A Novel Method for Shelf Life Detection of Processed Cheese Using Cascade Single and Multi Layer Artificial Neural Network Computing Models

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ABSTRACT

This paper presents the potential of Cascade Backpropagation algorithm based ANN models in detecting the shelf life of processed cheese stored at 30°C. Processed cheese is a dairy product made from ripened Cheddar cheese and sometimes a part of ripened cheese is replaced by fresh cheese; plus emulsifiers, extra salt, spices and food colorings. The cascade backpropagation algorithm (CBA) is the basis of a conceptual design for accelerating learning in ANNs. In this research input parameters were texture, aroma and flavour, moisture, free fatty acids. Sensory score was taken as output parameter. Bayesian regularization algorithm was used for training the network. Neurons in each hidden layers varied from 1 to 50. The network was trained with 200 epochs with single and multiple hidden layers. Transfer function for hidden layers was tangent sigmoid and pure linear was output function. Mean Square Error, Root Mean Square Error, Coefficient of Determination and Nash - Sutcliff Coefficient performance measures were used to test the prediction potential of the developed CBA model. CBA model detected 29.13 days shelf life which is quite close to experimentally obtained shelf life of 30 days suggesting that the product is acceptable.

Keywords: Cascade, ANN, Artificial Intelligence, Processed Cheese, Shelf Life Prediction.

1. INTRODUCTION

1.1 PROCESSED CHEESE

Processed cheese is a dairy product made from ripened Cheddar cheese and sometimes a part of ripened cheese is replaced by fresh cheese; plus emulsifiers, extra salt, spices and food colorings. Today in the market processed cheese in several flavors, colors, and textures is available. Processed cheese has many advantages over unprocessed cheese, viz., extended shelf life, resistance to separation of milk fat when cooked, and the ability to reuse scraps, trimmings and runoff from other cheese making process. The use of emulsifiers in processed cheese results in cheese that melts smoothly when cooked. Processed cheeses are very smooth and medium-firm [1].

1.2 ARTIFICIAL NEURAL NETWORK (ANN)

An ANN has several very simple processors called as "units" or "neurons", each possibly have a small amount of local memory form ANN. The units are connected by unidirectional connections, which carry numeric (as opposed to symbolic) data. The units operate only on their local data and on the inputs they receive via the connections. A neural network is a processing device, either an algorithm, or actual hardware, whose design is inspired by the design and functioning of animal brains and components thereof. ANNs have some sort of "training" rule whereby the weights of connections are adjusted on the basis of presented patterns. Neurons are often elementary non-linear signal processors. Another feature of ANNs is a high degree of interconnection which allows a high degree of parallelism. The term "neural net" should logically, but in common usage never does, also include biological neural networks, whose elementary structures are far more complicated than the mathematical models used for ANNs [2].

1.3 CASCADE BACKPROPAGATION ALGORITHM (CBA)

The CBA 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 CBA can be fabricated on the same VLSI circuit chips with the neural networks. ANNs learn slowly because it has been necessary to train them via MATLAB software, for lack of a good on-chip learning technique. ANNs are trained by example. 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 CBA. The CBA 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 CBA 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 waste of time that would occur if gradient descent were allowed to occur in many equivalent subspaces of synaptic-connection-weight space. The proposed analog implementation provides the effective high resolution that is needed for such computations. [3].

1.4 SHELF LIFE

Shelf life can be defined in several ways, and may be much confused by the different labels that are attached to foods like “use by,” “best by” or “best if used by.” Generally, shelf life refers to the time a prepared food item will remain fresh, remain healthy to eat, and maintain its fresh taste. Eating foods with expired shelf lives is definitely not recommended. [4]. Applications of ANN have been successfully applied for predicting shelf life of brown milk cakes decorated with almonds [5], kalakand [6], milky white dessert jeweled with pistachio [7], instant coffee flavoured sterilized drink [8, 9]. Time-Delay and Linear Layer ANN models were applied for predicting shelf life of soft mouth melting milk cakes stored at 6°C, and it was concluded that the developed expert system computing models were good in predicting the shelf life of soft mouth melting milk cakes [10]. Elman and self-organizing models predicted shelf life of soft cakes [11]. So far no study has been reported for predicting shelf life of processed cheese. The main aim of this research is to develop CBA models with single and multi layers, and to compare them with each other for predicting shelf life of processed cheese stored at 30°C.

2. MATERIAL AND METHODS

2.1 DATASET

Experimentally developed 36 observations for each input and output parameters were taken for developing CBA models. The dataset was randomly divided into two disjoint subsets, namely, training set containing 30 observations and validation set consisting of 6 observations.

![Figure 1: Input and output parameters of ANN](image)

Body and texture, aroma and flavour, moisture and free fatty acids for processed cheese stored at 30°C were taken as input parameters and sensory score was taken as output parameter for developing CBA models (Fig.1). Several different combinations of internal parameters, i.e., data preprocessing, data partitioning approaches, number of hidden layers, number of neurons in each hidden layer, transfer function, error goal, etc., were explored in order to optimize the prediction ability of the cascade model. Several algorithms were tried like Fletcher Reeves update conjugate gradient algorithm, Gradient Descent algorithm with adaptive learning rate, Bayesian regularization, Levenberg Marquardt algorithm and Powell Beale restarts conjugate gradient algorithm. Bayesian regularization mechanism was selected for training CBA models, as it gave the better results than other algorithms. The network was trained with 200 epochs and neurons in
each hidden layers varied from 1 to 50. The network was trained with single as well as double hidden layers and transfer function for hidden layer was tangent sigmoid while for the output layer, it was pure linear function. CBA models with single layer and multi layer were trained with training set after getting optimum values for architectural parameters; the CBA models were simulated with the testing data in order to validate the models. MATLAB 7.0 software was used for performing experiments.

