

Dynamic Scientific Method for Predicting Shelf Life of Buffalo Milk Dairy Product

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Article Info

Article history:

Received Feb 2, 2012
Revised Feb 28, 2012
Accepted Mar 7, 2012

Keyword:

Artificial Neural Networks
Buffalo Milk
Burfi
Dairy Product
Machine Learning

ABSTRACT

Feedforward multilayer machine learning models were developed for predicting the shelf life of burfi stored at 30°C. Experimental data of the product relating to moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value were used as input variables and the overall acceptability score assigned by the sensory expert panel as the output variable. Bayesian regularization algorithm was applied for training the network. The transfer function for hidden layers was *tangent* sigmoid, and for the output layer it was *purelinear* function. The network was trained with 100 epochs, and neurons in each hidden layers varied from 3:3 to 20:20. Excellent agreement was found between the actual and predicted values establishing that feedforward multilayer machine learning models are efficient in predicting the shelf life of burfi.

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1. INTRODUCTION

The first Artificial Neural Network (ANN) was invented in 1958 by psychologist Frank Rosenblatt. It was intended to model how the human brain processed visual data and learned to recognize objects. Other researchers have since used similar ANNs to study human cognition. An ANN operates by creating connections between many different processing elements, each analogous to a single neuron in a biological brain. These neurons may be physically constructed or simulated by a digital computer. Each neuron takes many input signals, then based on an internal weighting system, produces a single output signal that is typically sent as input to another neuron. The neurons are tightly interconnected and organized into different layers. The input layer receives the input; the output layer produces the final output [1]. A feedforward neural network is an ANN where connections between the units do not form a directed cycle. This is different from recurrent neural networks. The feedforward neural network was the first and simplest type of ANN devised. In this network, the information moves in only one direction, forward, from the input nodes, through the hidden nodes (if any) and to the output nodes. There are no cycles or loops in the network. Multilayer Feedforward Neural Network consists of multiple layers of computational units, usually interconnected in a feedforward way. Each neuron in one layer has directed connections to the neurons of the subsequent layer. In many applications the units of these networks apply a *sigmoid* function as an activation function. Multilayer networks use a variety of learning techniques, the most popular being back-propagation. Here, the output values are compared with the correct answer to compute the value of some predefined error-function. By various techniques, the error is then fed back through the network. Using this information, the algorithm adjusts the weights of each connection in order to reduce the value of the error function by some small amount. After repeating this process for a sufficiently large number of training cycles, the network usually converge to some state where the error of the calculations is small [2].

Burfi is very popular sweet confection prepared by desiccating water buffalo milk. In Indian subcontinent burfi is essentially and customarily served and consumed on all festive occasions and also during social gatherings. Though, several varieties of burfi such as coconut burfi, chocolate burfi, cashew nut burfi, almond burfi, pistachio burfi, cardamom burfi and plain burfi are sold in the market, but the latter variety is most popular which contains milk solids and sugar. The upper surface of burfi pieces are generally coated with an edible thin metallic silver leaf in order to make it more attractive and also due to its therapeutic value.

Shelf life studies provide important information to product developers and manufacturers enabling them to ensure that the consumer gets a high quality product for a significant period of time after its manufacture. The expensive and long time taking shelf life studies conducted in the laboratory do not fit with the speed requirement of the industry; therefore, of late accelerated studies for shelf life determination have been innovated. As the mechanisms of food deterioration became known to the food scientists, methods of counteracting them have been devised. The increasing number of newly developed foods compete for space on supermarket shelves, the words “speed and innovation” have become the keywords for food companies seeking to become “first to market” with successful products. The overall quality of the product is most important in present competitive scenario and needs to be maintained into the speed and innovation system. How the consumer perceives the product is the ultimate measure of total food quality. Therefore, the quality built in during the development and production process must last through the distribution and consumption stages [3].

