Evaluation of Shelf Life of Processed Cheese by Implementing Neural Computing Models

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Abstract — **For predicting the shelf life of processed cheese stored at 7-8º C, Elman single and multilayer models were developed and compared. The input variables used for developing the models were soluble nitrogen, pH; standard plate count, Yeast & mould count, and spore count, while output variable was sensory score. 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 Elman models got simulated very well and showed excellent agreement between the experimental data and the predicted values, suggesting that the Elman models can be used for predicting the shelf life of processed cheese.**

***Keywords*— Artificial Neural Network, Artificial Intelligence, Elman, Processed Cheese, Shelf Life**

I. Introduction

ARTIFICIAL neural network (ANN), usually called neural network is a mathematical model or computational model that is inspired by the structure and functional aspects of ANN. ANN based computing method is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In ANN based intelligent computing, simple artificial nodes called "neurons", "neurodes", "processing elements" or "units" are connected together to form a network of nodes mimicking the biological neural networks. Generally, ANN involves a network of simple processing elements that exhibit complex global behavior determined by connections between processing elements and element parameters. While an ANN does not have to be adaptive, its practical use comes with algorithms designed to alter the weights of the connections in the network to produce a desired signal flow [1].Elman models are two layered backpropagation networks, with the addition of a feedback connection from the output of the hidden layer to its input. This feedback path allows Elman model to learn to recognize and generate temporal patterns, as well as spatial patterns. The Elman ANN model has *tansig* neurons in its hidden layer, and *purelin* neurons in its output layer. This combination is special in that two layered networks with these transfer functions can approximate any function (with a finite number of discontinuities) with arbitrary accuracy. The only requirement is that the hidden layer must have enough neurons. More hidden neurons are needed as the function being fitted increases in complexity. Elman model differs from conventional two layer networks in that the first layer has a recurrent connection. The delay in this connection stores values from the previous time step, which can be used in the current time step. Therefore, even if two Elman models, with the same weights and biases, are given identical inputs at a given time step, their outputs can be different because of different feedback states. Because the network can store information for future reference, it is able to learn temporal patterns as well as spatial patterns. The Elman models can be trained to respond to, and to generate, both kinds of patterns [2].Shelf life studies can provide important information to product developers enabling them to ensure that the consumer will see a high quality product for a significant period of time after production. Of course, long shelf life studies do not fit with the speed requirement and therefore, accelerated studies have been developed as part of innovation [3]. Goyal and Goyal [4] implemented brain based artificially intelligent scientific computing models for shelf life detection of cakes stored at 30^{o}C. The potential of simulated neural networks for predicting shelf life of soft cakes stored at 10^{o}C was highlighted by Goyal and Goyal [5]. Cascade single and double hidden layer models were developed for predicting the shelf life of Kalakand, a desiccated sweetened dairy product [6]. For forecasting the shelf life of instant coffee drink, radial basis artificial neural engineering and multiple linear regression models were suggested [7]. Cascade forward and feedforward backpropagation artificial intelligence models for prediction of sensory quality of instant coffee flavoured sterilized drink have been evolved [8]. Artificial neural networks for predicting the shelf life of milky white dessert jeweled with pistachio were applied by Goyal and Goyal [9]. 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 [10]. Also, the time-delay and linear layer (design) intelligent computing expert system models have been developed for predicting the shelf life of soft mouth melting milk cakes stored at 6^{o}C [11]. The computerized models have been

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suggested for predicting the shelf life of post-harvest coffee sterilized milk drink [12]. Neuron based artificial intelligent scientific computer engineering models estimated the shelf life of instant coffee sterilized drink [13]. The aim of the present study is to develop Elman ANN models with single layer and multilayer, and to compare them with each other, for predicting the shelf life of processed cheese stored at 7-8ºC.

II. METHOD MATERIAL

The input variables used in the network were the processed cheese experimental data 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 (80% for training) observations, and validation set (20% for testing) consisting of 6 observations.

