

# MODELLING OF AN AUTOMATED FOOD QUALITY ASSESSMENT SYSTEM BASED ON FUZZY INFERENCE

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The quality of food and the issues of quantitative and qualitative nutrition, as well as the safety of food products, occupy an important place in the preservation of the population health. World Health Organization (WHO) considers the issue of food quality and safety as one of the priority areas in maintaining the health of consumers [1]. On the other hand, product quality is one of the main tools for the manufacturer to conquer the market. Therefore, issues of product quality assessment are extremely relevant.

The purpose of this study is to create a methodology for developing an automated system for assessing the quality of food products based on a comprehensive quality indicator and the use of fuzzy logic theory, namely, fuzzy inference. In our opinion, such an approach to quality assessment can reduce the subjective component that has a significant impact on making a final decision.

The mathematical apparatus of fuzzy sets and fuzzy logic, the founder of which is L. Zade, is designed to simulate the capabilities of human intelligence. Designing human approximate reasoning models allows us to make decisions based on information that is incomplete, fuzzy and/or with a large proportion of entropy.

The fuzzy inference system is currently one of the most applicable mathematical tools in decision theory [2]. The decision-making algorithm based on the use of fuzzy logic is as follows:

1. *Initial data*  $X = \{x_1, x_2, \dots, x_n\}$  *collection*, on the basis of which a decision will be made. Thus, this automated system will have  $n$  inputs and one output. Due to the specifics of the object of study, the initial data may be the results of laboratory measurements (for example, the content of nutrients, vitamins, harmful substances) as well as expert opinions based on organoleptic and laboratory indicators, packaging quality assessments, compliance with domestic and international standards, etc. Also, when using this methodology, it is possible to conduct a quality assessment for any single indicators, and not to take into account all indicators at once.

2. *Fuzzification of input variables*. That is, finding the correspondence between the crisp numerical value of the input variable and the value of a term of a linguistic variable membership function. To create an assessment using a comprehensive quality indicator,  $n$  linguistic variables must be defined. Each linguistic variable  $A_i$  ( $i = \overline{1, n}$ ) will be characterized by four linguistic terms  $\alpha_{ij}$  ( $i = \overline{1, n}, j = \overline{1, 4}$ ), which correspond to qualitative assessments “unsatisfactory”, “satisfactory”, “good”, “excellent”. Each term  $\alpha_{ij}$  will be described using a fuzzy set  $\alpha_{ij} = \left\langle x_i, \mu_{\alpha_{ij}}(x_i) \right\rangle$ ,  $i = \overline{1, n}, j = \overline{1, 4}$ , where

$\mu_{\alpha_{ij}}(x_i)$  is the value of membership function of  $x_i$  in the term  $\alpha_{ij} \in A_i$ , each of values  $\mu_{\alpha_{ij}}(x_i)$  maps each element of the set  $x_i \in X$  to a real number from the interval  $[0,1]$ .

To determine values of membership functions, there are direct and indirect methods [3]. Generally, direct methods are used for measurable concepts (for example, the amount of nutrients, micronutrients), and indirect methods are used for concepts that are difficult to measure (for example, color, taste quality of a food product).

3. *Formation of the rule base* of the fuzzy inference system. Such a base is a formalized reflection of experts' knowledge and is presented in the form of fuzzy production rules  $R = C \rightarrow D$ , where " $\rightarrow$ " is a symbol of fuzzy implication. For this task the right (antecedent) part of each rule will be represented by composite logical fuzzy statements, i.e. simple fuzzy statements are connected by fuzzy conjunctions, that is, we have  $i$  rules of the form:

$$R_i: \text{if } x_1 \text{ is } \alpha_{i1} \text{ and } \dots \text{ and } x_n \text{ is } \alpha_{in} \text{ then } y \text{ is } \beta_i,$$

where  $i = \overline{1, m}$ ,  $m$  is number of rules in the database;  $x_j$ ,  $j = \overline{1, n}$  are input variables;  $y$  is the output linguistic variable;  $\alpha_{ij}$  and  $\beta_i$  are the membership functions defined respectively on  $x_j$  and  $y$ .

4. *Fuzzy implication*. In this step values of the degree of fulfillment of fuzzy premises apply to the fuzzy conclusions for each rule. As a result, we get one fuzzy subset for output  $y$ . For this task the Mamdani's implication (i.e. using of *min* operator) is proposed. This actually is a "cut-off" in height of the membership function of the output at a level corresponding to degree of fulfillment of the antecedent part of the rule.

5. *Composition*. The formation of one fuzzy set by connecting all the fuzzy subsets for each output obtained on step 4. We also consider the composition according to Mamdani with the use of *max* operation. It means that resulting set obtains by taking pointwise maximums over all fuzzy subsets for output.

6. *Defuzzification* (obtaining crisp values). There are sufficient number of methods for this step – center of gravity (COG), mean of maxima (MOM), first of maximum (FOM), largest of maximum (LOM). Despite the fact that the COG and MOM methods are the most frequently used, choosing the actual method to obtain an adequate value can become an independent task that require a systematic approach.

The system, built on a given algorithm, allows us to assess the quality of food products, taking into account the data of laboratory studies on measurable quality indicators and expert opinions on difficult to measure indicators.

## References

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