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Machine Learning Time-Delay Model for Analyzing Shelf Life of Burfi

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ABSTRACT

Time-Delay algorithm based multilayer artificial neural network models were developed for predicting the shelf life of burfi stored at 30ºC. Moisture, titratable acidity, free fatty acids, tyrosine and peroxide value of the product were input variables, and overall acceptability score was the output variable. Mean square error, root mean square error, coefficient of determination and Nash–Sutcliffe coefficient were used in order to compare the prediction potential of the developed models. The results showed that the time-delay multilayer models were able to analyze non-linear multivariate data with good performance, requiring fewer variables, and in less evaluation time.

Keywords:*Machine Learning, Artificial Intelligence, Artificial Neural Network, Burfi, MATLAB, Time-Delay*

1. INTRODUCTION

The aim of this research is to develop time -delayArtificial Neural Network (ANN) multilayer models and to compare them with each other for predicting the shelf life of burfi stored at 30ºC.

Burfi is very popular sweetmeat prepared by desiccatingstandardized water buffalo milk. In Indian subcontinent burfi is essentially and customarily served and consumed on all festive occasions and also during get-togethers, social gatherings like marriages and birthday parties. Though, several varieties of burfi such as cashew nut burfi, almond burfi, pistachio burfi, cardamom burfi, coconut burfi, doddaburfi and plain burfi are sold in the market, but the latter variety is most popular, which contains milk solids and sugar only. On the upper surface of the plain burfi pieces a very thin layer of an edible metallic silver leaf is coated**.**

The first Artificial Neural Network (ANN) was invented in 1958 by psychologist Frank Rosenblatt. It was intended to model how the human brain processed visual data and learned to recognize objects. Other researchers have since used similar ANNs to study human cognition. An ANN operates by creating connections between many different processing elements, each analogous to a single neuron in a biological brain. These neurons may be physically constructed or simulated by a digital computer. Each neuron takes many input signals, then, based on an internal weighting system, produces a single output signal that's typically sent as input to another neuron. The neurons are tightly interconnected and organized into different layers. The input layer receives the input; the output layer produces the final output [1].

Time-delay neural networks are special ANNs, which receive input over several time steps. Time-delay neural network 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 real time applications, like time series prediction, online spell check, continuous speech recognition, *etc.* The architecture has a continuous input that is delayed and sent as an input to the neural network [2, 3].

Shelf life studies 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 its production. The long shelf life studies in the laboratory do not fit with the speed requirement and therefore accelerated studies have been developed as part of innovation. As the mechanisms of food deterioration became known to food scientists, methods of counteracting these losses in quality have been developed.The increasing number of newly developed foods vie for space on supermarket shelves, the words “speed and innovation” have become the keywords for food companies seeking to become “first to market” with successful products. Market share, which goes to the pioneer of each successful new product keeps that company in an excellent competitive position. The overall quality of the product is most important in present competitive era and needs to be maintained into the speed and innovation system. The ultimate measure of overall good quality is that how the consumer perceives the product. Therefore, the quality built in during the development and manufacture process must last through the distribution and consumption stages [4].

Quality of potatoes in chips industry is estimated from the intensity of darkening during frying. This is evaluated by human experts, subject to numerous factors of variation. Gray level intensities were obtained for the apex, the center, and the basal parts of each chip using image analysis of frying assays. Feedforward ANN was designed and tested to associate these data with color categories [5]. The developed ANN showed good performance, learning from a relatively small number of data values. The ANN model behaved better than multiple linear regression analysis. Predicted categories appear to reproduce the pattern of the experimental data assigned by the expert panel, revealing nonlinear mapping, existence of sub regions and partial overlapping of categories. Moreover, the generalization capacities of the network allowed to simulate plausible predictions for the whole set of parameter combinations. Theresearchers opined that the present work is to be considered as a first step toward a practical ANN model that will be used for objective, precise, and accurate online prediction of chips quality.

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Ability of multilayer perceptron ANN and radial-basis function networks was studied to predict *ochratoxinA* concentration over time in grape-based cultures of *aspergilluscarbonarius* under different conditions of temperature, water activity (a_w) and sub-inhibitory doses of the fungicide carbendazim. The obtained results revealed that ANNs are useful tools that should be fully explored in the field of food safety [6].

