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Predicting Shelf Life of Burfi through Soft Computing

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***Abstract* —** Soft computing cascade multilayer models were developed for predicting the shelf life of burfi stored at 30°C. The experimental data of the product relating to moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value were input variables, and the overall acceptability score was the output variable. The modelling results showed excellent agreement between the experimental data and predicted values, with a high determination coefficient (R^2 = 0.993499439) and low RMSE (0.006500561), indicating that the developed model was able to analyze nonlinear multivariate data with very good performance, and can be used for predicting the shelf life of burfi.

***Index Terms* —** Soft computing, artificial neural networks, artificial intelligence, burfi, shelf life prediction, cascade

I. INTRODUCTION

The approach of soft computing for predicting the shelf life of food products in food industry is quite recent. Soft computing techniques to food products were implemented mainly because the shelf life evaluation in the laboratory is very cumbersome, expensive, and time-consuming, while the soft computing procedure is sensitive, reliable, fast, simple and low-cost method for monitoring the authenticity of the products which provide consumers with a safer food supply. Soft computing models have been implemented in almost every field of science and engineering as they have proved useful tools for obtaining the desired output including the analyses and shelf life prediction in case of food products, which has been very beneficial for the food industry, consumers, wholesalers, retailers, regulatory agencies, food researchers and academicians. Soft computing has mainly three branches, artificial neural network (ANN), fuzzy logic and evolutionary computing. In the establishment of the predictive model, this study aims to develop cascade multilayer soft computing models for predicting the shelf life of burfi stored at 30°C.

ANNs over the years have given various solutions to different industries including food industry. Designing and implementing intelligent systems has become a crucial factor for the innovation and development of better products for society. Among the newest signal processing technologies nowadays, ANN is developed with a systematic step-by-step procedure which optimizes a criterion commonly known as the learning rule. Neural network is a parallel system, capable of resolving paradigms that linear computing cannot. An ANN is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. The input/output training data in ANNs is fundamental for these networks as it conveys the information which is necessary to discover the optimal operating point. In addition, non linear natures make neural network processing elements a very flexible system. Basically, an ANN is a system that receives an input, process the data, and provides an output [1].

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, 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 converges to a state where the error of the calculations is small [2].

The cascade algorithm is the basis of a conceptual design for accelerating learning in ANNs. The neural networks can be implemented as analog very-large scale integrated (VLSI) circuits, and circuits to implement the cascade algorithm can be fabricated on the same VLSI circuit chips with the neural networks. ANNs learn slowly because it has been necessary to train them by example via MATLAB software, for lack of a good on chip learning technique. A network is presented with training inputs for which the correct outputs are known, and the algorithm strives to adjust the weights of synaptic connections in the network to make the actual outputs approach the correct outputs. During training, weights are continuously modulated according to the cascade algorithm. The cascade algorithm specifies an iterative process for adjusting the weights of synaptic connections by descent along the gradient of an error measure in the vector space of synaptic connection weights. The cascade algorithm begins with calculation of the weights between the input and output layers of neurons by use of a pseudo-inverse technique. Then learning proceeds by gradient descent with the existing neurons as long as the rate of learning remains above a specified threshold level. When the rate of learning falls below this level, a new hidden neuron is added. When the quadratic error measure has descended to a value based on a predetermined criterion, the rate of learning is frozen. Thereafter, the network keeps learning endlessly with the existing neurons. The cascade aspect provides two important benefits: (1) it enables the network to get out of local minima of the quadratic error measure and, (2) it accelerates convergence by eliminating the wastage of time that would occur if gradient descent were allowed to occur in many equivalent subspaces of synaptic-connection-weight space. The analog implementation provides the effective high resolution that is needed for such computations [3].

Overall quality of the product is of prime importance in present day competitive market and needs to be built into the speed and innovation system. How the consumer feels about the product is the ultimate index of food quality. Therefore, the quality built in during the development of the product and production process must last through the distribution and consumption stages. Shelf life studies provide important information to product developers and manufacturers to ensure that the consumer will continue to get a high quality product for a significant period of time after its production. Since the shelf life evaluation conducted in the laboratory is a long time-consuming process, and hence does not fit with the speed requirement of the food industry; therefore accelerated methods for estimating the shelf life of food products have been recently developed. The modern food industry has flourished because of its ability to deliver a wide variety of high quality food products to consumers. This has been achieved by building stability into the products through adopting various technological techniques like processing, packaging, and additives. Consumer's demand for convenience has fueled new innovations in the food product development. As an increasing number of new foods compete for getting space on supermarket shelves, the words "speed and innovation" have become the watchwords for food companies seeking to become "first to market" with successful products [4].

