MATHEMATICAL BACKGROUND OF THE DEVELOPMENT OF BAKERY PRODUCT PRODUCTION

SÜTŐIPARI TERMÉKEK GYÁRTÁSÁNAK MATEMATIKAI HÁTTERE

Laura Trautmann PhD student, Attila Piros, PhD associate professor,
János Péter Rádics, PhD senior lecturer, Department of Machine and Product Design
Faculty of Mechanical Engineering Budapest University of Technology and Economics;
Katalin Badak- Kerti, PhD associate professor, Department of Grain and Industrial Plant Processing
Faculty of Food Science Szent István University;
Róbert Berényi, Slopmax Ltd.; Gábor Héber, Pr1mer Ltd.

ABSTRACT
Based on the literature research, fuzzy logic is the most effective mathematical method that can be applied to this task, where the goal was to create smart products from semi-finished bakery products. In order to specify input parameters, first of all we collected the aspects that could affect the quality of the final product (e.g. environmental aspects, ingredients, etc.). For these factors, we have assigned low, middle, and high values in order to create membership functions. The determination of the output values will be finalized according to the method of evaluation of the end product, however during the trial run, six aspects were distinguished. After creating the output membership functions, the goal was to set the fuzzy rule system up. The rule system will be expanded based on expert opinions. Subsequently, we can associate the given outputs with the given inputs during the defuzzification (bisector type).

1. INTRODUCTION

Semi-finished bakery products nowadays have great interest among customers. The reason behind this is that they can be made quickly and easily, they are also affordable and tasty. These advantages distinguish these kind of products from the competitors.

The aim of this project is to turn these into smart products, making them even easier to prepare, improving their quality while keeping them affordable. This can be achieved by examining the production process, documenting and storing as many conditions as possible. Among other things, the production line was modeled (Figure 1), and sensors were placed between the operations.

Our hypothesis is that the production data - with the help of an algorithm - provides information to the user about the preparation details of the product. Basically we would like to place unique baking information on each package of the product in order to guarantee the best quality of the unit. By applying these recommendations, it can be ensured that we always produce the best quality.

Figure 1: Parts of the production line

The main tasks for our goal is to

- collect mathematical methods, which are suitable for determining the relationship between the many input and output data in order to define the baking temperature and time required for the final preparation
- collect and categorize the quality influencing factors of a product
- model the effect of factors

2. MATHEMATICAL METHODS

Since often there are no clear physical relations between the input parameters and the results, parameters should be weighted according their effects on output data. Besides that, the data mostly uncertain, because of which it is advisable to use soft computing methods during calculations.

Soft computing methods represent a relatively new area, that is currently also one of the most researched part of mathematics. The applications of soft computing methods are very wide, often used in various simulation tasks, in order to describe and optimize complex systems. There are three main areas of soft computing [1]

- Neural network
- Genetic algorithm
- Fuzzy logic

The neural network method is not fully suitable for solving the given problem, since a lot of data is needed to set it up. Another problem is that we need to have a built-in fault in order to provide sufficient amount of data for teaching and control operations. This is not a fesable option as all the products that are manufactured should meet certain consumer protection standards.

Although the method of genetic algorithm would be suitable for solving our problem, it is very complex, and many populations are needed. In order to get accurate results, we should develop at least 1 million generations, which is time-consuming.

Fuzzy logic is the most suitable soft computing method for our task. Compared to the other two methods, much less computational capacity is required, functions can be built from few the available data we have at our disposal. Because of these factors, fuzzy logic is used to solve our task.

3. QUALITY INFLUENCING FACTORS OF BAKERY PRODUCTS

First of all the manufacturing process of two products (scone, cocoa roll) were examined. In addition to the description of the manufacturer's technology, control points have been selected for the task, which can be used to measure the relationship between the production parameters and the quality of the finished product.

4. MODEL OF THE FACTOR-EFFECTS

According to the literature review, fuzzy logic is the most suitable method for solving this task. To build the fuzzy model, Matlab 2018b software was used.

The steps of mathematical modelling:

1. Providing input and output parameters
2. Creating input and output membership functions
3. Defining fuzzy ruleset
4. Defuzzification

4.1. Providing input and output parameters

The collected food and health factors (such as environmental aspects, ingredients, etc.) and technical and production technology aspects were all provided by the participants with lower and upper values based on the measurements and expert estimates. Among these, the aspects that were included in the mathematical model were selected.

