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Optimal Distribution Management of a Milk Sector

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Abstract
Sanitary standards for drinking milk are often affected by unsuitable storage and transport conditions. The composition of milk is sensitive to external factors. The effect of physico-chemical factors on the bacteriology of milk during its storage phase and its transport phase is analyzed by artificial neural networks. Also, a strong acidity is unfavorable to their multiplication. Add to this, the hygiene of the container and the personnel as well as the shelf life play a big role. In order to maintain the milk in optimal conditions, it is necessary to control the storage and transport chain. This study supports the parameters that influence the process. An artificial neural network system is proposed in this analysis. The system input variables represent the factors characterizing these conditions. The output variable is expressed by maintaining the milk within the required standards. As artificial neural networks deal with complex phenomena, their application in this field makes it possible to optimize the conditions of storage and transport of drinking milk.

Keywords: Milk, Sanitary standards, Transport conditions, Storage conditions, Artificial neural networks.

JEL classification: M31.

1. Introduction

Because of the increase in milk consumption around the world, the Food and Agriculture Organization of the United Nations Reports (OECD/FAO, 2016) that this consumption increases by 20% by 2025. This will create storage and transport techniques to control the composition of milk (Malek et al., 2013). Milking and milk storage conditions can contribute to bacterial growth. These bacteria originate from the environment and even animal feed (Gleeson et al., 2013). However, microbiological tests carried out on milk for 96 hours can mislead us. Because something already stored the milk, it made additions at regular intervals (Griffiths, 2010; Perko, 2011). Either way, the effect of temperature on milk quality is obvious. Bacterial growth characterizes this in terms of the total number of bacteria and the number of psychrotrophic bacteria. This effect is also a function of the duration of storage (Reche et al., 2015).

A transformation takes place in the milk according to time and especially according to the temperature during storage. Public health authorities have set regulations that govern these storage conditions it should cool Milk to 2-4 °C after milking while others recommend a temperature of up to 6 °C (Cousin, 1982). Because of autolysis and lowering of temperature, the activity of plasmin in milk is reduced (Amy et al., 2021), and high-temperature influences' enzyme stability (Crudden et al., 2005a). In addition to the effect of diet and the stage of lactation, the fat and protein content are modified. The lactation period has a direct effect on the total number of milk bacteria because of environmental conditions and the increased prevalence of mastitis in the herd (Alichanidis et al., 1986). If the physicochemical parameters of milk during its storage are widely studied, the problem remains because, during the storage period, fresh milk is added and this changes the conditions for the quantity of the initial milk.

From the above, it seems that the conditions of milk transport in terms of storage, duration, and temperature are very complex to analyze mathematically. The regulatory standards set for this purpose remain far from exact due to several parameters involved in the process and interact with each other. This study addresses the factors involved in using an intelligent artificial neural network system. Classical mathematical tools are inapplicable. We built an analysis system with the factors that influence milk quality as input variables, matched with the output variable that expresses the degree of this quality.

2. Material and methods

The study took place over three months, from March to May of the year 2021. After milk collection, I store it in a refrigerated tank of the atmospheric type with a capacity of 4000 L. Equipped with an integrated indirect refrigerator (water refrigeration). It is double-walled, which is used to exchange the temperature between the milk and the cooling water. A stirrer in action guarantees the homogenization of the temperature distribution.

It took the temperature using an integrated thermometer. We fixed it in a threshold between 2°C and 6°C. Because it is within these limits that bacterial proliferation remains within an acceptable threshold.

The storage time can go up to 48 hours, the time needed to empty the tank to meet the commercial circuit.

The effect of physico-chemical and bacteriological factors on the storage and transport of milk are analyzed by artificial neural networks.

2.1. Microbiology and storage conditions

Since 1978, Muir et al., 2016, established this correspondence. Bacterial growth varies with temperature at (4°C, 5.2 × 105 cfu/mL); (6°C, 3.3 × 106 cfu/mL) and 8°C, 1.0 × 107 cfu/mL) this for a storage time of 48h. This leads to an alteration by the production of proteases and lipases, which break down proteins and fat (Muir et al., 1978).

Finally, raw milk spoils during storage as a result of enzymatic and microbial activity (Muir et al., 1996). This results in the very alteration of its flavor (Barbano et al., 1991; Deeth, 2006).