ANNs have been implemented for predicting the shelf life of several milk based products. Goyal and Goyal [4,5] suggested artificially intelligent scientific computing models for shelf life prediction of cakes. Cascade backpropagation models were implemented for predicting the shelf life of Kalakand [6]. ANN models have been reported to be very efficient for forecasting the shelf life of milk based coffee drink [7-9], milky white dessert jeweled with pistachios [10], brown milk cakes decorated with almonds [11], soft mouth melting milk cakes [12] and processed cheese [13-19].

The aim of this study is to develop feedforward machine learning multilayer ANN models for estimating the shelf life of burfi stored at 30°C. The findings of this investigation would be very beneficial to the product manufacturers, wholesalers, retailers, consumers, regulatory authorities, researchers and academicians.

2. METHOD MATERIAL

For developing the multilayer feedforward model 48 observations were used, which were divided into two disjoint subsets, viz., training set having 40 observations and validation set 8. Mean Square Error MSE (1), Root Mean Square Error RMSE (2), Coefficient of Determination R^2 (3) and Nash - Sutcliffe Coefficient E^2 (4) were applied in order to compare the prediction capability of the models. The Neural Network Toolbox under MATLAB software was used for development of the models.

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

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

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

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

Where,

Q_{exp} = Observed value; Q_{cal} = Predicted value; $\bar{Q}_{exp}$ = Mean predicted value; n = Number of observations in dataset. The experimentally obtained quality parameter data of burfi relating to moisture, titratable acidity (TA), free fatty acids (FFA), tyrosine, and peroxide value (PV) were taken as input variables and the overall acceptability score (OAS) assigned by the expert panel based on Hedonic scale as the output for examining the suitability of the developed feedforward multilayer models for estimating the shelf life of the product (Figure 1).

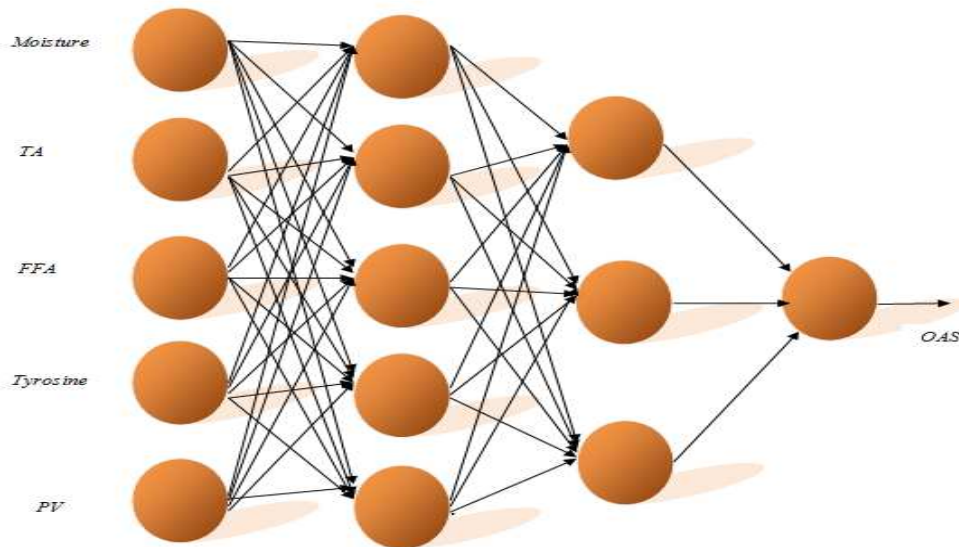


Figure 1. Input and output variables

3. RESULTS AND DISCUSSION

Feedforward ANN model's performance matrices for predicting the OAS are depicted in Table 1.

