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Soft Computing Methodology for Shelf Life Prediction of Processed Cheese

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ABSTRACT

Feedforward multilayer models were developed for predicting shelf life of processed cheese stored at 30^o C. Input variables were Soluble nitrogen, pH, Standard plate count, Yeast & mould count and Spore count. Sensory score was taken as output parameter for developing feedforward multilayer models. Mean square error, root mean square error, coefficient of determination and nash - sutcliffo coefficient performance measures were implemented for testing prediction potential of the soft computing models. The study revealed that soft computing multilayer models can predict shelf life of processed cheese.

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1. INTRODUCTION

Artificial Neural Networks (ANN), also known as "artificial neural nets" or "neural nets", are computational tool modeled on the interconnection of the neuron in the nervous systems of the human brain and that of other organisms. The term "neural net" refers to both the biological and artificial variants, although typically the term is used to refer to artificial systems only. Mathematically, neural nets are nonlinear. Each layer represents a non-linear combination of non-linear functions from the previous layer. Each neuron is a multiple-input multiple-output (MIMO) system that receives signals from the inputs, produces a resultant signal, and transmits that signal to all outputs. Practically, neurons in an ANN are arranged into layers. The first layer that interacts with the environment to receive input is known as the input layer. The final layer that interacts with the output to present the processed data is known as output layer. Layers between the input and the output layer that do not have any interaction with the environment are known as hidden layers. Increasing the complexity of an ANN, and thus its computational capacity, requires the addition of more hidden layers, and more neurons per layer [1]. Processed cheese is very nutritious and manufactured from ripened cheddar cheese. This variety of cheese has several advantages over raw cheese, such as tastier and longer shelf life. It is a nourishing high protein food, *i.e.*, a welcome supplement to meat protein [2].

1.1 Feedforward Neural Network

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 arguably 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 [3].

1.2 Multilayer Feedforward Neural Network

This class of networks consists of multiple layers of computational units, usually interconnected in a feed-forward 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 [3].

1.3 Shelf Life

Shelf life is the recommendation of time that products can be stored, during which the defined quality of a specified proportion of the food remains acceptable under specified conditions of distribution, storage and display. Most shelf life dates are used as guidelines based on normal and expected handling and exposure to temperature. Use prior to the expiration date does not necessarily guarantee the safety of a food or drug, and a product is not always dangerous or ineffective after the expiration date [4]. ANN have been applied for predicting shelf life of milky white dessert jeweled with pistachio [5], Kalakand [6], instant coffee flavoured sterilized drink [7,8]. Time-delay and linear layer models predicted shelf life of soft mouth melting milk cakes [9]. Elman and self-organizing models determined shelf life of soft cakes [10]. Radial basis models were developed for predicting shelf life of brown milk cakes decorated with almonds [11]. ANN have also predicted shelf life of cakes [12] , processed cheese [13,14,15], and burfi [16].The purpose of this investigation is to develop feedforward multilayer models for determining shelf life of processed cheese stored at 30^{o}C.This study would be beneficial to cheese manufactures, consumers, regulatory authorities, academicians and food researchers.

2. METHOD MATERIAL

Soluble nitrogen, pH, standard plate count, yeast & mould count, and spore count were taken as input parameters and sensory score as output parameter for developing feedforward soft computing models (Fig.1).

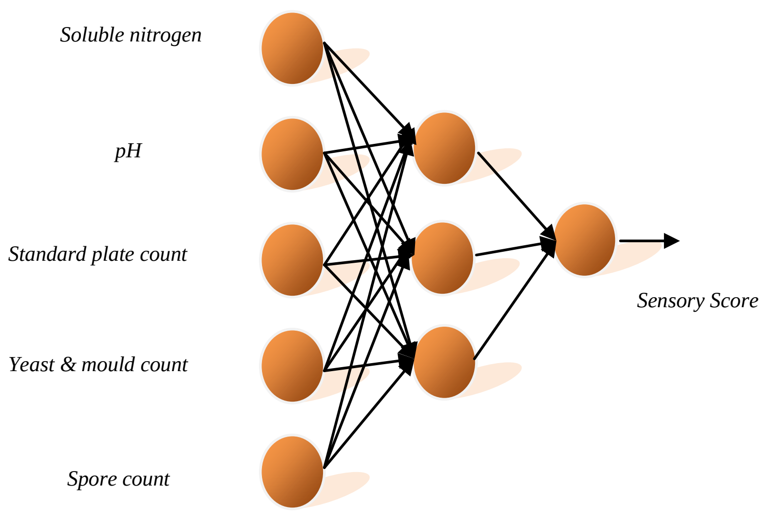

Figure1. Inputs and output for feedforward soft computing model

The data samples consisted of 36 observations, which were divided into two subsets, *i.e.*, 30 were used for training the network and 6 for validating the feedforward neural network.

2.1 Measures for Prediction Performance

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

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

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

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

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

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

n = Number of observations in dataset.