Input parameters:

- Temperature of flour (°C)
- Temperature of kneading water (°C)
- Temperature of butter (°C)
- Temperature of margarine (°C)
- Temperature of kneaded dough (°C)
- Temperature of stretched dough (°C) [before ripening and cooling]
- Temperature of ripe dough (°C)
- Time of ripening (h)
- Temperature of stretched dough (°C) [after ripening and cooling]
- Temperature of filling (°C)
- Temperature of dough before leavening (°C)
- Temperature of dough after leavening (°C)
- Time of freeze shock (minutes)
- Temperature of freeze shock (°C)
- Mass of unfilled, raw roll (g)
- Mass of filled, before leavening (g)
- Mass of filled, after leavening (g)

Output parameters:

- End product colour component (Red)
- End product colour component (Green)
- End product colour component (Black)
- Mass of end product (g)
- Texture of end product
- Appearance of end product

(These parameters will depend on the methods used to evaluate the samples.)

4.2. Creating input and output membership functions

In this chapter, the parameter “Cottage cheese temperature” is presented. Other aspects were created following a similar approach.

The cottage cheese temperature is low at 0 degrees, optimal between 3 and 5 degrees and high at 9 degrees. There are three functions for each parameter: a low, an optimal and a high value.

You can specify a function with

- Name
- Type
- and Parameters

In this research only triangle (tri) and trap (trap) forms were used.

All the features can be taken into account at the given temperature. For example, the cottage cheese temperature is 70% optimal and 30% high at 6 degrees. The membership functions of cottage cheese temperature can be seen at Figure 2.

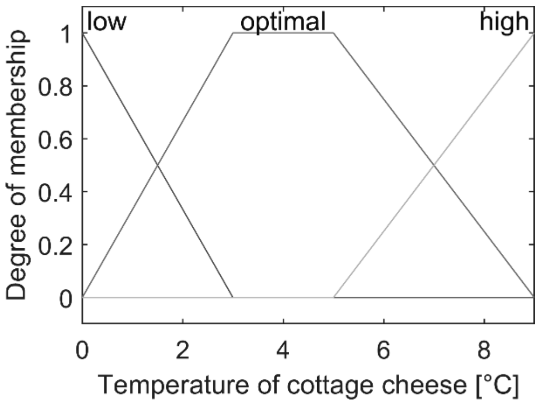

Figure 2: Membership functions – cottage cheese temperature

4.3. Defining fuzzy ruleset

Table 1 shows the effects of the parameters, collected by experts. These rules were used in the mathematical model.

Table 1: Fuzzy ruleset

Name	Value	Effect and / or Compensation
Temperature of basic material	High	Adding cooler cooling water
Intensity of kneading	High	Reduce kneading time
Intensity of kneading	High	Adding cooler kneading water
Intensity of kneading	Low	Increase the kneading time
Intensity of kneading	Low	Adding warmer kneading water
Time of mixing	Short	Solider dough structure
Time of mixing	Short	Pasta with uneven temperature distribution
Time of mixing	Long	Looser texture
Time of mixing	Long	Pasta temperature overheated
Time of mixing	Long	It requires a longer cooling time
Time of cooling	Little	Difficult to handle pasta
Time of cooling	Little	Solider dough structure
Time of cooling	Little	More time for cooling
Time of cooling	Many	Looser dough structure
Time of cooling	Many	Longer mixing time
Temperature of cooling	High	Difficult to handle pasta
Temperature of cooling	High	It requires cooler temperatures
Volume of folding	Many	Looser texture
Volume of folding	Many	Refolding is required
Volume of folding	Little	Solider dough structure
Volume of folding	Little	Refolding is required
Stretching thickness	Low	Low height finished product
Stretching thickness	Low	Less weight finished product
Stretching thickness	Low	Shorter cooking time and / or lower baking temperature
Stretching thickness	High	Higher end product
Stretching thickness	High	Higher weight of end product
Stretching thickness	High	Longer baking time and / or higher baking temperature
Dough temperature before leavening	High	Shorter time of leavening
Dough temperature before leavening	Low	Longer time of leavening
Dough temperature after leavening	High	Baking for shorter periods
Dough temperature after leavening	Low	Longer baking
Temperature of baking	High	Baking for shorter periods
Temperature of baking	Low	Longer baking / pre-cooking

Temperature of dough after baking	High	Longer shock time
Temperature of dough after baking	Low	Shorter shock time

4.4. Defuzzification

In the process, we get fuzzy aggregations, but we need a numerical value. The process of assigning values to output aggregation is called defuzzification. There are several types of defuzzification methods (Figure 3), of which the bisector type was used in this exercise, which divides the area under the function into two equal parts.

