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Estimating Processed Cheese Shelf Life with Artificial Neural Networks

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ABSTRACT

Cascade multilayer artificial neural network (ANN) models were developed for estimating the shelf life of processed cheese stored at 7-8^{o}C.Mean square error , root mean square error,coefficient of determination and nash - sutcliffo coefficient were applied in order to compare the prediction ability of the developed models.The developed model with a combination of 5→16→16→1 showed excellent agreement between the actual and the predicted data , thus confirming that multilayer cascade models are good in estimating the shelf life of processed cheese.

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1. INTRODUCTION

1.1 Artificial Neural Network (ANN)

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].

1.2 Multilayers

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 backpropagation, where 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].

1.3 Cascade Models

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. 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 [3].

1.4 Shelf Life

Shelf life studies can provide important information to product developers enabling them to ensure that the consumer will get a high quality product for a significant period of time after production. Since much time taking shelf life studies in the laboratory do not fit with the speed requirement, hence new accelerated studies [4] based on artificial neural networks have been innovated.

1.5 Processed Cheese

Processed cheese is very popular dairy product which is made from medium ripened Cheddar cheese, and sometimes a part of ripened cheese is replaced by fresh cheese. During its manufacture some amount of water, emulsifiers, extra salt, preservatives, food colorings and spices (optional) are added, and the mixture is heated to 70º C for 10-15 minutes with steam in a cleaned double jacketed stainless steel kettle (which is open, shallow and round-bottomed) with continuous gentle stirring (about 50-60 circular motions per minute) with a flattened ladle in order to get unique body & texture and consistency in the product.The main aim of this research is to develop multilayer cascade ANN models for estimating the shelf life of processed cheese stored at 7-8ºC.

2. REVIEW OF LITERATURE

Application of ANN has been impelemented for following various dairy products and milk based sterilized drinks:

2.1 Cakes

Cascade Neural Network (CNN) and Probabilistic Neural Network (PNN) models were developed. 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, Root Mean Square Error, Coefficient of determination and Nash - Sutcliffo Coefficient were used in order 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 detection of cakes [5].

2.2 Soft cakes

Elman and self organizing simulated neural network models were developed. 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 [6].

2.3 Kalakand

Cascade ANN models were developed and compared with each other for predicting the shelf life of Kalakand, which is dessicated milk based sweetmeat [7]. 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°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 developed. 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 [8].

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 [9]. The comparison of the two neural network models showed that the feedforward backpropagation model is better than Cascade forward artificial intelligence model in 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 [10].

2.6 Milky white dessert jeweled with pistachio

Artificial neural networks for predicting the shelf life of milky white dessert jeweled with pistachio were applied [11]. 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% were used 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 artificial neural networks 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 predicted by developing artificial neural network based radial basis (exact fit) and radial basis (fewer neurons) models, and the developed models were compared with each other. Both the developed models predicted the shelf life of the product exceedingly well [12]. 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 artificial neural network 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 developed for predicting shelf life of soft mouth melting milk cakes stored at 6°C.The outcome of the study revealed that intelligent computing expert system models are efficient in predicting the shelf life of soft mouth melting milk cakes [13].

2.9 Post-harvest roasted coffee sterilized milk drink

Artificial intelligence neural network Elman model was developed for predicting shelf life of roasted coffee sterilized cow milk drink stored at 30°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). Regression equations were developed to estimate shelf life of the roasted coffee sterilized cow milk drink. The predicted shelf life was found to be 37.80 days, which was within the experimentally obtained shelf life of 45 days, suggesting that the product is acceptable. From the study it was concluded that artificial intelligence models are quite effective in predicting the shelf life of roasted coffee sterilized cow milk drink stored at 30° C [14].

3. METHOD AND MATERIAL

The input variables used in the ANN were the experimental data of processed cheese relating to soluble nitrogen, pH; standard plate count, yeast & mould count, and spore count. The sensory score assigned by the trained panelists was taken as output variable for developing computing models (Fig.1). Experimentally obtained 36 observations for each input and output variables were used for developing the models. The dataset was randomly divided into two disjoint subsets, namely, training set having 30 observations (80% for training), and validation set having 6 observations (20% for testing). 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 applied in order to compare the prediction ability of the developed models.

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

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

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

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

Where, $Q_{\exp}$ = Observed value; Q_{cal} = Predicted value; $\overline{Q}_{\exp}$ =Mean predicted value; n = Number of observations in dataset.

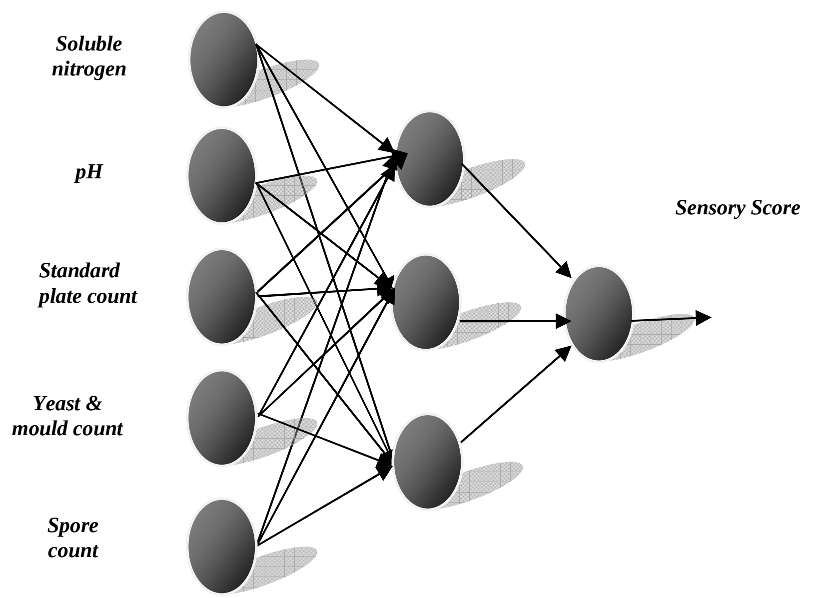

Figure1. Input and output parameters for ANN models

The ANN was trained with multiple hidden layers, and transfer function for hidden layers was *tangent sigmoid*, while for the output layer it was *pure linear* function. MALTAB software was used for performing the experiments.

