Development of Intelligent Computing Expert System Models for Shelf Life Prediction of Soft Mouth Melting Milk Cakes

Sumit Goyal
Senior Research Fellow
National Dairy Research Institute,
Karnal-132001 (Haryana), India

Gyanendra Kumar Goyal
Emeritus Scientist
National Dairy Research Institute,
Karnal-132001 (Haryana), India

ABSTRACT
Soft mouth melting milk cakes from water buffalo milk were prepared by using milk collected from Experimental Dairy, National Dairy Research Institute, Karnal, India. This milk was standardized to 6% fat. 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^{o}C. Linear layer (design) model gave best outcomes **(MSE: 0.000293366, RMSE: 0.017127919, R^2: 0.996479613)**. Regression equations were developed based on these outcomes, shelf life was predicted 49.54 days. The predicted value is close to the experimentally obtained shelf life of 50 days. Therefore, from the study it is concluded that intelligent computing expert system models are effective tool predicting the shelf life of soft mouth melting milk cakes.

General Terms
Artificial Neural Networks, Neurons, Prediction

Keywords
Intelligent Computing, Artificial Neural Networks, Time-Delay, Linear layer (Design), Shelf Life Prediction, Cakes.

1. INTRODUCTION
Soft mouth melting milk cakes from water buffalo milk were prepared by using milk collected from Experimental Dairy, National Dairy Research Institute, Karnal, India. The milk was standardized to 6% fat. The sweetmeat was manufactured in a double jacketed stainless steel kettle, and stored at 6^{o}C. Soft mouth melting milk cakes are awesome sweetmeat cuisine made out of heat and acid thickened solidified sweetened milk. The dataset of soft mouth melting milk cakes samples used in the study relate to sensory evaluation at regular intervals by a panel of well trained sensory judges, and changes in physicochemical characteristics, *viz.*, moisture, titratable acidity, free fatty acids, tyrosine, peroxide value and overall acceptability score. Expert system computing model performs a task that would otherwise be performed by a human expert. Expert system computing models are artificial neural networks based on biological neural network.

1.1 TIME - DELAY
The most straightforward dynamic network, which consists of a feedforward network with a tapped delay line at the input. This is called time-delay neural network. This is part of a general class of dynamic networks, called focused networks, in which the dynamics appear only at the input layer of a static multilayer feedforward network.

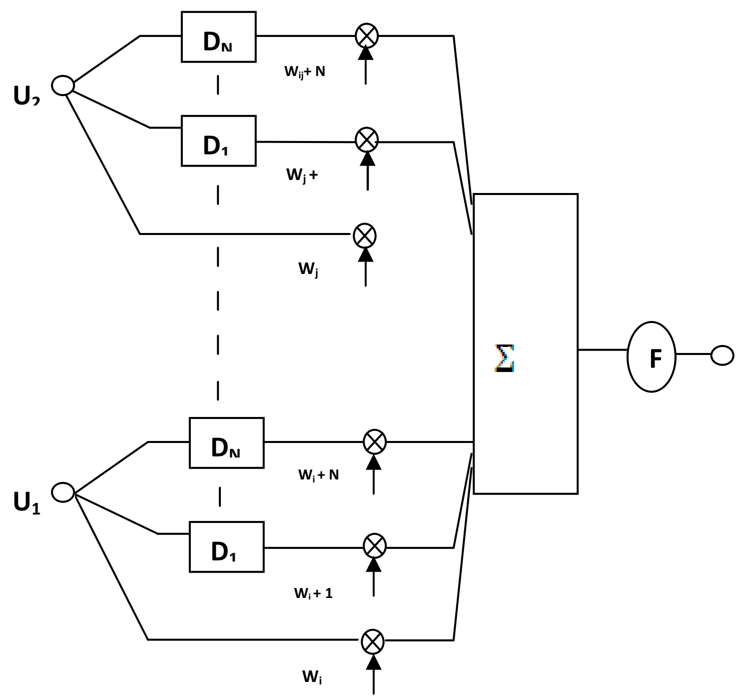

Fig. 1. Architecture of time – delay model

This network is well suited to time-series prediction. Fig.1 illustrates architecture of time-delay artificial neural network [1].