Mean Square Error: MSE (1), Root Mean Square Error: RMSE (2), Coefficient of Determination: R^2 (3) and Nash - Sutcliffo Coefficient :E^2 (4) were used in order to compare the prediction ability of the developed models.

3. RESULTS AND DISCUSSION

Soft computing feedforward model’s performance matrices for predicting sensory scores are presented in Table 1.

Table 1. Performance of feedforward multilayer model for predicting sensory score

Neurons	MSE	RMSE	R^2	E^2
3:3	0.011724037	0.108277592	0.891722408	0.988275963
4:4	0.01286477	0.11342297	0.88657703	0.98713523
5:5	0.000125365	0.011196632	0.988803368	0.999874635
6:6	0.000141198	0.011882682	0.988117318	0.999858802
7:7	**2.2053E-05**	**0.004696063**	**0.995303937**	**0.999977947**
8:8	0.009778813	0.098887882	0.901112118	0.990221187
10:10	0.000224532	0.014984403	0.985015597	0.999775468
12:12	0.000114004	0.010677263	0.989322737	0.999885996
14:14	0.000224894	0.014996482	0.985003518	0.999775106
15:15	0.000143967	0.011998635	0.988001365	0.999856033
16:16	3.50274E-05	0.005918392	0.994081608	0.999964973
17:17	0.007871296	0.088720325	0.911279675	0.992128704
18:18	0.000225184	0.015006144	0.984993856	0.999774816
19:19	7.23037E-05	0.00850316	0.99149684	0.999927696
20:20	0.000149232	0.012216045	0.987783955	0.999850768

The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for soft computing feedforward multilayer models are illustrated in Fig.2.

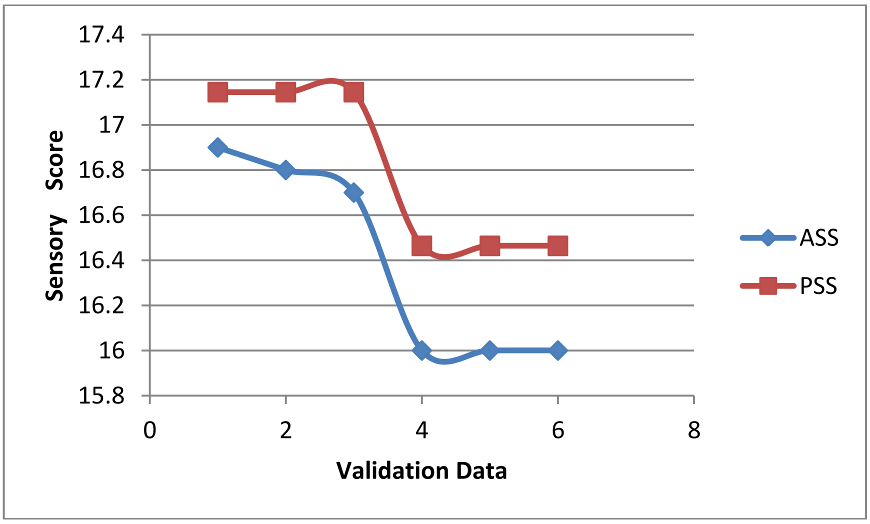

Figure 2. Comparison of ASS and PSS for multilayer model

Different algorithms were tried like Polak Fletcher Reeves update conjugate gradient algorithm, Levenberg Marquardt algorithm, Gradient Descent algorithm with adaptive learning rate, Bayesian regularization, Powell Beale restarts conjugate gradient algorithm and BFG quasi-Newton algorithm. Backpropagation algorithm based on Bayesian regularization mechanism was finally selected for training the feedforward models, as it gave better results.Several combinations were tried and tested, as there is no defined rule of getting good results rather than hit and trial method. As the number of neurons increased, the training time also increased. The network was trained upto 100 epochs with multiple hidden layers; transfer function for hidden layers was tangent sigmoid while for the output layer, it was pure linear function. The Neural Network Toolbox under MATLAB software was used for development of the models. Multilayer feedforward model with 5→7→7→1 topology **(MSE:** 2.2053E-05**, RMSE:** 0.004696063**,** $\mathbf{R^2}$**:** 0.995303937**,** $\mathbf{E^2}$**:** 0.999977947**)** gave the best fit, reflecting that the developed models are excellent for estimating shelf life of processed cheese stored at 30^oC.

4. CONCLUSION

Soft computing feedforward multilayer models were developed for predicting shelf life of processed cheese stored at 30^oC. Soluble nitrogen, pH, standard plate count, yeast & mould count, and spore count were taken as input parameters. The output parameter was sensory score.Several experiments were conducted. It was observed that 5→7→7→1 topology performed the best, suggesting that the developed models are able to analyze non-linear multivariate data with excellent performance, fewer parameters, and shorter calculation time. Therefore, from the investigation it can be concluded that feedforward multilayer models are good for predicting shelf life of processed cheese stored at 30^oC.

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