Time-Delay Artificial Neural Network Computing Models for Predicting Shelf Life of Processed Cheese

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Abstract

This paper presents the capability of Time–delay artificial neural network models for predicting shelf life of processed cheese. Datasets were divided into two subsets (30 for training and 6 for validation). Models with single and multi layers were developed and compared with each other. Mean Square Error, Root Mean Square Error, Coefficient of Determination and Nash - Sutcliffo Coefficient were used as performance evaluators, Time- delay model predicted the shelf life of processed cheese as 28.25 days, which is very close to experimental shelf life of 30 days.

Keywords: Time – delay, ANN, Artificial Intelligence, Processed Cheese, Shelf Life, Prediction

1. Introduction

This paper highlights the significance of Artificial Neural Network (ANN) models for predicting shelf life of processed cheese stored at 30^{o}C. ANN is inspired by the functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase [1].Processed cheese is very nutritious and generally manufactured from ripened Cheddar cheese, but sometimes less ripened Cheddar cheese is also added in lesser proportion. Its manufacturing technique includes addition of emulsifier, salt, water and sometimes selected spices. The mixture is heated in jacketed vessel with continuous stirring in order to get homogeneous mass. It is a protein rich food. This variety of cheese has several advantages over raw and ripened Cheddar cheese, such as excellent supplement to meat protein, tastier with longer shelf life.

Time-Delay Neural Network (TDNN) is an alternative neural network architecture whose primary purpose is to work on continuous data. The advantage of this architecture is to adapt the network online and hence helpful in many applications. The architecture has a continuous input that is delayed and sent as an input to the neural network [2]. In this study, TDNN's models with single and multilayer layers for predicting shelf life of processed cheese have been developed.

Single Layer

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). Neurons with this kind of activation function are also called artificial neurons or linear threshold units [3].

Multilayer

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].

Shelf Life

Shelf life is the length of time given before a product is considered unsuitable for sale, use, or consumption. In some regions, a best before, use by or freshness date is required on packaged perishable foods. 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]. ANNs have been applied for predicting shelf life of Kalakand [5], milky white dessert jeweled with pistachio [6], and instant coffee flavoured sterilized drink [7, 8]. Time-Delay and Linear Layer ANN models were developed for predicting shelf life of soft mouth melting milk cakes [9], soft cakes [10]. Radial Basis models were successfully applied for predicting shelf life of Brown milk cakes [11]. The aim of this study is to develop TDNN single and multilayer models for predicting shelf life of processed cheese stored at 30^{o}C, and to compare the developed models with each other. The outcome of this research would be very useful for cheese manufacturers, retailers, consumers and researchers.

2. Method Material

The data consisted of 36 samples, which were divided into two subsets, *i.e.,* 30 used for training the network and 6 for testing the TDNN models. 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 TDNN single and multilayer models (Fig.1).

