Intelligent Modeling for the food chain using Fuzzy Cognitive Maps

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Abstract. The development of a methodological framework for evaluating the quality of a "product" on a food chain is an important issue for managing agriculture applications. This paper addresses this issue from an intelligent point of view. In this research study, the methodology of Fuzzy Cognitive Maps is used. The farm product of milk is used to implement it on the generic approach just described. Simulation studies are performed, and the results are presented in the paper. Discussion of the promising results is discussed, and future research is presented.

Keywords: Fuzzy Cognitive Maps, Food Chain

1 Introduction

Milk stands out among other animal and vegetable foods because it is the only food for humans from the initial stage of their life. From this, it is concluded that milk contains all the required ingredients (especially proteins and salts) for an organism to grow. In this context, the importance of this food is emphasized and, by extension, the need for an objective and standardized standard for evaluating milk quality.

Before formulating the evaluation method, the exact parameters affecting the milk quality must be defined. At the same time, they will also be the subject of analysis. The entire production process is initially divided into three (3) basic steps:

- Milk collection, where the milk is collected from the animals,
- Milk processing, which includes all the individual processes required to upgrade the quality of the raw material,
- Packaging and distribution is the transfer of milk to the final consumers.

The main objective of this research is the systematic examination of all main processes that make up this complex process and, at the same time, the consideration of a model for the evaluation of the quality of the "product", considering the "intelligent modelling" of the quality of all the individual stages of the agricultural process in delivering a high quality "product" to the customer. In the present paper, we address the issue of milk quality assessment based on Fuzzy Cognitive Maps.

2 Methods

For evaluating and extracting the quality index, the intelligent control technique is used as a non-parametric method for managing the data that make up the final decision. Intelligent Control [1] results from applying computational intelligence in system control. It addresses the problem of Control from a distinct perspective from the conventional control model. Knowledge and experience of experts form the core of the process and are the basis for the learning method that makes up the control model. The objective of an intelligent controller is its function like the human operator, with the same rules but without its weaknesses, while avoiding non-consistency so that there is a uniform and standardized framework for managing the parameters that lead to the final solution.

We propose an FCM [2] approach. FCMs are a soft computing modelling methodology representing complex problems in graphs. The experts and the engineers define the input and output concepts of the system. They also define the weights that represent the relationship between the system's concepts. This relation is initially described verbally. FMCs may, therefore, embody human knowledge. FCM involve concept value updates that reflect the disturbances caused by one concept to another. An intelligent formula is used to calculate the value of each concept during the process. This formula is analytically described in [3–5].

In the present work, the input concepts are defined according to an extensive literature review and are as follows:

C1: Nutrition of dairy animals, C2: Receiving raw milk, C3: Milk conservation, C4: Homogenization of raw milk, C5: Pasteurization of raw milk, C6: Milk Storage in the Central Unit, C7: Milk packaging for distribution, C8: Distribution of Milk for final consumption, C9: Workforce and impact on the final product, C10: Milk quality. The potential values of each concept and their fuzzy expressions are presented in **Table 1**.

Table 1. Potential concept values

Concept	Quantifiable factor	Possible values	Fuzzy value
C1	Quantity (raw material the amount of feed kg/100 kg animal)	0-1, 1-3, 3-4	Low, Medium, High
C2	Temperature indicator during product transport	<6, 6-8, >8	Low, Medium, High
C3	Unit/Hours of product staying in the tanks	<48, 48-72, >72	Low, Medium, High
C4	Pressure indicator during product homogenization	<4, 4-15, >15	Low, Medium, High
C5	Temperature unit during pasteurization of the product	<85, 85-95, >95	Low, Medium, High

C6	Unit/Hours of product staying in the tanks	<8, 8-12, >12	Low, Medium, High
C7	Packaging Type	Plastic, Paper, Glass	Low, Medium, High
C8	Unit/ Days product stays in distribution	<1, 1-3, >3	Low, Medium, High
C9	Quantity of Workforce	Limited, Adequate, Complete	Low, Medium, High
C10	Milk Quality		Very Low, Low, Medium, High, Very High

One expert assigned verbal weight expressions for each concept, as seen in **Table 2**.