Table 1. Results of feedforward model

Neurons	MSE	RMSE	R ²	E ²
3:3	0.000131018	0.011446291	0.988553709	0.999868982
4:4	5.9082E-06	0.00243068	0.99756932	0.999994092
5:5	2.51848E-06	0.001586973	0.998413027	0.999997482
6:6	5.29973E-06	0.002302115	0.997697885	0.9999947
7:7	2.09775E-05	0.004580123	0.995419877	0.999979022
8:8	8.47217E-05	0.009204441	0.990795559	0.999915278
9:9	3.70974E-05	0.006090761	0.993909239	0.999962903
10:10	2.72664E-06	0.001651255	0.998348745	0.999997273
11:11	3.1187E-07	0.000558454	0.999441546	0.999999688
12:12	4.41518E-06	0.002101232	0.997898768	0.999995585
13:13	8.41432E-06	0.002900745	0.997099255	0.999991586
14:14	6.94628E-06	0.00263558	0.99736442	0.999993054
15:15	7.8417E-06	0.002800304	0.997199696	0.999992158
16:16	3.67069E-05	0.006058619	0.993941381	0.999963293
17:17	4.5125E-05	0.006717514	0.993282486	0.999954875
18:18	3.52609E-05	0.00593809	0.99406191	0.999964739
19:19	4.01938E-05	0.006339855	0.993660145	0.999959806
20:20	7.86422E-06	0.002804321	0.997195679	0.999992136

The comparison of actual overall acceptability score (AOAS) and predicted overall acceptability score (POAS) for ANN model is illustrated in Figure 2.

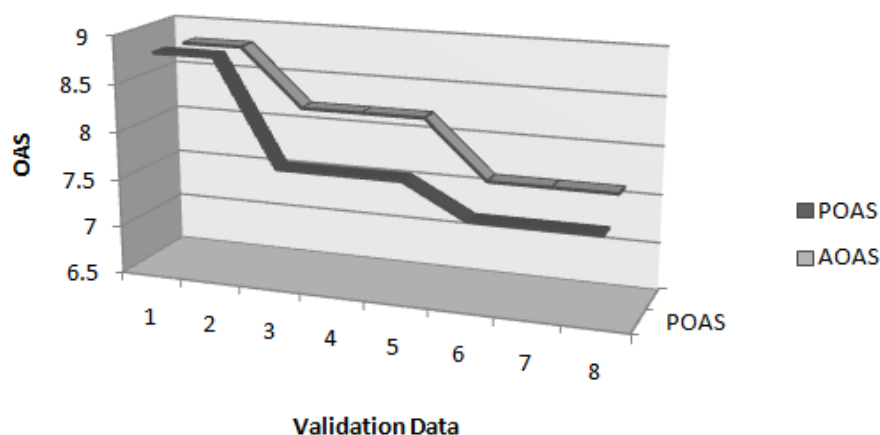


Figure 2. Comparison of AOAS and POAS for feedforward multilayer model

Feedforward multilayer models were developed and compared with each other for predicting the shelf life of burfi. Bayesian regularization algorithm was used for training. The transfer function for hidden layers was *tangent sigmoid*, and for the output layer it was *pure linear* function. The network was trained with 100 epochs, and neurons in each hidden layers varied from 3:3 to 20:20. The best results were obtained with the combination of 5→11→11→1, with high coefficient of determination (0.999441546), Nash - sutcliffe coefficient (0.999999688) and RMSE as low as 0.000558454 (Table 1), exhibiting excellent correlation between the actual and the predicted values. From the obtained results it is observed that the developed feedforward multilayer models are quite suitable for predicting the shelf life of burfi.

4. CONCLUSION

In the establishment of prediction model for burfi, the data of the product relating to moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value were taken as input variables, and overall acceptability score assigned by the expert panel based on Hedonic scale as the output. Mean square error, root mean square error, coefficient of determination and Nash - sutcliffe coefficient were used as performance measures for testing the prediction ability of the developed models. The investigation showed very good correlation between the actual and the predicted values with a high determination coefficient and Nash-sutcliffe coefficient, and low root mean square error, suggesting that the developed models were able to analyze non-linear multivariate data with excellent performance. From the study, it is concluded that the application of developed feedforward multilayer model is a better option to expensive, cumbersome and long time taking laboratory testing method for determining the shelf life of buffalo milk dairy product, viz., burfi.

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