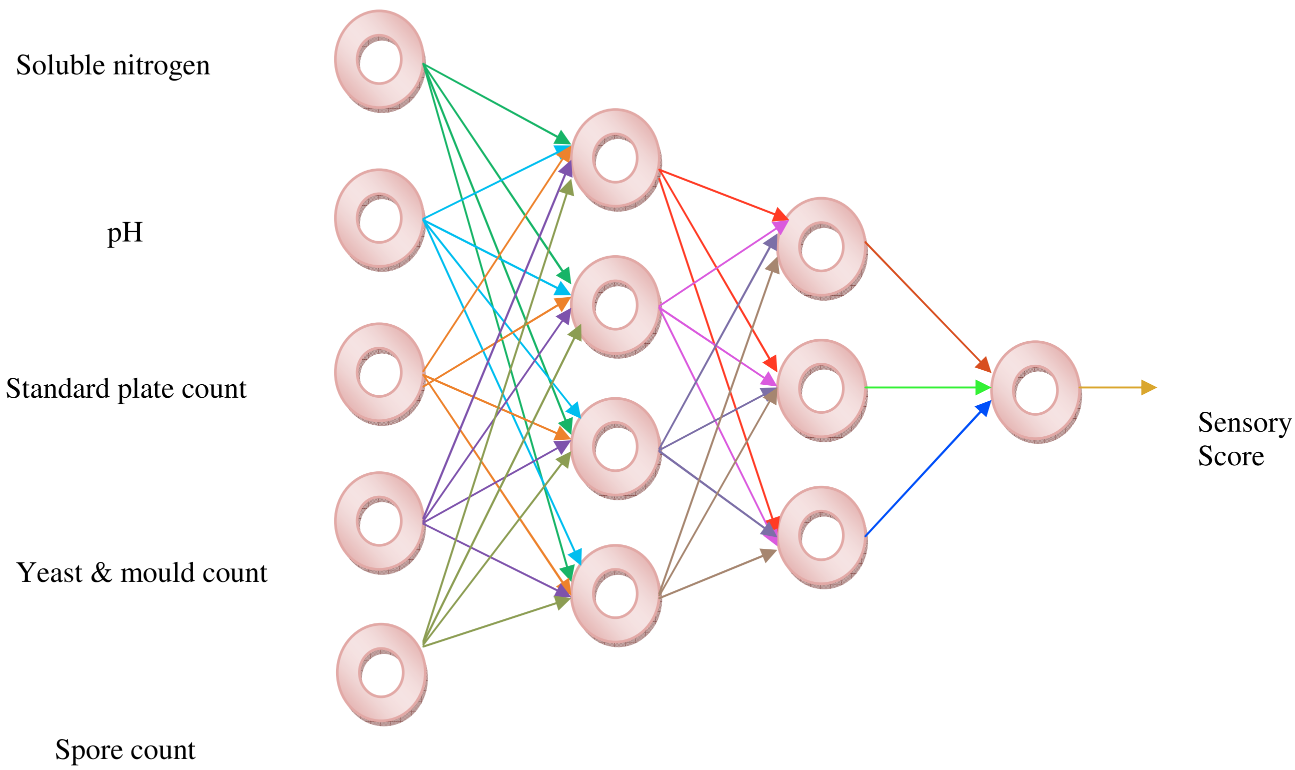

Figure 1. Inputs and output parameters for TDNN models

Many 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. Several algorithms like *Bayesian regularization, Levenberg Marquardt algorithm, Gradient Descent algorithm with adaptive learning rate, Powell Beale restarts conjugate gradient algorithm* and *BFG quasi-Newton* algorithms were tried. Backpropagation algorithm based on *Bayesian regularization* was finally selected for training the networks, as it gave most promising results. TDNN was trained up to 100 epochs with single as well as multiple hidden layers. Transfer function for hidden layer was *tangent sigmoid* while for the output layer, it was *pure linear* function.

