rated according to their shape, smell, inner structure, smell and taste. The test results were compared to the Matlab model, that showed the same group (not appropriate at all, not appropriate, medium, good, perfect) in all cases. *(Table 3)*

Table 3

Comparison of Experiment and Matlab results

Rising Temp. [°C]	Time of Rising [min]	Baking temp. [°C]	Baking time [min]	Evaluation EXPERIMENT	Evaluation MATLAB
40	20	200	5	Excellent	Excellent
40	20	200	7	Excellent	Excellent
40	20	230	5	Good	Good
40	20	230	7	Good	Good
40	20	180	2	Good	Good
40	20	180	12	Good	Good
40	20	250	2	Good	Good
40	20	250	12	Not appropriate	Not appropriate
40	20	215	6	Excellent	Excellent
20	5	215	6	Medium	Medium
20	35	215	6	Good	Good
50	5	215	6	Excellent	Excellent
50	35	215	6	Excellent	Excellent

It means that a fuzzy system could estimate the output of the baking process, that saves a lot of time and resources.

4. Conclusions and further research

The goal of this research was to create a fuzzy logic based Matlab model that can simulate a baking process of cakes. In the first step, we gained data from experts in order to define the input, output parameters, and the rules between them. With the first test round, the model resulted in very near values, and all of the evaluation groups were the same. The results of this research prove that the fuzzy system could estimate the baking process's output, which means it could replace tests in different situations. It is easily can be adapted to other environments by change the inputs and outputs parameters.

In the near future, information about the factory process will be collected. These data will be integrated into the model, that is why it will be possible to estimate the semi-finish product's optimal baking time and temperature, that will be placed on the package by label, as shown in Figure 5. This information will automatically be updated based on the collected sensor information analyzed by the fuzzy system.

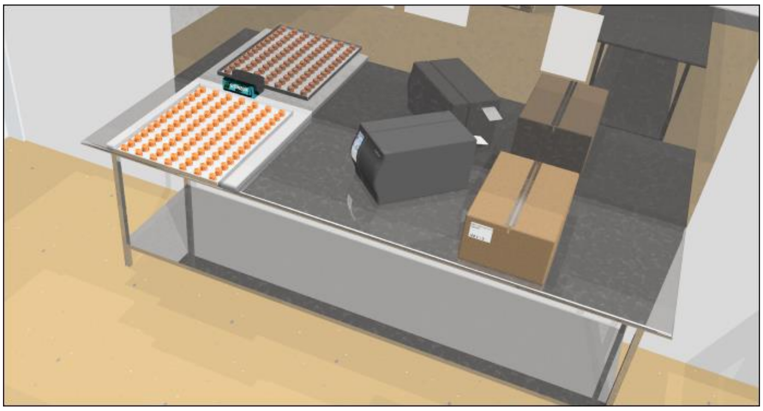

Figure 5
Model of a product package

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