1.2 LINEAR LAYER (DESIGN)
Linear layers are single layers of linear neurons. They may be static, with input delays of 0, or dynamic, with input delays greater than 0. They can be trained on simple linear time series problems, but often are used adaptively to continue learning while deployed so they can adjust to changes in the relationship between inputs and outputs while being used [2]. Sofu and Ekinci [3] developed neurocomputing model using back-

propagation learning algorithm for prediction of shelf life of set-type whole-fat and low-fat yoghurts, and found that the soft computing model was able to analyze nonlinear multivariate data with very good performance, fewer parameters and shorter calculation time; Goñi *et al.* [4] trained and validated a feedforward neurocomputing model using experimental values of freezing and thawing times of foods and test substances of different geometries, and found that neurocomputing model provided a simple and accurate prediction method for freezing and thawing times. Goyal and Goyal [5] developed artificial neural engineering and regressions models for forecasting shelf life of instant coffee drink. Artificial Neural Network (ANN) predicts soya bean equilibrium moisture content more accurately than mathematical model [6]. The ANN predicted shelf lives, agreed very well with actual shelf life data pertaining to rice snacks, and neurocomputing could be used as an alternative method for shelf life prediction of moisture-sensitive food products [7]. Presently, the consumers are extremely conscious about quality of the foods they buy. Regulatory agencies are also very vigilant about quality and safety issues and insist on the manufacturers adhering to the label claims about quality and shelf life. Such discerning consumers, therefore, pose a far greater challenge in product development and marketing. The development of intelligent computing expert system models for predicting shelf life of popular food product, *i.e.,* soft mouth melting milk cakes would be extremely beneficial to the manufactures, retailers, consumers and regulatory agencies from the quality, health and safety points of view. Till date there is no research done on predicting shelf life of soft mouth melting milk cakes using intelligent computing expert system models. The main aim of this study is to develop intelligent computing expert system models of time-delay backpropagation and linear layer (design) and to compare them with each other for predicting shelf life soft mouth melting milk cakes.

2. MATERIAL AND METHODS

2.1. DATA MODELLING

The dataset comprised of experimental 60 observations. The dataset was randomly divided into two disjoint subsets, namely, training set containing 48 observations (80% of total observations) and test set consisted of 12 observations (20% of total observations).

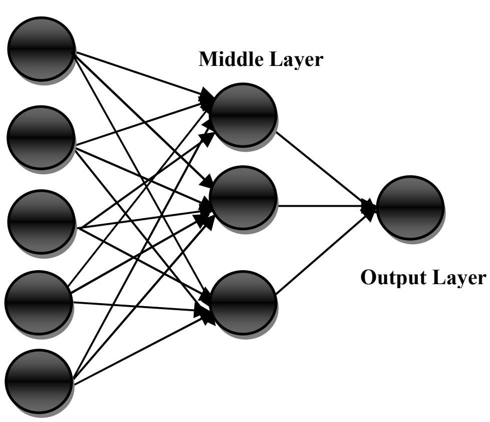

Fig. 2. Structure of intelligent computing expert system

Moisture, titratable acidity, free fatty acids, peroxide value and tyrosine were used as input parameters. The Overall acceptability was used as output parameter for developing the expert computing models. The structure of intelligent computing expert system is presented in Fig.2. The performance of expert system computing models were evaluated using Root Mean Square Error (RMSE) Eq. (1), Mean Square Error (MSE) Eq. (2) and R^2 Eq. (3) technique. The following criterion of root mean square error has defined to minimize the training error [1].

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

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

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

$Q_{\exp}$ = Observed value; Q_{cal} = Predicted value; n = Number of observations in dataset. The best score for R^2 measure is 1 and for other measures is zero.

3. RESULTS AND DISCUSSION

Time-Delay Backpropagation model performance matrices for predicting sensory scores are presented in Table 1.

