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Cascade Modelling for Predicting Solubility Index of Roller Dried Goat whole Milk Powder

Sumit Goyal, Gyanendra Kumar Goyal
National Dairy Research Institute, Karnal, India
e-mail: thesumitgoyal@gmail.com; gkg5878@yahoo.com

Abstract

The aim of this work was to investigate the prediction ability of Cascade artificial neural network (ANN) models for solubility index of roller dried goat whole milk powder. The input variables for ANN model were: loose bulk density, packed bulk density, wettability and dispersibility, while solubility index was the output variable. Mean square error, root mean square error, coefficient of determination and Nash-sutcliffo coefficient were used as performance measures. Modelling results indicated very good agreement between the actual and the predicted data, thus confirming that ANN could be used to predict solubility index of roller dried goat whole milk powder.

Keywords: *Cascade, ANN, Soft Computing, Artificial Intelligence, Goat Milk Powder*

1. Introduction

The objective of the present study was to develop a predictive model for determining solubility index of roller dried goat whole milk powder using Cascade single hidden layer artificial neural networks (ANN) capable of giving reliable and accurate predictions. The potential for solubility index of roller dried goat whole milk powder prediction constitutes a valuable information source for food industries, especially dairy, which apply food quality assurance systems.

ANN is a system based on the operation of biological neural networks. Although, at present computing is quite advanced, but there are certain tasks that a program made for a common microprocessor is unable to perform; even so a software implementation of a neural network can be made with their advantages and disadvantages. Another aspect of the ANNs is that there are different architectures, which consequently require different types of algorithms, but despite to be an apparently complex system, a neural network is relatively simple. Currently ANNs are among the newest signal processing technologies. In the world of engineering, neural networks have two main functions: Pattern classifiers and as non linear adaptive filters. As its biological predecessor, an ANN is an adaptive system, *i.e.,* each parameter is changed during its operation and deployed for solving the problem in matter. This is called the training phase. ANN is developed with a systematic step-by-step procedure which optimizes a criterion commonly known as the learning rule. The input/output training data is fundamental for these networks as it conveys the information which is necessary to discover the optimal operating point [1].

Cascade models are similar to feedforward networks, but include a weight connection from the input to each layer and from each layer to the successive layers. While two layer feedforward networks can potentially learn virtually any input-output relationship, feedforward networks with more layers might learn complex relationships more quickly. The function *news* creates Cascade forward networks. For example, a three layer network has connections from layer 1 to layer 2, layer 2 to layer 3, and layer 1 to layer 3. The three layer network also has connections from the input to all three layers. The additional connections might improve the speed at which the network learns the desired relationship [2].

Goat milk has played a very important role in health and nutrition of young and elderly people. Goat milk has been known for its beneficial and therapeutic effects on the people who have cow milk allergy. These nutritional, health and therapeutic benefits enlighten the potentials and values of goat milk and its specialty products. The chemical characteristics of goat milk can

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be used to manufacture a wide variety of products, including fluid beverage products (low fat, fortified, or flavoured) and UHT (ultra high temperature) milk; fermented products such as cheese, buttermilk or yogurt; frozen products such as ice cream or frozen yogurt; butter, condensed/dried products, sweets and candies. In addition, other specialty products such as hair, skin care and cosmetic products made from goat milk have recently gained further attention. Nevertheless, high quality products can only be produced from good quality goat milk. The quality milk should have the potential to tolerate technological treatment and be transformed into a product that satisfies the expectations of consumers in terms of nutritional, hygienic and sensory attributes. Taste is the main criteria used by consumers to make decisions to purchase and consume goat milk and its products. Although it may not be important in certain parts of the world, the contribution of goat milk to the economic and nutritional well being of humanity is undeniable in many developing countries, especially in the Mediterranean, Middle East, Eastern Europe and South American countries [3].

2. Review of literature

ANN modelling has been implemented for various dairy products and milk based sterilized drinks:

2.1 Cakes

Cascade Neural Network (CNN) and Probabilistic Neural Network (PNN) models were developed for shelf life determination of cakes. Input variables were moisture, titratable acidity, free fatty acids, peroxide value, and tyrosine; while overall acceptability sensory score was the output variable. Mean Square Error (MSE), Root Mean Square Error (RMSE), Coefficient of determination (R^2) and Nash-Sutcliffo Coefficient (E^2) were used with the aim to compare the prediction performance of the developed models. The best results of all the models were compared with each other, and it was observed that CNN model with single hidden layer having twenty five neurons was better for shelf life determination of cakes [4].