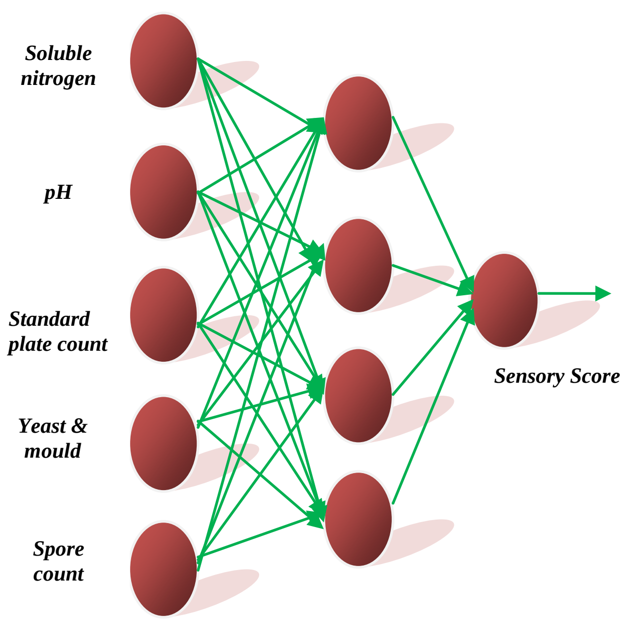

Fig. 1: Input and output parameters for elman models

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

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

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

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

Where,

$Q_{\exp}$ = Observed value;

Q_{cal} = Predicted value;

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

n = Number of observations in dataset.

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. *Gradient Descent algorithm with adaptive learning rate, Powell Beale restarts conjugate gradient algorithm, Levenberg Marquardt algorithm, Fletcher Reeves update conjugate gradient algorithm,* and *Bayesian regularization* algorithms were tried. *Bayesian regularization* mechanism was finally selected for training ANN models, as it exhibited the best results. The network was trained up to 100 epochs, and neurons in each hidden layers varied from 1 to 20. The network was trained with single as well as multiple hidden layers, and transfer function for hidden layer was *tangent sigmoid*, while for the output layer it was *pure linear* function. MALTAB software was used for performing experiments.

III. RESULTS AND DISCUSSION

Elman single layer (Table 1) and multilayer (Table 2) ANN models were developed and compared with each other for predicting the shelf life of processed cheese stored at 7-8º C.

TABLE I
RESULTS FOR SINGLE LAYER ELMAN MODEL

Neurons	*MSE*	*RMSE*	R^2	E^2
3	9.13178E-05	0.009556034	0.990443966	0.999908682
4	0.000314749	0.01774116	0.98225884	0.999685251
5	0.000449704	0.021206231	0.978793769	0.999550296
6	9.14141E-05	0.009561074	0.990438926	0.999908586
7	0.00039364	0.019840363	0.980159637	0.99960636
8	0.00039364	0.019840363	0.980159637	0.99960636
9	9.15588E-05	0.009568634	0.990431366	0.999908441
10	9.1607E-05	0.009571154	0.990428846	0.999908393

11	0.000330042	0.018167049	0.981832951	0.999669958
12	3.34199E-05	0.005780997	0.994219003	0.99996658
13	0.000188492	0.013729239	0.986270761	0.999811508
14	4.20792E-06	0.002051322	0.997948678	0.999995792
15	9.18484E-05	0.009583755	0.990416245	0.999908152
16	9.18967E-05	0.009586275	0.990413725	0.999908103
17	9.1945E-05	0.009588795	0.990411205	0.999908055
18	0.000115845	0.010763139	0.989236861	0.999884155
19	9.20417E-05	0.009593835	0.990406165	0.999907958
20	**1.87878E-07**	**0.000433449**	**0.999566551**	**0.999999812**

TABLE 2
RESULTS FOR MULTILAYER ELMAN MODEL

Neurons	*MSE*	*RMSE*	R^2	E^2
3:3	9.1366E-05	0.009558554	0.990441446	0.999908634
4:4	0.000561383	0.023693521	0.976306479	0.999438617
5:5	9.14141E-05	0.009561074	0.990438926	0.999908586
6:6	9.14141E-05	0.009561074	0.990438926	0.999908586
7:7	9.14623E-05	0.009563594	0.990436406	0.999908538
8:8	9.14623E-05	0.009563594	0.990436406	0.999908538
9:9	9.15105E-05	0.009566114	0.990433886	0.999908489
10:10	4.78872E-05	0.006920061	0.993079939	0.999952113
11:11	0.000535418	0.02313911	0.97686089	0.999464582
12:12	0.000554478	0.023547358	0.976452642	0.999445522
13:13	9.16552E-05	0.009573674	0.990426326	0.999908345
14:14	9.17035E-05	0.009576194	0.990423806	0.999908296
15:15	9.17518E-05	0.009578715	0.990421285	0.999908248
16:16	8.80247E-05	0.009382151	0.990617849	0.999911975
17:17	3.93431E-05	0.006272407	0.993727593	0.999960657
18:18	9.18484E-05	0.009583755	0.990416245	0.999908152
19:19	0.000711004	0.026664661	0.973335339	0.999288996
20:20	**1.17981E-05**	**0.00343483**	**0.99656517**	**0.999988202**