4. RESULTS AND ANALYSIS

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

Table 1. Performance of cascade model for predicting sensory score

Neurons	MSE	RMSE	R^2	E^2
3:3	0.000199014	0.014107246	0.985892754	0.999800986
4:4	5.87289E-05	0.007663476	0.992336524	0.999941271
5:5	0.000119453	0.010929462	0.989070538	0.999880547
6:6	0.000105146	0.010254088	0.989745912	0.999894854
7:7	0.000148338	0.012179407	0.987820593	0.999851662
8:8	0.000207203	0.014394532	0.985605468	0.999792797
9:9	0.000190365	0.01379728	0.98620272	0.999809635
10:10	9.99409E-05	0.009997043	0.990002957	0.999900059
11:11	6.93684E-05	0.008328769	0.991671231	0.999930632
12:12	0.000146441	0.012101286	0.987898714	0.999853559
13:13	0.000224225	0.014974144	0.985025856	0.999775775
14:14	0.000163952	0.01280438	0.98719562	0.999836048
15:15	0.000196887	0.014031645	0.985968355	0.999803113
16:16	**1.04537E-05**	**0.003233226**	**0.996766774**	**0.999989546**
17:17	0.000130897	0.011441032	0.988558968	0.999869103
18:18	6.3375E-05	0.007960842	0.992039158	0.999936625
19:19	8.91157E-05	0.009440112	0.990559888	0.999910884
20:20	9.209E-05	0.009596355	0.990403645	0.99990791

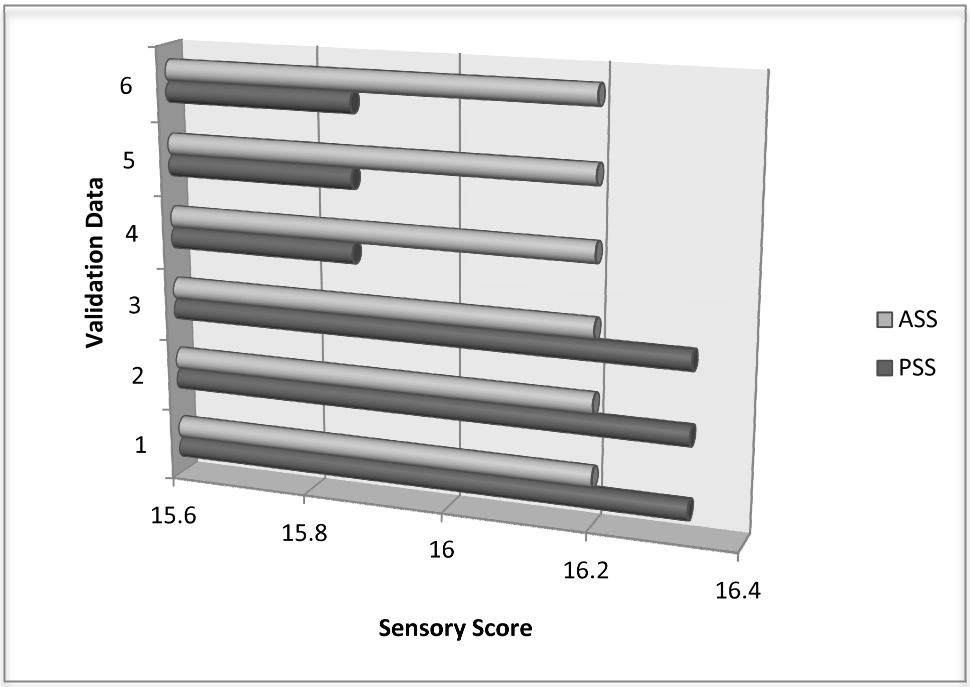

Figure 2. Comparasion of ASS and PSS for multilayer cascade model

The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for cascade multilayer ANN model are illustrated in Fig.2 Cascade multilayer model was developed for estimating shelf life of processed cheese stored at 7-8^o C.Several experiments were conducted (Table 1) and it was observed that 5→ 16→ 16→ 1 combination gave the best results (MSE: 1.04537E-05; RMSE: 0.003233226; R^2: 0.996766774; E^2: 0.999989546). From these results it is clear that cascade multilayer model with 5→ 16→

16→ 1 combination predicted shelf life of processed cheese very well, as value obtained for RMSE is less than 1% and values of R^2, E^2 are quite high showing very good correlation between the actual and predicted data.

5. CONCLUSION

Cascade multilayer ANN models were developed for estimating the shelf life of processed cheese stored at 7-8^o C. The input variables consisted of soluble nitrogen, pH; standard plate count, yeast & mould count, and spore count, while the output variable was sensory score. The results of the research established very good correlation between the actual data and the predicted values, with a high determination coefficient, nash - sutcliffo coefficient establishing that the developed cascade multilayer ANN models are able to analyze non-linear multivariate data with excellent performance.From the study it is concluded that the multilayer cascade models estimated the shelf life of processed cheese very well.

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