In Indian subcontinent burfi is very popular sweetmeat prepared by desiccating the water buffalo milk. It is essentially and customarily served and consumed on all festive occasions and also during social gatherings. Though, several verities of burfi such as almond burfi, cashew nut burfi, cardamom burfi, chocolate burfi, coconut burfi, pistachio burfi, and plain burfi are sold in the market, but the latter variety is most popular which contains milk solids and sugar. On the upper surface of burfi pieces, a very thin edible metallic silver leaf is placed for two specific purposes, firstly the product becomes more attractive, and secondly the silver has therapeutic value.

II. LITERATURE SURVEY

2.1 Yogurt

Changes in the physical, chemical, and microbiological structure of yogurt determine the storage and shelf life of the product. In a reported study [5] microbial counts and pH values of yogurt during storage were determined at d 1, 7, and 14. Simultaneously, image processing of yogurt was digitized by using a machine vision system (MVS) to determine color changes during storage, and the obtained data were modeled with ANN for prediction of shelf life of set-type whole-fat and low-fat yogurts. The ANN models were developed using back-propagation networks with a single hidden layer and *sigmoid* activation functions. The input variables of the network were pH; total aerobic, yeast, mold, and coliform counts; and color analysis values measured by the machine vision system. The output variable was the storage time of the yogurt. The modeling results showed that there was excellent agreement between the experimental data and predicted values, with a high determination coefficient ($R^2 = 0.9996$) showing that the developed model was able to analyze nonlinear multivariate data with very good performance, fewer parameters, and shorter calculation time. The researchers were of the view that the developed model might be an alternative method to control the expiration date of yogurt shown in labeling and provide consumers with a safer food supply.

The growing consumption of low- and reduced-fat dairy products demands routine control of their authenticity by health agencies. The usual analyses of fat in dairy products are very simple laboratory methods; however, they require manipulation and use of reagents of a corrosive nature, such as sulfuric acid, to break the chemical bonds between fat and proteins. Additionally, they generate chemical residues that require an appropriate disposal. The use of an ANN based on simple instrumental analyses, such as pH, color, and hardness (inputs) has been proposed [6] for the classification of commercial yogurts in the low- and reduced-fat categories (outputs). A total of 108 strawberry-flavored yogurts (48 probiotic low-fat, 36 low-fat, and 24 full-fat yogurts) belonging to several commercial brands and from different batches were used in this research. The statistical analysis showed different features for each yogurt category; thus, a database was built and a neural model was trained with the Levenberg-Marquardt algorithm by using the neural network toolbox of the software MATLAB 7.0.1. Validation with unseen data pairs showed that the proposed model was 100% efficient. The authors were of the view that because the instrumental analyses do not require any sample preparation and do not produce any chemical residues, hence the proposed ANN procedure which is a fast and interesting method for monitoring the authenticity of low- and reduced-fat dairy products may be preferred over routine laboratory test methods.

2.2 Bergamot

Thin-layer drying of bergamot was modeled by employing ANN technique [7]. An experimental dryer was used. Thin-layer of bergamot slices at five air temperatures (40, 50, 60, 70 & 80 ℃), one thickness (6 mm) and three air velocities (0.5, 1 & 2 m/s) were artificially dried. Initial moisture content during all experiments ranged from 5.2 to 5.8 (g.g) (d.b.). Mass of samples were recorded and saved every 5 sec. using a digital balance connected to a PC. MLP with momentum and Levenberg-Marquardt (LM) were used to train the ANNs. In order to develop ANN models, temperatures, air velocity and time were used as input vectors and moisture as the output. Results showed a 3-8-1 topology for thickness of 6 mm, with LM algorithm and TANSIG activation function was able to predict moisture ratio with R^2 of 0.99936. The corresponding MSE for this topology was 0.00006.