Elman single layer and multilayer computerized models were developed for predicting the shelf life of processed cheese stored at 7-8^{o} C. Single layer model with 5-20-1 combination (**MSE**: **1.87878E-07**; **RMSE**: **0.000433449**; $\mathbf{R^2}$: **0.999566551**; $\mathbf{E^2}$: **0.999999812)** gave the best result among single layer experiments (Table 1); and for multilayer Elman models, the best result was with 5-20-20-1 combination (**MSE**: **1.17981E-05**; **RMSE**: **0.00343483**; $\mathbf{R^2}$: **0.99656517**; $\mathbf{E^2}$: **0.999988202)** (Table 2). The comparison of these two results showed that the multilayer model with a combination of 5-20-20-1 performed better for predicting the shelf life of processed cheese. The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for Elman single layer and multilayer models are illustrated in Fig.2 and Fig.3, respectively.

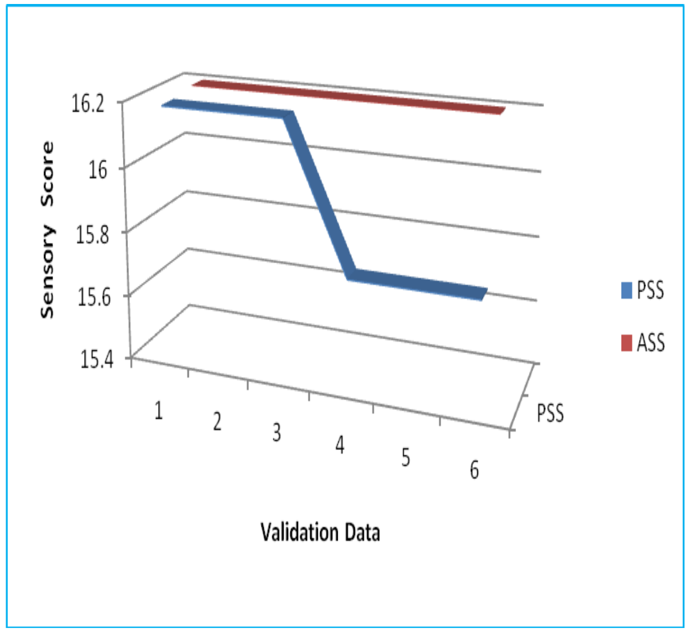

Fig. 2: Comparison of ASS and PSS for Elman single layer model

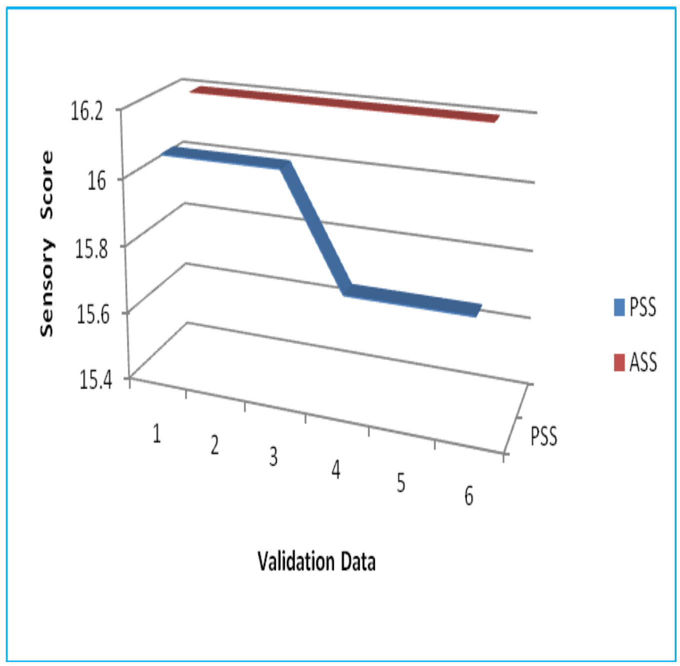

Fig. 3: Comparison of ASS and PSS for Elman multilayer model

From the results, it is observed that Elman models got simulated exceedingly well, and are very effective in predicting the shelf life of processed cheese stored at 7-8^{o} C.

IV. CONCLUSION

Elman single and multilayer ANN models were developed and compared with each other. The inputs variables of the network consisted of soluble nitrogen, pH; standard plate count, yeast & mould count, and spore count. The output variable was sensory score of the processed cheese stored at 7-8^{o}C. The modelling results revealed very good agreement between the experimental data and the predicted values, with a high determination coefficient, establishing that the developed Elman ANN models were able to analyze non-linear multivariate data with excellent performance, fewer parameters, and shorter calculation time. This Elman model might be an alternative low cost and less time consuming method for determining the expiration date of stored processed cheese, shown on labels and provide consumers with a safer food supply [14-20].

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