2.2. Artificial neural networks

Biology has provided a large amount of information on the functioning of the brain, especially its neurons. This constituted a source of data for mathematicians in order to model this natural system. Mathematicians then tried to reproduce the functioning of the brain by integrating this knowledge of biology into computer programs, and giving them the possibility of learning. Artificial neural networks are currently finding various applications in the fields of science and technology (Ma et al., 2000).

Artificial neural networks have the capability of storing empirical knowledge and making it available for use. The network's treatment abilities (and thus knowledge) will be stored in synaptic weights got through adaptation or learning processes (Brion et al., 2002; Fusi, 2005). In this sense, artificial neural networks therefore resemble the brain because knowledge is acquired through learning, but, it stored this knowledge in the connections (Graves, 2013; Bouharati et al., 2018).

The principle of the artificial neuron can be simplified in figure 1. We can consider this neuron as an operator (or a processor element) which receives several inputs and provides an output only when the sum exceeds a certain internal threshold. The weighted inputs do the evaluation of the output. Mathematically, this can be modeled by the following equations: Each input of the system is associated with a mathematical coefficient like the synaptic weight at the level of natural neurons.

$$Y = f(\sum_{j=1}^{n} w_j x_j - f(s))$$

Where:

xj : are the input vectors

Wj : are the synaptic weight vectors.

The term (x_0 .w_0) represents the value of the internal threshold which must be exceeded for neuron activation.

f(s): represents the activation function

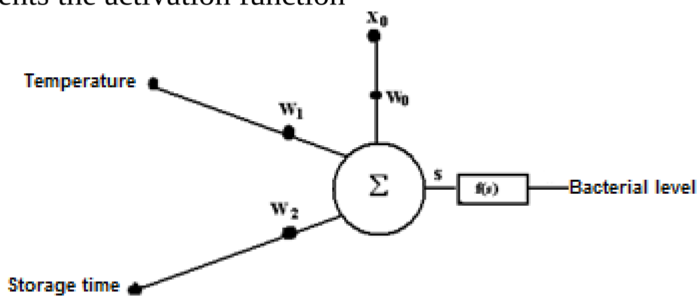

Figure 1. Structure of a neural network with (2) inputs and one output

Our proposed system is illustrated in figure 2. The built system makes the correspondence between the two inputs space which expresses the temperature and the storage duration of the milk and the output space which represents the quality of milk as a bacterial number.

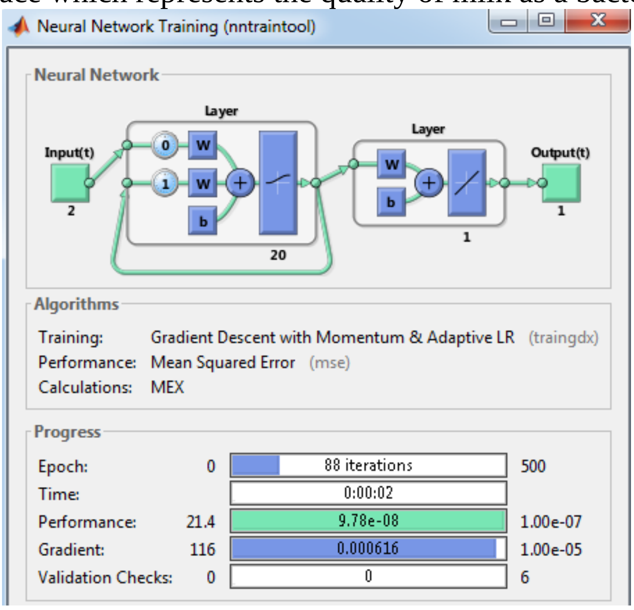

Figure 2. Structure of a neural network with (2) inputs and one output *(generated by Matlab, 2016a)*

Input variables

Each variable is numerically expressed

• Temperature is coded in three levels (2; 4; 6°C)

• Storage time is coded in three durations (12; 24; 48h)

Output variables:

- The bacterial number is represented by its logarithm

Learning the neural network

Actual values of input and output variables are delivered. A transfer function is created for each value (input-output). With each variation, an adjustment of the function takes place by the variation of the weights (in the form of mathematical coefficients). During this learning phase, the function is adjusted to its minimum error. In our case, we fixed 500 iterations in the correction loop. It should be noted that at only 88 iterations, the fit is achieved with an error of $9.7.10^{-8}$. Figure 3.

