Cascade Artificial Neural Network Models for Predicting Shelf Life of Processed Cheese

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***Abstract*—The purpose of this study is to develop artificial neural network (ANN) models for predicting shelf life of processed cheese stored at 7-8ºC. Body & texture, aroma & flavour, moisture and free fatty acids were taken as input parameters, and sensory score as output parameter for developing the models. The developed Cascade single layer ANN models were compared with each other. Bayesian regularization was used for training ANN models. Network was trained with 100 epochs, and neurons in each hidden layer(s) varied from 3 to 20. Cascade ANN models very well predicted the shelf life of processed cheese.**

***Index Terms*—Artificial Intelligence, Cascade, Artificial neural networks (ANN), Processed Cheese, Shelf Life, Soft Computing**

I. INTRODUCTION

Processed cheese, a protein rich food is good supplement to meat protein. Generally, it is prepared from ripened Cheddar cheese, but often some quantity of less ripened or fresh cheese is also added. Its manufacturing technique involves addition of emulsifier, salt, water and spices (optional). The mixture is heated in a double jacketed kettle with continuous gentle stirring with a flattened ladle in order to get homogeneous paste. This variety of cheese has pleasing taste, unique body and texture, and longer shelf life.

An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received surpass a certain threshold, the neuron is activated and emits a signal though the axon. This signal might be sent to another synapse, and might activate other neurons. These basically consist of inputs, which are multiplied by weights (strength of the respective signals), and then computed by a mathematical function which determines the activation of the neuron. By adjusting the weights of an artificial neuron, desired output can be obtained for specific inputs. Algorithms can adjust the weights of the ANN for getting the desired output from the network, called training. The function of ANNs is to process information; and they are also used for engineering purposes, such as pattern [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 *newcf* creates cascade forward networks [2-3]. Single layer perceptron network consists of a single layer of output nodes; the inputs are fed directly to the outputs via a series of weights. The sum of the products of the weights and the inputs is calculated in each node, and if the value is above some threshold (typically 0), the neuron fires and takes the activated value (typically 1); otherwise it takes the deactivated value (typically -1) [4].

Shelf life is the guideline of time period for which the product remains acceptable under specified conditions of distribution, storage and display. However, use prior to the expiration date does not necessarily guarantee the safety of a food, and a product is not always dangerous or ineffective after the expiration date [5]. The aim of this study is to develop cascade single hidden layer ANN models for predicting the shelf life of processed cheese stored at 7-8ºC.

II. LITERATURE REVIEW

The application of ANN for predicting the shelf life of food products in food industry is quite an effective approach [6]. ANNs are vibrant new tools to evaluate food quality, analyze shelf life and predict various properties of foodstuffs [7].

A. Milk

The usefulness of ANN models for prediction of shelf-life of milk by multivariate interpretation of gas chromatographic profiles, and flavour-related shelf-life was evaluated and compared with Principal Components Regression (PCR). The training set consisted of dynamic headspace gas chromatographic data collected during storage of pasteurized milk (input information for the ANN models used to make a decision) and its corresponding shelf-life (prediction or response). The study revealed that ANN had better predictability than PCR. A standard error of the estimate of 2 days in shelf life resulting from regression analysis of experimental versus predicted values indicated a high predictability of ANN [8].

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B. *Butter*

The seasonal variations of the fatty acids composition of butters were investigated over three seasons during a 12-month study in the protected designation of origin Parmigiano-Reggiano cheese area. Fatty acids were analyzed by GC-FID, and then computed by ANN [9].

C. *Processed Cheese*

The Time-delay single layer and multilayer ANN models were suggested for predicting the shelf life of processed cheese stored at 7-8^{o}C [10]. The input parameters of the ANN consisted of soluble nitrogen, pH; standard plate count, yeast & mould count, and spore count. The output parameter was sensory score. The results of the experiments showed excellent correlation between the training data and the validation data with a high Nash - Sutcliffe coefficient (E^2) and determination coefficient (R^2), suggesting that the developed models are able to analyze the non-linear multivariate data with excellent performance and shorter calculation time. From the study it was inferred that time-delay ANN models are very good for predicting the shelf life of processed cheese.