### Performance Prediction Measures

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

(1)

\[
RMSE = \left[ \frac{1}{N} \sum_{i=1}^{N} \left( \frac{Q_{\text{exp}} - Q_{\text{cal}}}{Q_{\text{exp}}} \right)^2 \right]^{1/2}
\]

(2)

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

(3)

\[
E^2 = 1 - \left[ \frac{1}{N} \sum_{i=1}^{N} \left( \frac{Q_{\text{exp}} - Q_{\text{cal}}}{Q_{\text{exp}}} \right)^2 \right]
\]

(4)

Where, 
\(Q_{\text{exp}}\) = Observed value; \(Q_{\text{cal}}\) = Predicted value; \(Q_{\text{exp}} \) = Mean predicted value; \(n\) = Number of observations in dataset. MSE (1), RMSE (2), \(R^2\) (3) and \(E^2\) (4) were used in order to compare the prediction potential of the developed CBA models.

### 3. RESULTS AND DISCUSSION

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

Table 1: Performance of CBA model with single hidden layer for predicting sensory score

<table>
<thead>
<tr>
<th>Neurons</th>
<th>MSE</th>
<th>RMSE</th>
<th>(R^2)</th>
<th>(E^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.00115</td>
<td>0.03397473</td>
<td>0.9930743</td>
<td>0.9988457</td>
</tr>
<tr>
<td>5</td>
<td>0.00126</td>
<td>0.03554971</td>
<td>0.9924173</td>
<td>0.9987362</td>
</tr>
<tr>
<td>8</td>
<td>2.95842E-05</td>
<td>0.06543913</td>
<td>0.9998224</td>
<td>0.9999704</td>
</tr>
<tr>
<td>10</td>
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<td>0.06543913</td>
<td>0.9998224</td>
<td>0.9999704</td>
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<tr>
<td>15</td>
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<td>0.9999940</td>
</tr>
<tr>
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<td>0.9999051</td>
</tr>
<tr>
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<td>0.09921322</td>
<td>0.99949039</td>
<td>0.9999151</td>
</tr>
<tr>
<td>37</td>
<td>4.05758E-06</td>
<td>0.00201434</td>
<td>0.99997565</td>
<td>0.9999959</td>
</tr>
<tr>
<td>40</td>
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<td>0.01039595</td>
<td>0.99935154</td>
<td>0.9998919</td>
</tr>
<tr>
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<td>0.9987074</td>
</tr>
<tr>
<td>50</td>
<td>0.001334</td>
<td>0.03652396</td>
<td>0.99199600</td>
<td>0.998666</td>
</tr>
</tbody>
</table>

CBA models with single hidden layer and multi hidden layers were developed for detecting shelf life of processed cheese stored at 30° C. The best results of CBA model with single hidden layer having 37 neurons were MSE: 4.05758E-06, RMSE: 0.00201434, \(R^2\): 0.99997565, \(E^2\): 0.9999959, and with two hidden layers having 27 neurons in the first and second layer were MSE: 0.011921513, RMSE: 0.00198691, \(R^2\): 0.99985787, \(E^2\): 0.99996052. The best results of both the models were compared with each other and it was observed that CBA model with multi layer having 27:27 was better. The comparison of Actual Sensory Score (ASS) and Predicted Sensory Score (PSS) for CBA single and double hidden layer models are illustrated in Fig.2 and Fig.3.
Figure 2: Comparison of ASS and PSS for CBA single hidden layer model

Figure 3: Comparison of ASS and PSS for CBA double hidden layer model

3.1 SHELF LIFE

Regression equations were applied to predict shelf life of processed cheese, i.e., in days for which product has been in the shelf, based on sensory score. The processed cheese was stored at 30° C taking storage intervals (in days) as dependent variable and sensory score as independent variable. $R^2$ was found to be 0.54 percent of the total variation as explained by sensory scores. Time period (in days) for which the product has been in the shelf can be predicted based on sensory score for processed cheese (Fig. 4).

Shelf life of processed cheese is evaluated by subtracting the obtained value of days from experimentally determined shelf life, which was found to be 29.13 days. The predicted value is within the experimentally obtained shelf life of 30 days; hence, the product is acceptable.

4. CONCLUSION

Cascade Back propagation Algorithm models were developed for detecting shelf life of processed cheese stored at 30° C. The performances of the different developed models were compared with each other. CBA model with double hidden layer having 27:27 neurons gave best results. Based on these results regression equations were developed for detecting shelf life of processed cheese. The detected shelf life came out to be 29.13 days, whereas laboratory determined shelf life is 30 days. Therefore, from the study it can be concluded that CBA based ANN models are good in detecting shelf life of processed cheese stored at 30° C.

REFERENCES