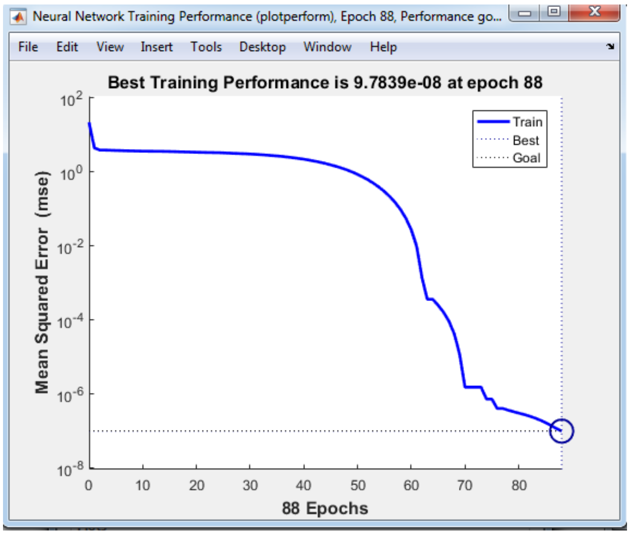

Figure 3. Error correction during learning *(generated by Matlab, 2016a)*

3. Result and discussion

From the actual values resulting from the quality control analyses carried out, the relationship between these factors and the quality of the milk is established. During the learning of the network, the function is adjusted to its minimum error, which makes it possible to predict the quality of the milk. By randomly introducing temperature and storage time values, the system allows the automatic reading of the expected bacterial count. This gives an idea of the quality of the milk and therefore makes it possible to adjust these factors for better quality.

The evolution of bacterial numbers is not linear as a function of time. Several other factors are involved in the duration, including the addition of fresh milk to milk already stored, hence the need for this analysis.

The transfer function that links the inputs to the output is of sigmoid type. During the learning phase, the least squares technique performs error correction. With a fitting gradient of 6.1.10-4, we find we reached the minimum error only at 88 loop iterations. During the learning phase, we note that at the 60th and 70th iterations; the rate is the highest. This rate is 0.04 at the 88th iteration. (Figure 4), input test values are introduced. The result in bacterial number at the exit merges perfectly.

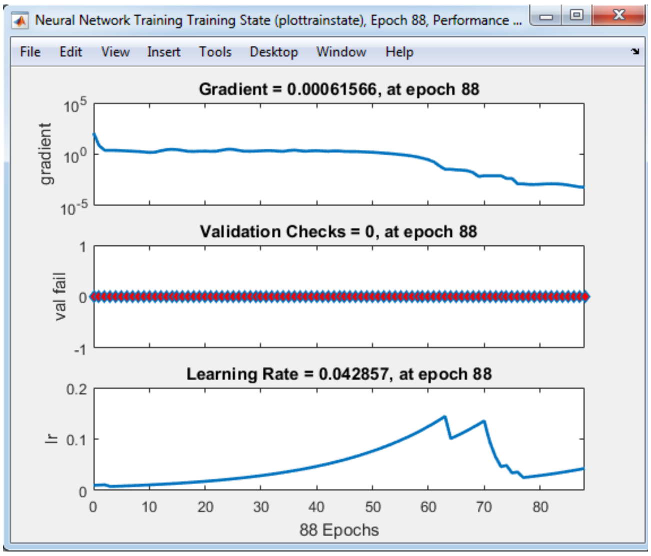

***Figure 4. Fit gradient, learning rate and function validation** (generated by Matlab, 2016a)*

3. Conclusion

Considering the complexity of the system of bacterial growth in milk as a function of various factors, in particular the temperature and the duration of storage, the artificial neural network system proves to be adequate.

This study takes into consideration only the two factors of temperature and duration of storage. However, bacterial growth can be a function of other factors, such as feed season, cow's diet, breed of cow, milking conditions, and so forth. The system is very complex. For the sake of simplification, this study is limited and remains to be extended to other parameters. Whatever the complexity of the data is impossible to analyze by classical mathematical techniques, artificial neural networks give better results in the complexity management of the data.

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