2.3 Kiwifruit

ANNs predicted mass transfer kinetics and color changes of osmotically dehydrated kiwifruit slices [8]. Kiwifruits were dehydrated implementing four different sucrose concentrations, at three processing temperatures and during four osmotic time periods. A multilayer ANN was developed by using the operation conditions as inputs to estimate water loss, solid gain, and color changes. It was found that the ANN with 16 neurons in hidden layer gave the best fitting with the experimental data, which made it possible to predict solid gain, water loss, and color changes with acceptable mean-squared errors (1.005, 2.312, and 2.137, respectively). The results showed that ANN could potentially be used to estimate mass transfer kinetics and color changes of dehydrated kiwifruit.

2.4 Tomatoes

Movagharnejad and Nikzad [9] experimentally dried tomatoes in a tray dryer covering different variables like power of heater and air flow velocity. The data were modeled using ANN and empirical mathematical equations. The results were compared with experimental data and it was found that the predictions of the ANN model fit the experimental data more accurately in comparison to the various mathematical equations.

2.5 Food Processing

High-pressure processing is an interesting technology for the food industry that offers some important advantages compared to thermal processing. But, the results obtained after a pressure treatment depend as much on the applied pressure as the temperature during the treatment. Modelling the thermal behaviour of foods during high-pressure treatments using physical-based models is a really hard task. The main difficulty is the almost complete lack of values for thermophysical properties of foods under pressure. An ANN was tried to evaluate its capability in predicting process parameters involved in thermal/pressure food processing [10]. ANN was trained with a data file composed of: applied pressure, pressure increase rate, set point temperature, high-pressure vessel temperature, ambient temperature and time needed to re-equilibrate temperature in the sample after pressurization. The authors observed that the trained ANN accurately predicted the last variable.

2.6 Dairy Products

ANN efficiently predicted the shelf life of dairy products, *viz.*, processed cheese [11-16], burfi [17, 18] and kalakand [19-21].

III. METHOD MATERIAL

The input variables for developing soft computing cascade multilayer models for predicting the shelf life of burfi stored at 30°C were the experimental data of the product relating to moisture, titratable acidity (TA), free fatty acids (FFA), tyrosine, and peroxide value (PV); while the overall acceptability score (OAS) assigned by the human jury was output variable (Fig.1).

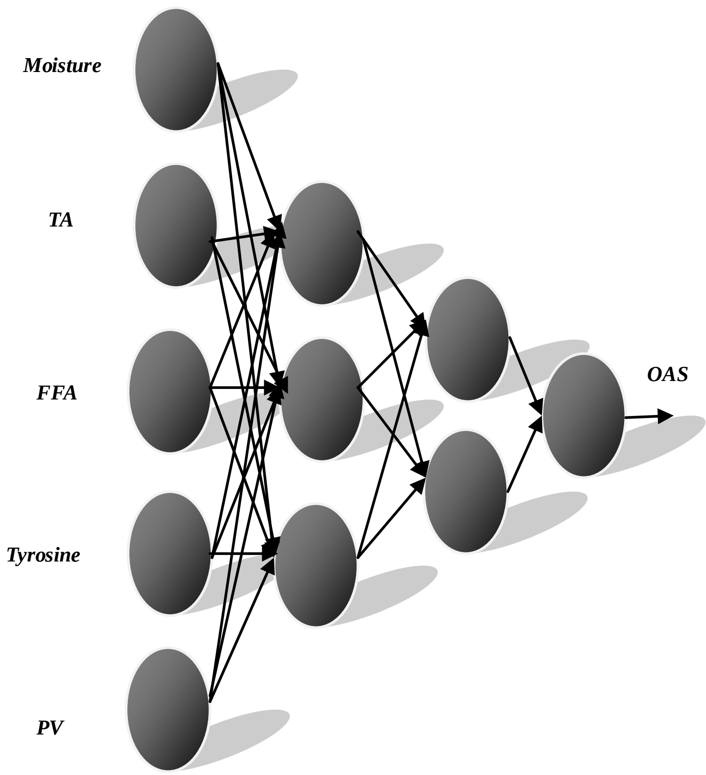

Figure 1. Input and output variables for multilayer soft computing model

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

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

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

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

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

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

n = Number of observations in dataset.

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 implemented in order to compare the prediction ability of the developed soft computing models. Neural Network Toolbox under MATLAB software was used for developing the soft computing cascade models.

IV. RESULTS AND DISCUSSION

Soft computing multilayer's performance matrices for predicting the OAS are presented in Table 1.