Table 1: Performance of time-delay model with single hidden layer for predicting overall acceptability score

Neurons in Hidden Layer	MSE	RMSE	R^2
3	0.001794296	0.042359133	0.978468446
4	0.001494813	0.038662817	0.982062239
5	0.001472407	0.038371959	0.982331113
6	0.001466934	0.038300575	0.982396791
7	0.001462429	0.038241718	0.982450852
8	0.005460098	0.073892475	0.934478825
9	0.001883088	0.043394558	0.977402948
10	0.001754438	0.041886009	0.978946747
12	0.003404096	0.058344628	0.959150853
14	0.001453493	0.038124707	0.982558081
16	0.007433312	0.086216655	0.910800262
18	0.001526811	0.039074427	0.981678269
20	**0.001332342**	**0.036501259**	**0.984011897**

Table 2: Performance of time-delay model with double hidden layer for predicting overall acceptability score

Neurons in Hidden Layer	MSE	RMSE	R^2
2:2	0.001441941	0.037972892	0.982696714
3:3	0.002207148	0.046980295	0.973514222
5:5	0.007352893	0.085749014	0.91176528
7:7	0.020382287	0.142766547	0.755412558
8:8	**0.001318004**	**0.036304329**	**0.984183948**
10:10	0.007115042	0.084350711	0.914619491
12:12	0.002024871	0.044998564	0.975701551
15:15	0.000878033	0.029631624	0.989463602
18:18	0.010986169	0.104814929	0.868165969
20:20	0.001923635	0.043859261	0.976916383

Table 3: Performance of linear layer (design) model for predicting overall acceptability score

MSE	RMSE	R^2
0.000293366	**0.017127919**	**0.996479613**

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 results of time-delay model with single hidden layer, double hidden layer and linear layer (design) are illustrated in table 1, 2, and 3 respectively. The best results for time-delay model with single hidden layer having 20 neurons are **MSE: 0.001332342, RMSE: 0.036501259, R^2: 0.984011897** for time-delay model with double hidden layers having 8 neurons in the first and second layers **MSE: 0.001318004, RMSE: 0.036304329, R^2: 0.984183948**. Best results for linear layer (design) model are **MSE: 0.000293366, RMSE: 0.017127919, R^2: 0.996479613**.

Table 4: Comparison of best results of three models

Model	MSE	RMSE	R^2
time-delay single hidden layer	0.001332342	0.036501259	0.984011897
time-delay double hidden layers	0.001318004	0.036304329	0.984183948
linear layer (design)	**0.000293366**	**0.017127919**	**0.996479613**

The best results of the developed 3 models were compared with each other (Table 4) and it was observed that linear layer (design) model gave the finest results. Actual overall acceptability score (AOAS) and predicted overall acceptability score (POAS) for the developed models are graphically represented in Fig. 3, 4 and 5, respectively.

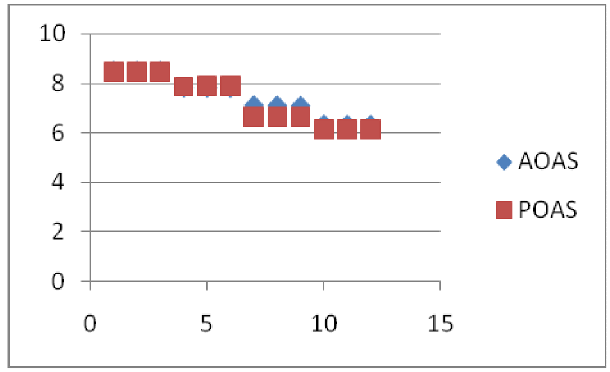

Fig.3. Graphical representation of AOAS and POAS for time- delay model with one hidden layer