Table 2. Weights of the proposed FCM. VS: Very Small, S: Small, M: Medium, S: Strong, VS: Very Strong, 0: no connection

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
C1	0	VS	0	W	W	0	0	0	VS	VS
C2	W	0	VS	M	M	S	0	VS	S	W
C3	VS	S	0	M	M	S	S	W	0	S
C4	S	W	S	0	VS	S	W	0	0	S
C5	S	W	VS	VS	0	S	W	0	0	VS
C6	0	W	S	VS	VS	0	W	0	0	M
C7	0	W	W	0	0	0	0	VS	S	S
C8	0	S	0	0	0	S	W	0	M	M
C9	0	S	W	0	0	W	VS	S	-	W
C10	0	0	0	0	0	0	0	0	0	0

The verbal weights are transformed into numeric values using the methodology presented in [6, 7].

3 Results

In the present section, we provide an experimental case to inspect the stability of the presented model. **Table 3** summarizes the input concepts' values for the simulation.

Table 3. Experimental case scenario

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Low	Medium	High	Medium	High	Medium	Low	Medium	High

After four iterations, the model reaches a stable condition, wherein the values of the concepts are no longer updating. This process is visualized in **Fig. 1**. The value of the output concept is 0.9984, which represents a very high-quality condition of the milk. The developed FCM greatly simplifies the study of the milk quality system.

However, the technician who configures it must emphasize the table of weights towards the configuration of the result. In this case, the weight tables formed by the same person (use of virtual experts) have small deviations from each other. It is also observed that the number of iterations necessary for the system to reach the equilibrium point is small, with the result that the convergence results of the model are immediately present. The system is expected to be much more accurate if real experts are used.

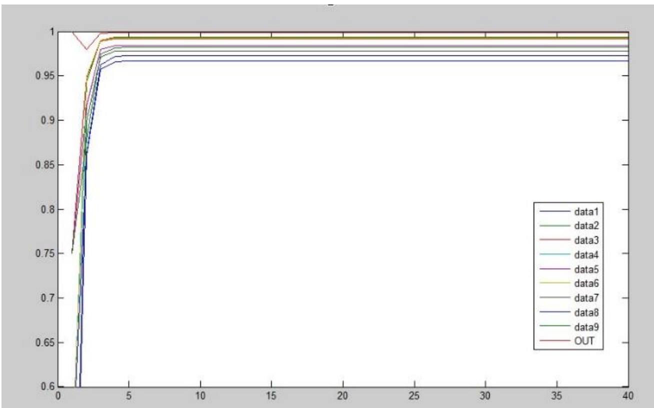

Fig. 1. Concept values until stabilization

4 Discussion and Conclusion

With the help of Fuzzy Cognitive Networks, it became possible to examine milk quality, taking into account different parameters and data that reflect on the chain's overall flow towards the final product's production. Such a prediction is important in cases where the time or equipment is not available to carry out more complex and detailed studies. In addition, this system could be tested and expanded by the production companies themselves, with more accurate data, to be a useful tool for the immediate evaluation of the quality of the final product. From the above investigation, the weighting table affects the results by a very large percentage. In this case, the decision tables had relatively small deviations from each other. Nevertheless, a significant deviation is observed in the final results. The more incomplete the information or, the more limited the amount of data that defines the problem, the more imprecise the results. Therefore, the synthesis of the fuzzy network should be done after thoroughly examining the parameters that affect the final variable. The above tables were obtained after online research and cannot replace those set by the rating models as set by global standards. In the context of this work, different problems and techniques are examined, but at the same time, the foundations are laid for the future examination of additional issues. In this context, the potential next steps to study could be:

- Formulation and examination of additional parameters of importance in the quality assessment of milk production.
- Sensitivity analysis with a prediction for the input parameters in the existing model.
- Comparative examination with other quality assessment techniques, especially at the Greek level.
- Transfer the methodological framework to software to compose a tool for immediate use by a multitude of stakeholders.

Despite the suggestions for the next steps, this work remains a first step for the methodological approach to quality assessment and, in this context, is presented as a very useful material for examining milk production quality at all stages of the chain.

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