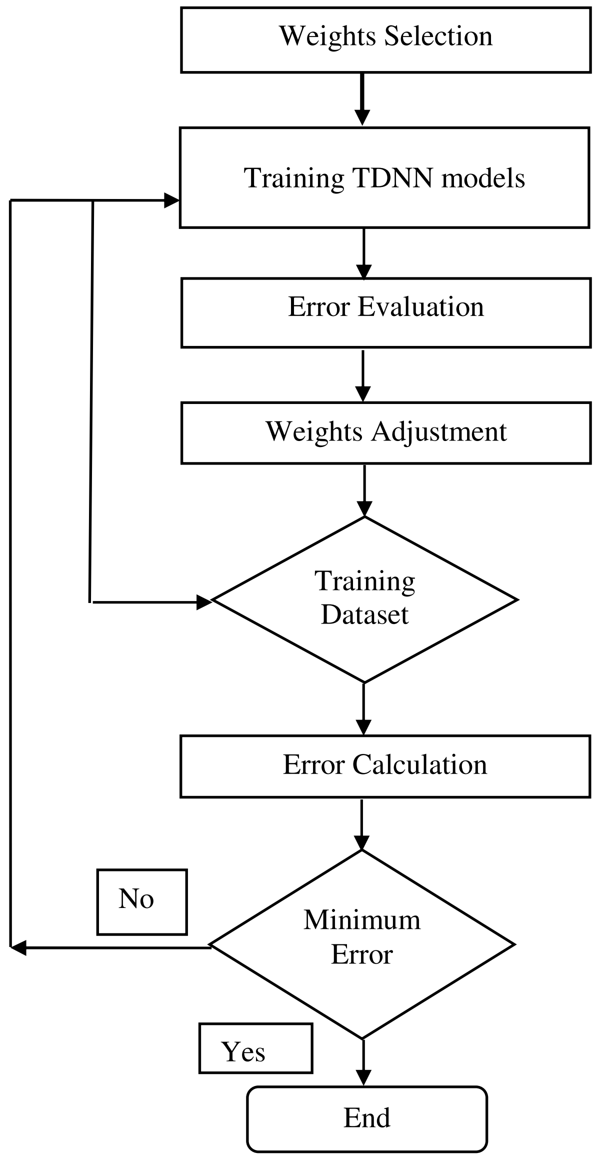

Figure 2. Training pattern of TDNN models

The Neural Network Toolbox under MATLAB software was used for developing the TDNN models. Training pattern of TDNN models is presented in Fig.2.

Measures for Prediction Performance

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

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

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

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

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

TDNN model's performance matrices for predicting sensory scores are presented in Table 1 and Table 2, respectively.

Table 1. Performance of single layer for predicting sensory score

Neurons	MSE	RMSE	R^2	E^2
3	3.01226E-05	0.005488403	0.994511597	0.999969877
5	0.000128522	0.011336741	0.988663259	0.999871478
6	0.00019086	0.013815219	0.986184781	0.99980914
8	0.000177938	0.013339332	0.986660668	0.999822062
10	***1.20278E-06***	***0.001096714***	***0.998903286***	***0.999998797***
12	2.41185E-05	0.004911058	0.995088942	0.999975882

14	3.46851E-05	0.005889404	0.994110596	0.999965315
15	0.00021437	0.014641378	0.985358622	0.99978563
16	0.001314906	0.036261628	0.963738372	0.998685094
18	0.000840727	0.028995291	0.971004709	0.999159273
20	8.5198E-05	0.009230276	0.990769724	0.999914802
24	8.91481E-06	0.002985769	0.997014231	0.999991085
30	9.62368E-05	0.009810037	0.990189963	0.999903763

Table 2. Performance of multilayer for predicting sensory score

Neurons	**MSE**	**RMSE**	**R^2**	**E^2**
3:3	4.67356E-05	0.006836347	0.993163653	0.999953264
4:4	2.77834E-05	0.005270993	0.994729007	0.999972217
5:5	3.40619E-05	0.00583626	0.99416374	0.999965938
7:7	0.000428285	0.020695048	0.979304952	0.999571715
8:8	2.18493E-05	0.004674322	0.995325678	0.999978151
9:9	0.000160167	0.012655697	0.987344303	0.999839833
10:10	***1.3025E-05***	***0.003609012***	***0.996390988***	***0.999986975***
11:11	0.000266194	0.016315438	0.983684562	0.999733806
12:12	4.47103E-05	0.006686576	0.993313424	0.99995529
13:13	0.000111797	0.010573389	0.989426611	0.999888203
14:14	0.000112257	0.01059513	0.98940487	0.999887743
15:15	0.00022446	0.014981988	0.985018012	0.99977554
16:16	9.56217E-05	0.009778634	0.990221366	0.999904378

TDNN single and multilayer models were developed; for single layer TDNN model with 10 neurons, the best performance was **MSE:** ***1.20278E-06***, **RMSE:** ***0.001096714***, **R^2:** ***0.998903286***, **E^2:** ***0.999998797***; while for the multilayer combination of 10:10 neurons **MSE:** ***1.3025E-05***, **RMSE:** ***0.003609012***, **R^2:** ***0.996390988***, **E^2:** ***0.999986975*** performed the best. On comparing them with each other, it was observed that single layer TDNN model performed better. Therefore, it was selected for predicting the shelf life of processed cheese. The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for single layer and multilayer models are illustrated in Fig.3 and Fig.4, respectively.