A neural network to determine whether sweet red peppers are processed or not was developed [7]. The researchers used biocrystallogram images of sweet red peppers for this neural network model, since these images were taken from a lab bear information related to the process type of pepper. However, this information is not readily quantifiable and lacks uniquely recognizable features. Therefore, a neural network becomes appealing for classifying these images, because neural network is trainable. The optimal values for the neural network weights were estimated using the backpropagation algorithm. Experimental measurements of the pepper were utilized to train and test the process neural network. This network showed a remarkable 100% classification performance. Parallel classification performance was also achieved when training the neural network. The results suggested that neural networks are potentially useful for discriminating sweet red peppers processed by different methods. Furthermore, neural network renders practical advantages such as real-time processing, adaptability, and training capability.The workers were of the opinion that similar neural network designs could also be used in classification of food grains' images, detection of contaminated food products, evaluation of the surface quality of food raw materials, determination of quality features of foods, such as object recognition, geometrical parameters, and surface colour.

Brain based artificially intelligent scientific computing models have been implemented for shelf life detection of cakes stored at 30^{o} C [8]. In this study, Cascade Neural Network (CNN) and probabilistic neural network models were developed. Input variables were the product experimental data relating to 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–Sutcliffecoefficient were included in order to compare the prediction performance of the developed models.The best results of models were compared with each other, which showed that CNN model with single hidden layer having twenty five neurons was better for the shelf life detection of cakes.

The simulated neural network Elman and Self Organizing models were developed for predicting the shelf life of soft cakes stored at 10^{o}C. Moisture, titratable acidity, free fatty acids, tyrosine and peroxide value were input variables; while overall acceptability score was the output variable. The network was trained with single as well as double hidden layers; transfer function for hidden layer was tangent sigmoid, while for the output layer it was pure linear function. The investigation suggested that the simulated neural networks are excellent tools for predicting shelf life of soft cakes [9]. The efficiency of Cascade single and multiple hidden layer models was tested for shelf life prediction of Kalakand, a sweetened desiccated dairy product. For developing the models, the network was trained with 100 epochs. Cascade models with two hidden layers having twenty neurons in the first layer and twenty neurons in the second layer gave best result (MSE 0.000988770; RMSE: 0.03144471; R^2: 0.988125331) [10]. Radial Basis artificial neural engineering and multiple linear regression models forecasted the shelf life of instant coffee drink [11]. Cascade forward and Feedforward artificial intelligence models for predicting sensory quality of instant coffee flavoured sterilized drink were proposed. Several combinations of several internal parameters, *viz.*, data pre-processing, data partitioning, number of hidden layers, number of neurons in each hidden layer, transfer function, error goal, *etc.*, along with backpropagation algorithm based on Levenberg–Marquardt mechanism as training function were explored. The network was trained with 100 epochs. The number of neurons in each hidden layer varied from 1 to 20. The results of Cascade forward and Feedforward artificial intelligent models were evaluated with three types of prediction performance measures, *viz.*,root mean square error, coefficient of determination and mean square error. Feedforwardbackpropagation artificial intelligence model exhibited best results (3.70% RMSE; 0.998 R^2; 0.0013 MSE), followed by Cascade forward artificial intelligence model (5.36% RMSE; 0.996 R^2; 0.0028 MSE) for predicting sensory quality of instant coffee flavoured sterilized drink [12]. Artificial intelligent scientific models predicted the shelf life of instant coffee sterilized drink [13]. ANNs were implemented for predicting shelf life of milky white dessert jeweled with pistachio [14]. Time-delay and Linear layer (Design) expert system models detected the shelf life of soft mouth melting milk cakes [15]. The shelf life of brown milk cakes decorated with almonds was forecasted by Radial Basis (Exact Fit) and Radial Basis (Fewer Neurons) models [16]. ANNs also predicted the shelf life of post-harvest roasted coffee sterilized milk drink[17].

2. METHOD MATERIAL

The experimental data of stored product relating to changes in moisture, titratable acidity (TA), free fatty acids (FFA), tyrosine, and peroxide value (PV) were taken as input variables, and the overall acceptability score (OAS) assigned by the expert panelists was taken as output variable for developing the Time- delay multilayer models (Fig.1).

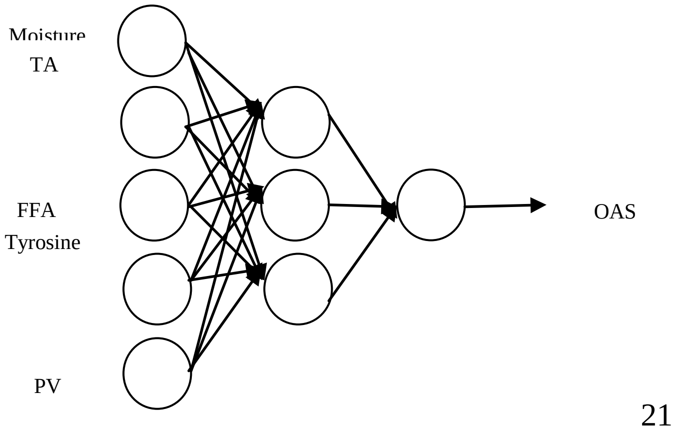

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Fig. 1. Input and output parameters of ANN model

In all 48 observations were used for developing the ANN models, which were divided into two disjoint subsets, *viz.*, training set having 40 observations and testing set 8 observations [16-20].Mean square error (MSE) (1), Root mean square error (RMSE) (2), Coefficient of determination: R^2 (3) and Nash–Sutcliffe coefficient: E^2 (4) were used in order to compare the prediction potential of ANN models [21-23].