D. *Kalakand*

The shelf life of kalakand, which is milk based desiccated sweetened dairy product, was estimated by implementing Cascade single and double hidden layer models. The developed models were compared with each other for observing their supremacy over the other [11].

E. *Burfi*

Radial basis (exact fit) model was suggested for estimating the shelf life of an extremely popular milk based sweetmeat namely burfi [12]. The input variables were the lab data of the product relating to moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value; and the overall acceptability score was output. Mean square error (MSE), root mean square error (RMSE), R^2 and E^2 were applied for comparing the prediction ability of the developed models. The observations indicated exceedingly well correlation between the actual data and the predicted values, with a high R^2 and E^2 establishing that the models were able to analyze non-linear multivariate data with very good performance. From the study, it was concluded that the developed model, which is very convenient, less expensive and less time consuming can be a good alternative to expensive, time consuming and cumbersome laboratory testing method for estimating the shelf life of burfi.

F. *Roller Dried Goat Whole Milk Powder*

The possibility of using radial basis function artificial neural network (RBF ANN) model as an alternative to expensive, time consuming and cumbersome laboratory testing method for predicting the solubility index of roller dried goat whole milk powder has been successfully explored. The ANN models were trained with a data file composed of variables: loose bulk density, packed bulk density, wettability and dispersibility, while solubility index was the output variable. The modeling results showed that there was good agreement between the experimental data and the predicted values [13].

III. METHOD MATERIAL

Body & texture, aroma & flavour, moisture, and free fatty acids of processed cheese stored at 7-8º C were taken as input parameters, and sensory score was taken as output parameter for developing Cascade single and multilayer ANN models (Fig.1).

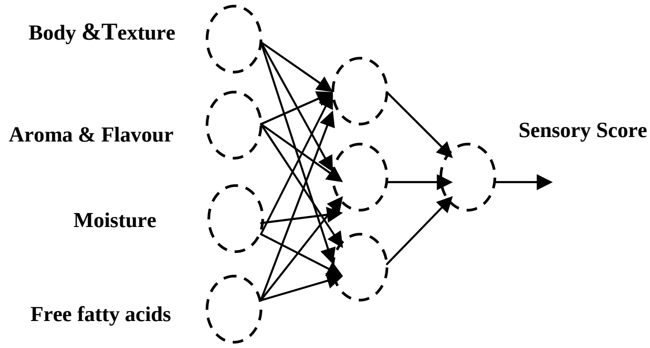

Figure 1. Input and output parameters of models

Data consisted of 36 observations, which were divided into two subsets, *i.e.,* 30 for training and 6 for validation. Different combinations of internal parameters, *i.e.,* data preprocessing, data partitioning approaches, number of hidden layers, number of neurons in each hidden layer, transfer function, error goal, *etc.*, were explored in order to optimize the prediction ability of the cascade model. Several algorithms like *Gradient Descent algorithm with adaptive learning rate, Bayesian regularization, Fletcher Reeves update conjugate gradient algorithm, Levenberg Marquardt algorithm and Powell Beale restarts conjugate gradient algorithm* were tried. *Bayesian regularization* mechanism was finally selected for training ANN models, as it exhibited best results. The network was trained with 100 epochs, and neurons in each hidden layer varied from 3 to 20. The network was trained with single hidden layers and transfer function for hidden layer was *tangent sigmoid,* while for the output layer it was *pure linear* function. MALTAB software was used for performing the experiments.

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

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

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

Where, $Q_{\exp}$ = Observed value; Q_{cal} = Predicted value; $\overline{Q}_{\exp}$ =Mean predicted value; n = Number of observations in dataset. RMSE (1), Coefficient of Determination: R^2 (2) and Nash-Sutcliffe Coefficient: E^2 (3) were used in order to compare the prediction ability of the developed ANN models

IV. Results and Discussion

Cascade models performance matrices for predicting the shelf life of processed cheese are presented in Table 1.

