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

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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 \textit{tangent} sigmoid, and for the output layer it was \textit{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.

Keyword: Artificial Neural Networks, Buffalo Milk, Burfi, Dairy Product, Machine Learning

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 \textit{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 30ºC. 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 R² (3) and Nash - Sutcliffo Coefficient E² (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.

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

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

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

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

Where,
\( Q_{\text{exp}} = \) Observed value; \( Q_{\text{cal}} = \) Predicted value; \( \bar{Q}_{\text{exp}} = \) 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](image)

3. RESULTS AND DISCUSSION

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

| 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 | 0.999996888     |
| 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 | 0.00235558 | 0.99736442  | 0.999995034     |
| 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.

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 \( \text{tangent sigmoid} \), and for the output layer it was \( \text{pure linear} \) 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 \( 5 \rightarrow 11 \rightarrow 11 \rightarrow 1 \), 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.

REFERENCES

[1] http://www.computerworld.com/s/article/57545/Artificial_Neural_Networks (accessed on 20.1.2011).
[2] http://en.wikipedia.org/wiki/Feedforward_neural_network (accessed on 21.1.2011).
[3] Medlabs Website, 2011: http://www.medlabs.com/Downloads/food_product_shelf_life_web.pdf (accessed on 15.1.2011).
[4] Sumit Goyal and G.K. Goyal. “Brain based artificial neural network scientific computing models for shelf life prediction of cakes”. Canadian Journal on Artificial Intelligence, Machine Learning and Pattern Recognition, vol.2, no.6, pp.73-77, 2011.
[5] Sumit Goyal and G.K. Goyal.”Simulated neural network intelligent computing models for predicting shelf life of soft cakes”. Global Journal of Computer Science and Technology, vol.11, no.14, version1.0, pp.29-33, 2011.
[6] Sumit Goyal and G.K. Goyal.”Advanced computing research on cascade single and double hidden layers for detecting shelf life of kalakand: An artificial neural network approach”. International Journal of Computer Science & Emerging Technologies, vol.2, no.5, pp.292-295, 2011.
[7] Sumit Goyal and G.K. Goyal. “Application of artificial neural engineering and regression models for forecasting shelf life of instant coffee drink”. International journal of computer science issues, vol. 8, no.4, pp. 320-324, 2011.
[8] Sumit Goyal and G.K. Goyal. "Cascade and feedforward backpropagation artificial neural networks models for prediction of sensory quality of instant coffee flavoured sterilized drink". *Canadian Journal on Artificial Intelligence, Machine Learning and Pattern Recognition*, vol.2, no.6, pp.78-82, 2011.

[9] Sumit Goyal and G.K. Goyal. “Development of neuron based artificial intelligent scientific computer engineering models for estimating shelf life of instant coffee sterilized drink”. *International Journal of Computational Intelligence and Information Security*, vol.2, no.7, pp.4-12, 2011.

[10] Sumit Goyal and G.K. Goyal. “A new scientific approach of intelligent artificial neural network engineering for predicting shelf life of milky white dessert jeweled with pistachio”. *International Journal of Scientific and Engineering Research*, vol.2, no.7, pp.1-4, 2011.

[11] Sumit Goyal and G.K. Goyal. "Radial basis artificial neural network computer engineering approach for predicting shelf life of brown milk cakes decorated with almonds". *International Journal of Latest Trends in Computing*, vol.2, no.3, pp.434-438, 2011.

[12] Sumit Goyal and G.K. Goyal. "Development of intelligent computing expert system models for shelf life prediction of soft mouth melting milk cakes". *International Journal of Computer Applications*, vol.25, no.9, pp.41-44, 2011.

[13] Sumit Goyal and G.K. Goyal. “Estimating processed cheese shelf life with artificial neural networks”. *International Journal of Artificial Intelligence*, vol.1, no.1, pp.19-24, 2012.

[14] Sumit Goyal and G.K. Goyal. “Radial basis (exact fit) and linear layer (design) ANN models for shelf life prediction of processed cheese”. *International Journal of u- and e- Service, Science and Technology*, vol.5, no.1, pp.63-69, 2012.

[15] Sumit Goyal and G.K. Goyal. “Time-delay artificial neural network computing models for predicting shelf life of processed cheese”. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, vol.3, no.1, pp.63-70, 2012.

[16] Sumit Goyal and G.K. Goyal. “Shelf life estimation of processed cheese by artificial neural network expert systems”. *Journal of Advanced Computer Science & Technology*, vol.1, no.1, pp.32-41, 2012.

[17] Sumit Goyal and G.K. Goyal. “A novel method for shelf life detection of processed cheese using cascade single and multi layer artificial neural network computing models”. *ARPN Journal of Systems and Software*, vol.2, no.2, pp.79-83, 2012.

[18] Sumit Goyal and G.K. Goyal. “Linear layer and generalized regression computational intelligence models for predicting shelf life of processed cheese”. *Russian Journal of Agricultural and Socio-Economic Sciences*, vol.3, no.3, pp.28-32, 2012.

[19] Sumit Goyal and G.K. Goyal. “Performance of generalized regression, radial basis (fewer neurons), and linear layer (design) computational ANN techniques for shelf life prediction of processed cheese”. *International Journal of Artificial Intelligence and Knowledge Discovery*, vol.1, no.4, pp.12-15, 2012.