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

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

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

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

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

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

n = Number of observations in dataset.

3. RESULTS AND DISCUSSION

ANN model's performance matrices for predicting OAS are presented in Table 1.

TABLE 1
RESULTS OF MULTILAYER TIME-DELAY ANN MODEL

Neurons	MSE	RMSE	R^2	E^2
3:3	0.000128637	0.01134183	0.988658168	0.999871363
4:4	0.000132031	0.01149048	0.988509515	0.999867969
5:5	1.70495E-06	0.001305737	0.998694263	0.999998295
6:6	6.57987E-05	0.00811164	0.99188836	0.999934201
7:7	4.28114E-06	0.00206909	0.997930909	0.999995719
8:8	5.29973E-06	0.00230211	0.997697885	0.9999947
9:9	1.75781E-06	0.00132582	0.998674175	0.99999824
10:10	4.75931E-06	0.00218158	0.997818415	0.99999524
11:11	3.30078E-07	0.00057452	0.999425476	0.99999967
12:12	2.25781E-06	0.00150260	0.998497398	0.99999774
13:13	3.08737E-05	0.00555641	0.99444358	0.99996912
14:14	0.00014508	0.01204492	0.98795507	0.99985492
15:15	2.18325E-05	0.00467252	0.99532747	0.99997816
16:16	4.05512E-05	0.00636797	0.99363202	0.99995944
17:17	4.39453E-05	0.00662912	0.99337087	0.99995605
18:18	1.04139E-06	0.00102048	0.99897951	0.99999895
19:19	**2.36328E-07**	**0.00048613**	**0.99951386**	**0.99999976**
20:20	4.94334E-07	0.00070308	0.99929691	0.99999950

The comparison of actual overall acceptability score (AOAS) and predicted overall acceptability score (POAS) for multilayer time-delay models are illustrated in Fig.2.

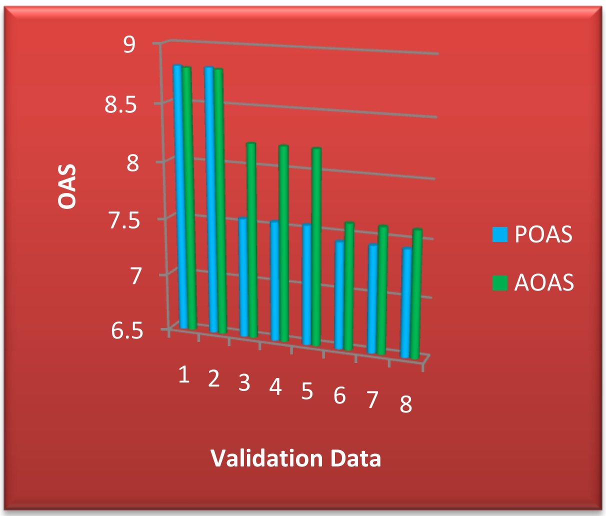

Fig.2. Comparasion of AOAS and POAS for time-delay model

From the results it can be seen (Table 1) that the multilayer Time-delay ANN model with 5→19→19→1 combination (**MSE**: 2.36328E-07; **RMSE**: 0.00048613; $\mathbf{R^2}$: 0.99951386; $\mathbf{E^2}$: 0.99999976) gave the best fit among all the performed experiments showing high correlation between the actual and the predicted data, suggesting that the developed multilayer Time- delay model is quite efficient in estimating the shelf life of burfi.

4. CONCLUSION

In the establishment of the prediction models moisture, titratable acidity, free fatty acids, tyrosine and peroxide valuewere input taken as input variables and the overall

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acceptability score as output variable.Mean square error, root mean square error, coefficient of determination and Nash–Sutcliffe coefficient were used in order to compare the prediction potential of the developed models. Several experiments were carried out and it was observed that the combination of 5→19→19→1 gave the best performance showing high correlation between the actual and the predicted variables.It is concluded that the developed multilayer models are good in predicting shelf life of burfi stored at 30°C.

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