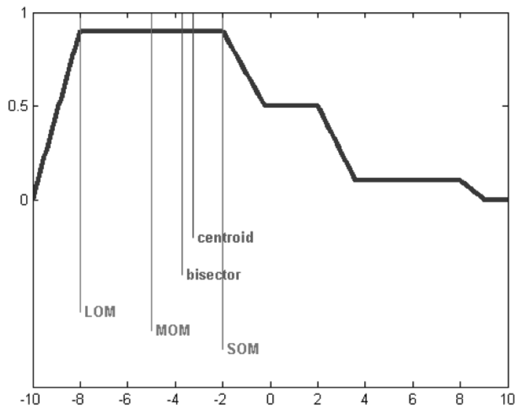

Figure 3: Defuzzification methods [2]

By defining four rules, the defuzzification in Matlab software can be seen on Figure 4. The six charts in the bottom right corner of the figure show the final result, the red lines indicate the location of the output number value.

5. CONCLUSION

Based on preliminary research and consultation with partners, the mathematical method was based on the fuzzy logic, where values were assigned to the factors in order to create membership functions. During the trial run, color components, mass, texture and appearance of the end product were modelled.

An important result of the research is that more variables give more accurate results. That is why the next step of this study the laboratory experiments, since with the measurement results we will be able to finalize the mathematical model and describe the final products optimal temperature and baking time.

6. ACKNOWLEDGMENT

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7. REFERENCES

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[2] MathWorks.„Defuzzification Methods.” 2018. www.mathworks.com

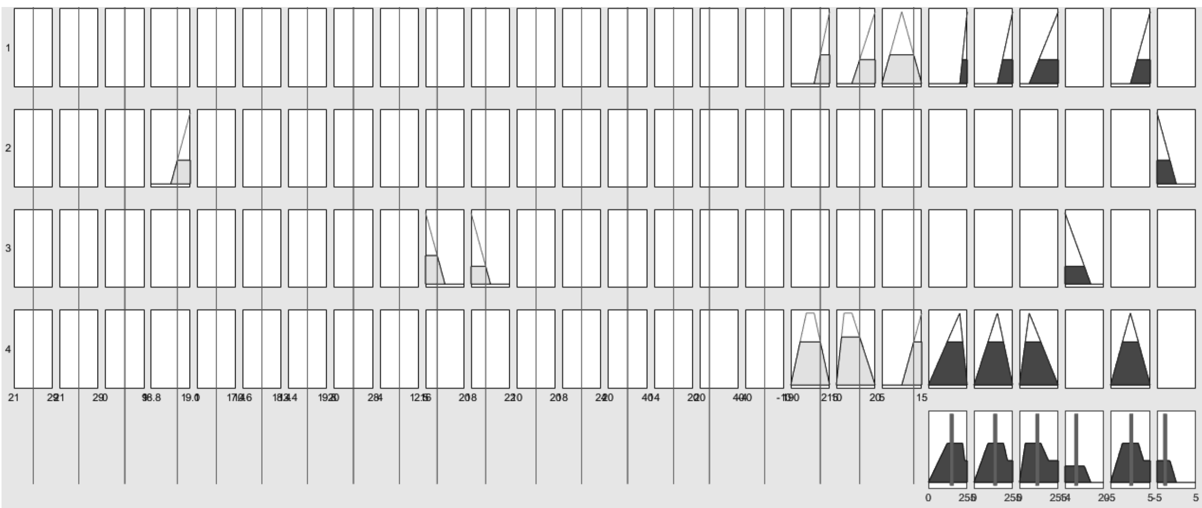

Figure 4: Defuzzification