TABLE 1.
RESULTS OF CASCADE ANN MODEL

Neurons	RMSE	R^2	E^2
3 (Layer I)	0.00183711	0.99816288	0.99999662
4(Layer I)	0.01059933	0.98940066	0.99988765
5(Layer I)	0.00566003	0.99433996	0.99996796
6(Layer I)	0.00143642	0.99856357	0.99999793
7(Layer I)	0.02756684	0.97243316	0.99924006
8(Layer I)	0.01732031	0.98267968	0.99970000
9(Layer I)	0.02573728	0.97426271	0.99933759
10(Layer I)	0.01443989	0.98556010	0.99979148
11(Layer I)	0.00944767	0.99055232	0.99991074
12(Layer I)	0.01306646	0.98693353	0.99982926
13(Layer I)	0.03343351	0.96656648	0.9988822
14(Layer I)	0.02026625	0.97973374	0.99958927
15(Layer I)	0.04465782	0.95534217	0.99800567
16(Layer I)	0.00703346	0.99296653	0.99995053
17(Layer I)	0.00383299	0.99616700	0.99998530
18(Layer I)	**0.00101434**	**0.99898565**	**0.99999897**
19(Layer I)	0.00682933	0.99317066	0.99995336
20(Layer I)	0.00849761	0.99150238	0.99992779

Khazaei et al. [14] used ANN technique for yield estimation and clustering of chickpea. Their ANN model predicted 90.3% of the yield data with relative errors ranging between ±5%. Izadifar and Abdolahi [15] dried *Curcuma amada* (Mango ginger) at four different power levels ranging 315–800 W to determine the effect of microwave power on moisture content, moisture ratio, drying rate, drying time and effective diffusivity. An ANN using backpropagation algorithm was employed to predict the moisture content during microwave drying. It was found to be quite adequate for predicting the drying kinetics with R^2 of 0.985. Pandey et al. [16] established a radial basis function neural network (RBFNN) model for the retrieval of crop parameters of spinach. It was noted that retrieved parameters were so close to the experimental results that confirmed the potential of RBFNN as estimator. The main advantages of RBFNN over other theoretical approaches are that it is less time taking and less complex approach.

We developed cascade ANN models with single hidden layers for predicting the shelf life of processed cheese stored at 7-8ºC. The best results of cascade model with single hidden layer having 18 neurons were RMSE: *0.00101434*, R^2: 0.99898565 and E^2:0.99999897 (Table 1). The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for single and multiple hidden layer models are illustrated in Fig.2.

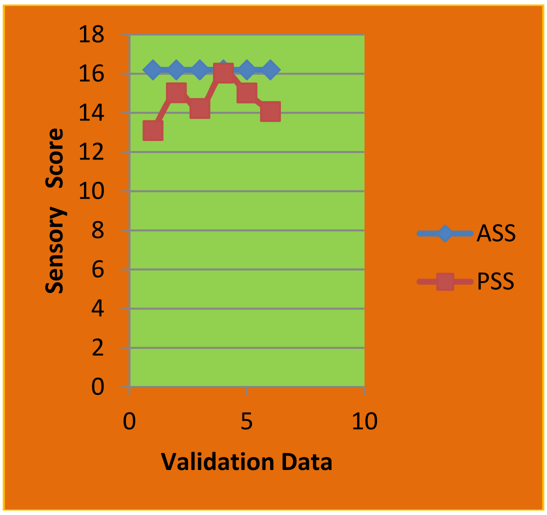

Figure 2. Comparison of ASS and PSS single layer model

Several experiments were performed, as there is no defined method to reach to a good conclusion other than hit and trial approach. Different constituents of threshold functions were used in layers, combination of *TANSIG-TRAINBR-PURELIN* as threshold function and Bayesian regularization as learning algorithm was finally selected. Cascade ANN model with single hidden layer having 18 neurons predicted the shelf of processed cheese very well.

V. Conclusion

Cascade single hidden layer ANN models were developed for predicting the shelf life of processed cheese stored at 7-8ºC. Cascade model with single hidden layer having 18 neurons gave best RMSE: 0.00101434, indicating that the cascade ANN models simulated the shelf life of processed cheese very efficiently. Based on these results, it is concluded that cascade models are excellent tool for predicting the shelf life of processed cheese.

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