Table 1. Performance of soft computing multilayer model for predicting OAS

Neurons	MSE	RMSE	R^2	E^2
3:3	4.30444E-05	0.006560826	0.993439174	0.999956956
4:4	4.32027E-05	0.006572879	0.993427121	0.999956797
5:5	4.22573E-05	0.006500561	0.993499439	0.999957743
6:6	4.35202E-05	0.006596985	0.993403015	0.99995648
7:7	4.32556E-05	0.006576897	0.993423103	0.999956744
8:8	4.36263E-05	0.00660502	0.99339498	0.999956374
9:9	4.39986E-05	0.006633144	0.993366856	0.999956001
10:10	4.68688E-05	0.006846079	0.993153921	0.999953131
11:11	4.41053E-05	0.006641179	0.993358821	0.999955895
12:12	4.39453E-05	0.006629126	0.993370874	0.999956055
13:13	4.25713E-05	0.006524667	0.993475333	0.999957429
14:14	4.4426E-05	0.006665285	0.993334715	0.999955574
15:15	4.41053E-05	0.006641179	0.993358821	0.999955895
16:16	4.45332E-05	0.00667332	0.99332668	0.999955467
17:17	4.4426E-05	0.006665285	0.993334715	0.999955574
18:18	4.46405E-05	0.006681356	0.993318644	0.999955359
19:19	5.6385E-05	0.007508992	0.992491008	0.999943615
20:20	4.45332E-05	0.00667332	0.99332668	0.999955467

Comparison of Actual Overall Acceptability Score (AOAS) and Predicted Overall Acceptability Score (POAS) for the soft computing multilayer model is illustrated in Fig. 2.

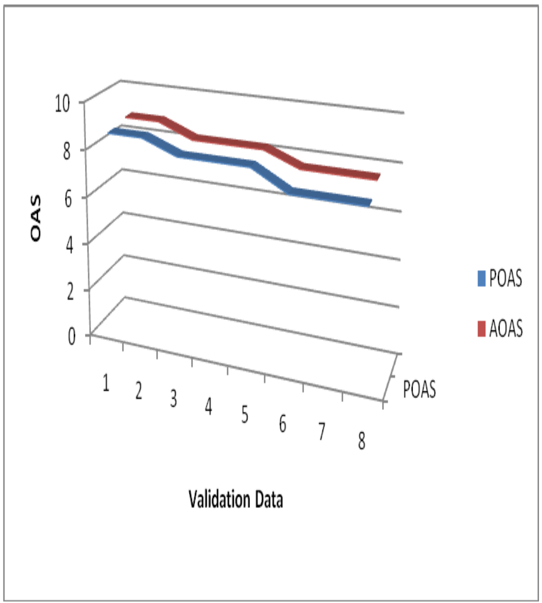

Figure 2. Comparison of POAS and AOAS

Cascade soft computing multilayer model was developed for predicting the shelf life of burfi stored at 30°C. Many experiments were performed in order to reach an optimum solution. A perusal of Table 1 indicates that the combination of 5→5→5→1 resulted in best correlation between the experimental and the predicted values with high R^2 (**0.993499439**), E^2 (**0.999957743**), and low RMSE (**0.006500561**), showing that the developed model was able to analyze nonlinear multivariate data with very good performance, fewer parameters, and shorter calculation time. These findings, in general, are in harmony with the earlier reported work that the ANN Cascade models are quite efficient in predicting the shelf life of dairy products, *viz.*, kalakand [19], processed cheese [22] and sensory quality of roasted coffee flavoured sterilized drink [23]. Therefore, the results suggested that the developed Cascade soft computing multilayer model is a better option for predicting the shelf life of burfi.

VI. CONCLUSION

Soft computing multilayer models for predicting the shelf life of burfi stored at 30 °C were developed. The input variables were moisture, titratable acidity, free fatty acids, tyrosine, and peroxide value; and the overall acceptability score was the output variable. Mean square error, root mean square error, coefficient of determination and Nash - Sutcliffo coefficient were applied in order to compare the prediction capability of the soft computing models. Several experiments were conducted and it was observed that with the combination of 5→5→5→1 excellent agreement existed between the experimental values and the predicted values. Considering the outcome of the results, it is concluded that the soft computing models are excellent tool for predicting the shelf life of burfi. The proposed procedure is reliable, rapid, simple and low-cost as compared to laboratory's cumbersome, expensive, and time- consuming method for predicting the shelf life of burfi.

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