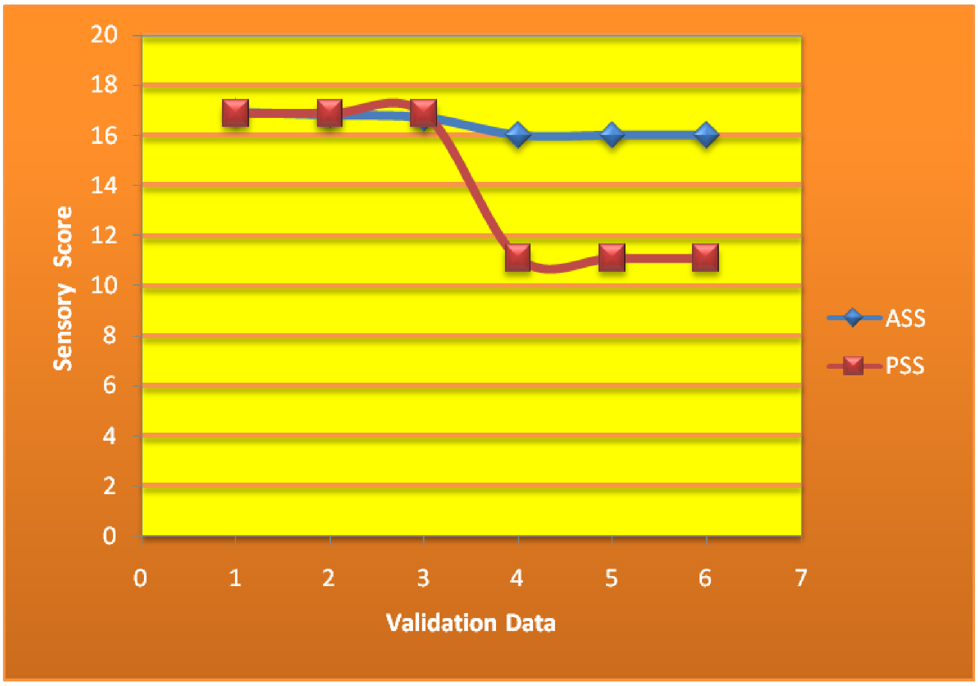

Figure 3. Comparison of ASS and PSS single layer model

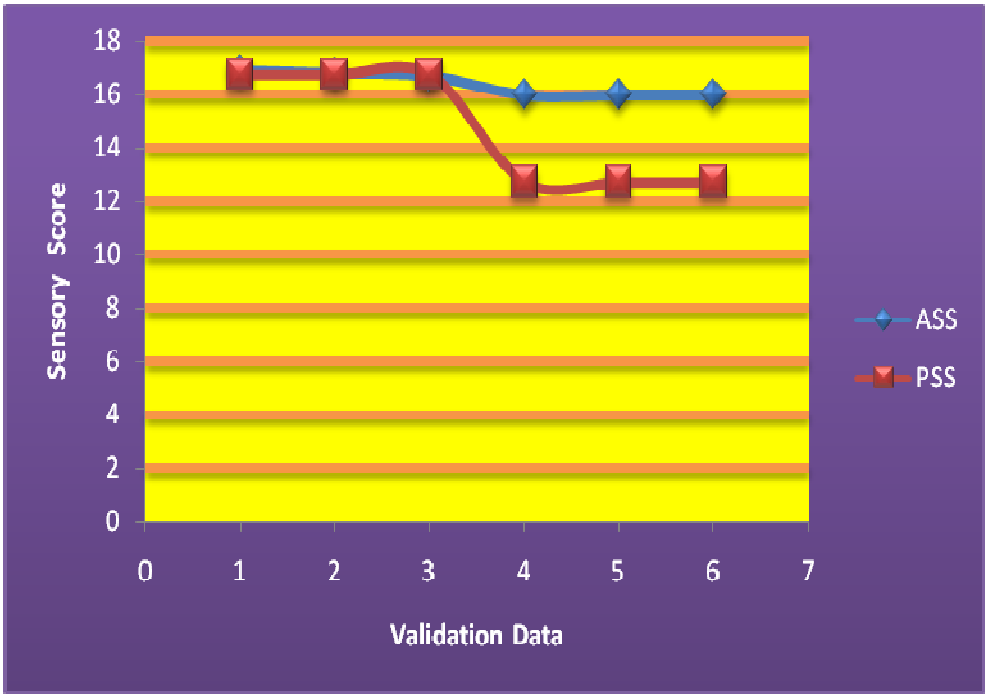

Figure 4. Comparison of ASS and PSS for multilayer model

R^2 was found to be 96.5 percent of the total variation as explained by sensory scores. Period of storage (days) for which the processed cheese has been in the shelf can be determined based on sensory score (Fig. 5).

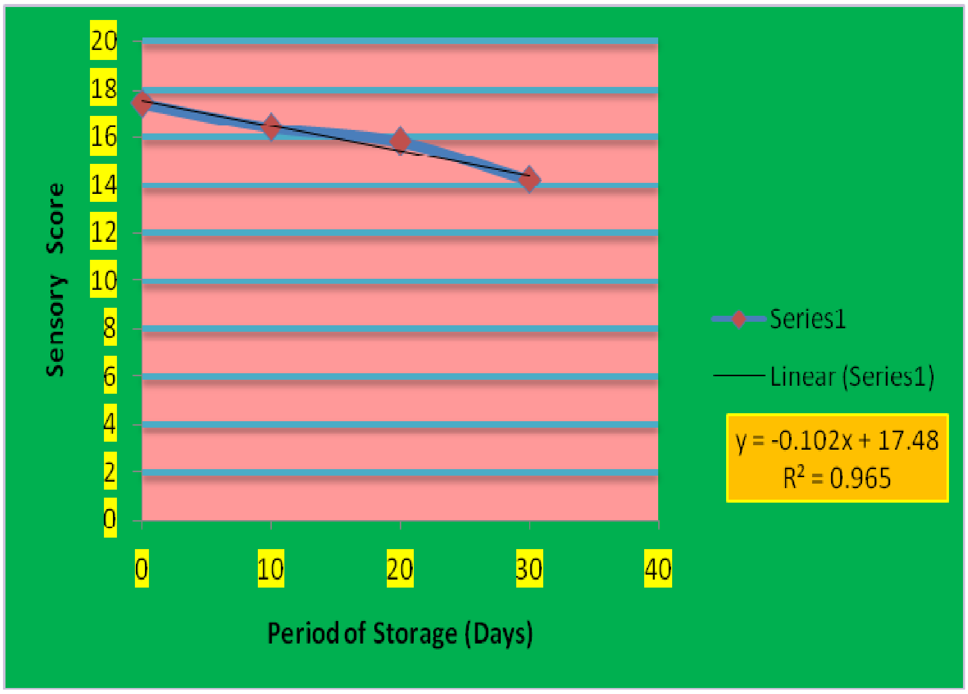

Figure 5. Sensory score and period of storage for processed cheese

The shelf life is calculated by subtracting the obtained value of days from experimentally determined shelf life, which was found to be 28.25 days. The predicted value is slightly higher than the experimentally obtained shelf life of 30 days.

4. Conclusion

TDNN models with single and multi layers were developed taking soluble nitrogen, pH, standard plate count, yeast & mould count, spore count as input parameters, and sensory score as output parameter for predicting the shelf life of processed cheese stored at 30^o C. Mean Square Error, Root Mean Square Error, Coefficient of Determination and Nash - Sutcliffo Coefficient were used in order to compare the prediction ability of the developed TDNN models. Regression equations were developed for predicting the shelf life of processed cheese, which came out as 28.25 days. Since, predicted value is close to the experimentally determined shelf life of 30 days, hence from the study it can be concluded that TDNN artificial neural network models are quite efficient in predicting shelf life of processed cheese.

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