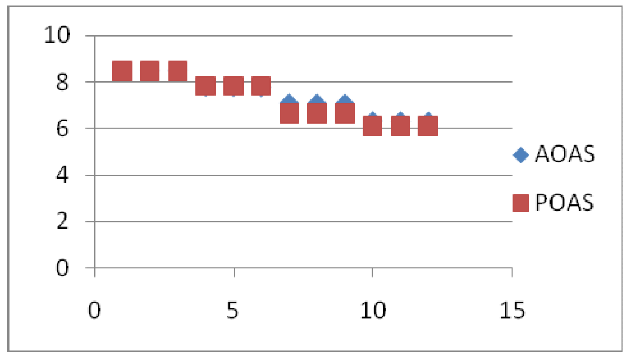

Fig.4.Graphical representation of AOAS and POAS for time-delay model with two hidden layers

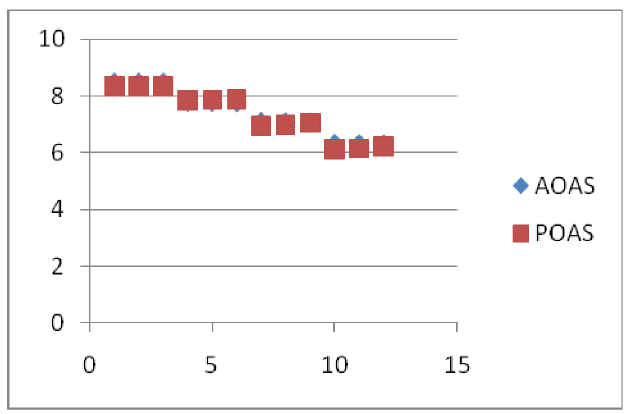

Fig.5. Graphical representation of AOAS and POAS for linear layer(design) model

3.1. SHELF LIFE PREDICTION

Based on the best results given by intelligent computing expert system linear layer (design) model **(MSE: 0.000293366, RMSE: 0.017127919, R^2: 0.996479613)**, regression equations were developed to predict shelf life of the soft mouth melting milk cakes, *i.e.*, in days (*d*) for which product has been in the shelf, based on sensory score (Fig.6). The soft mouth melting milk cake was stored at 6°C taking storage intervals (in days) as dependent variable and overall acceptability score as independent variable.

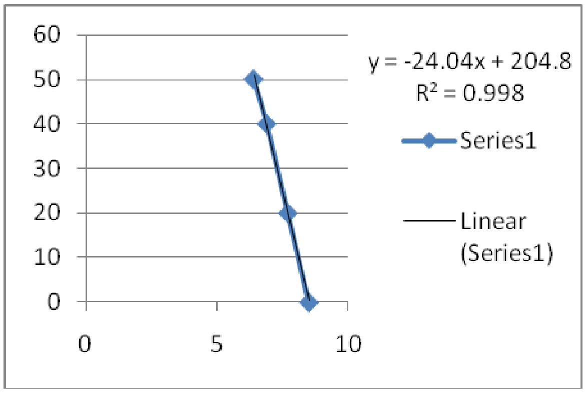

Fig.6. Displaying regression equations

R^2 was found to be 99 percent of the total variation as explained by sensory scores. For instance, the time period (in days) for which the product has been in the shelf can be predicted for an arbitrary overall acceptability score of 8.5 for soft mouth melting milk cake stored at 6 ^oC. Now, the shelf life is computed by subtracting the above obtained value of *d* from experimentally determined shelf life, which was found 49.54 days. Since, this value is within the experimentally obtained shelf life of 50 days, hence the product should be accepted. Thus, the study reveals that intelligent computing expert systems are quite effective in predicting shelf life of soft mouth melting milk cakes stored at 6^{o}C.

4. CONCLUSION

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^{o}C. The performances of the developed intelligent computing expert system models were compared with each other. Linear layer (design) model exhibited best results **(MSE: 0.000293366, RMSE: 0.017127919, R^2: 0.996479613)**. Further, regression equations were developed based on these results and shelf life was computed 49.54 days. Since the predicted value is close to the experimentally obtained shelf life of 50 days, therefore the product is acceptable. From the research, it is concluded that the developed expert system computing models are good in predicting shelf life of soft mouth melting milk cakes stored at 6^{o}C.

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