2.2 Soft cakes

Elman and self organizing simulated neural network models for predicting the shelf life of soft cakes were proposed. In this study, the experimental data of soft cakes relating to moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value were taken as input variables; and the overall acceptability sensory score was output variable. Neurons in each hidden layers varied from 1 to 30. The network was trained with single as well as double hidden layers with 1500 epochs, and transfer function for hidden layer was *tangent sigmoid*; while for the output layer, it was *pure linear* function. The experiments revealed that the developed neural network models predicted the shelf life of soft cakes exceedingly well [5].

2.3 Kalakand

Cascade ANN models were developed and compared with each other for predicting the shelf life of Kalakand, which is desiccated milk based sweetmeat [6]. The network was trained with 100 epochs and number of neurons in single and double hidden layers varied from 1 to 30. Cascade models with single hidden layer having four neurons gave the best outcome (MSE 0.000592818; RMSE: 0.024347850; R^2: 0.992884381). Cascade models with two hidden layers having twenty neurons in the first layer and twenty neurons in the second layer gave best fit (MSE 0.000988770; RMSE: 0.03144471; R^2: 0.988125331) for predicting the shelf life of kalakand stored at 6^{o}C.

2.4 Instant coffee drink

For forecasting the shelf life of instant coffee drink, radial basis artificial neural engineering and multiple linear regression models were suggested. Colour and appearance, flavour, viscosity and sediment were taken as input variables; while overall acceptability sensory score was taken as output variable. The investigation revealed that multiple linear regression model was superior over radial basis model for predicting the shelf life of instant coffee drink [7].

2.5 Instant coffee flavoured sterilized drink

Cascade forward and feedforward backpropagation artificial intelligence models for prediction of sensory quality of instant coffee flavoured sterilized drink were developed [8]. The comparison of the two neural network models showed that the feedforward backpropagation model is better than Cascade forward artificial intelligence model for predicting the sensory quality of instant coffee flavoured sterilized drink. Elman and generalized regression artificial intelligence models for detecting the shelf life of instant coffee flavoured sterilized drink have been reported [9].

2.6 Milky white dessert jeweled with pistachio

ANNs for predicting the shelf life of milky white dessert jeweled with pistachio were applied [10]. Linear layer (train) and generalized regression models were developed and compared with each other. Neurons in each hidden layers varied from 1 to 30. Data samples were divided into two disjoint subsets, *i.e.,* 80% of data samples were used for training the network, and remaining 20% for validating the developed models. Mean square error, root mean square error, coefficient of determination and Nash-sutcliffo coefficient were included in the study for comparing the prediction performance of the developed models. The study revealed that ANNs are effective tool for determining the shelf life of milky white dessert jeweled with pistachios.

2.7 Brown milk cakes

The shelf life of brown milk cakes decorated with almonds was determined by ANN based radial basis (exact fit) and radial basis (fewer neurons) models. The developed models were compared with each other. Both the developed models predicted the shelf life of the product exceedingly well [11]. Comparison of the developed models gave very interesting observation, *i.e.,* output results were the same when numerous experiments were conducted after having taken the same spread constant in both the models, suggesting that both the developed ANN computing models are convenient, less time consuming and powerful alternative tool to laboratory's experimental expensive and long time taking shelf life testing method for predicting the shelf life.

2.8 Soft mouth melting milk cakes

The time-delay and linear layer (design) intelligent computing expert system models were suggested for predicting the shelf life of soft mouth melting milk cakes stored at 6^{o}C.The outcome of the study revealed that intelligent computing expert system models are efficient in predicting the shelf life of the product [12].

2.9 Post-harvest roasted coffee sterilized milk drink

Artificial intelligence neural network Elman model was proposed for predicting the shelf life of roasted coffee sterilized cow milk drink stored at 30^{o}C. To compare prediction potential Radial Basis model was also developed. The final results of both the models were compared with each other. The Elman model with single hidden layer having eighteen neurons gave the best fit (MSE: 9.97756E-07, RMSE: 0.000998877, $R^{2:}$ 0.999990022, $E^{2:}$ 0.999996211), followed by Elman model with two hidden layers having seven neurons in the first layer and 5 neurons in the second layer (MSE: 8.48661E-06 , RMSE : 0.002913179, R^2 : 0.999915134, E^2 : 0.999999923); and Radial Basis model with spread constant as 100 (MSE : 4.1554E-05 , RMSE: 0.006446238 , R^2 : 0.99958446, E^2 : 0.999951677). From the study it was concluded that artificial intelligence models are quite effective in predicting the shelf life of roasted coffee sterilized drink [13].

2.10 Milk

Sanzogni and Kerr [14] forecasted the accuracy of milk production on dairy farms using a *FFANN* (feedforward ANN) with polynomial post-processing. Historical milk production data was used to derive models that are able to predict milk production from farm inputs, using a standard *FFANN*, a *FFANN* with polynomial post-processing and multiple linear regressions. Forecasts obtained from the models were then compared with each other. Within the scope of the available data, it was found that the standard *FFANN* did not improve on the multiple regression technique, but the *FFANN* with polynomial post processing did.

The scanning of published literature reveals that though ANNs have been applied for other dairy products, *viz.,* processed cheese, burfi and roasted coffee flavoured sterilized drink, but no research has been carried out using Cascade modelling for predicting the solubility index of roller dried goat whole milk powder

3. Method and material

For determining the solubility index of roller dried goat whole milk powder, ANN models were designed by using input parameters, *viz.*, loose bulk density, packed bulk density, wettability and dispersibility, while solubility index was the output (Figure 1).

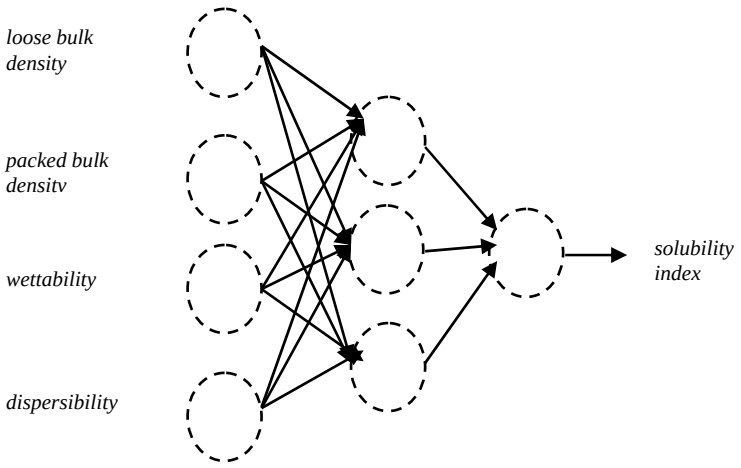

Figure1. Input and output parameters for ANN model

$$MSE = \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{n} \right)^2 \right] \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}} \right)^2 \right]} \quad (2)$$

$$R^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp}^{\,2}} \right)^2 \right] \quad (3)$$

$$E^2 = 1 - \left[\sum_{1}^{N} \left(\frac{Q_{\exp} - Q_{cal}}{Q_{\exp} - \overline{Q_{\exp}}} \right)^2 \right] \quad (4)$$

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

$\overline{Q}_{\exp}$ =Mean predicted value;

n = Number of observations in dataset.

MSE (1), RMSE (2), R^2 (3) and E^2 (4) were applied as prediction performance measures. The Neural Network Toolbox under MATLAB software was used for the development of ANN models.

4. Results and analysis

Cascade model's performance matrices are presented in Table 1.

Table 1. Performance of Cascade single hidden layer model

Neurons	MSE	RMSE	R^2	E^2
7	0.001876802	0.043322075	0.956677925	0.998123198

Fernandez *et al.* [15] studied the weekly milk production in goat flocks and clustering of goat flocks by using self organizing maps for prediction, establishing the effectiveness of ANN modelling in animal science applications. Sutrisno *et al.* [16] applied ANN models with back propagation algorithm for predicting the mangosteen quality during storage at the most appropriate pre-storage conditions which performed the longest storage period. In their experimental R^2 was found close to 1 (more than 0.99) for each parameter, indicating that the model was good to memorize data Our ANN models indicated similar trend. Combination of 4→7→1 topology (MSE: 0.001876802; RMSE: 0.043322075; R^2: 0.956677925; E^2: 0.998123198) gave the best fit (Table 1). The developed methodology for predicting the solubility index of roller dried goat whole milk powder is reliable, simple, and rapid, indicating that the use of ANN models is a better option than laboratory testing method, which is expensive, cumbersome and time consuming procedure [17-21].

5. Conclusion

This study proposed a Cascade single hidden layer artificial neural network model for predicting the solubility index of roller dried goat whole milk powder. The modelling results showed excellent results with high coefficient of determination (0.956677925) and Nash-sutcliffo coefficient (0.998123198). From the study it is concluded that the developed Cascade single hidden layer model can be advantageously used for the purpose.

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