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# Finite Impulse Response Type Multilayer Perceptron Artificial Neural Network Model For Bacteria Growth Modeling Inhibited by Lemon Basil Waste Extract

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**Abstract.** The tools to predict the growth of bacteria over the time is essential to maintain the process stability in bio processes. Currently, not all tools have been fully used to fulfil these interests which can be applied in industry and laboratory. In this paper, a mathematical modelling approach based on the type of multi layer perceptron artificial neural network created by Finite Impulse Response (FIR) is proposed. The neural network model was developed using data collected from laboratory work. A total of 75% the growth of bacteria (*S. Aureus*, *B. Cereus* and *S. Typhimurium*) which is inhibited by lemon basil waste extract, over the time data are used to train Artificial Neural Network (ANN), and the rest of the data are used to validate the model. ANN has been model the growth of *S. Aureus*, *B. Cereus* and *S. Typhimurium* which is inhibited by lemon basil waste extract over the time. Mean Square Error (MSE) results during training and validation obtained from this modeling were 0.087 and 0.147, respectively. It means the mathematical modeling approach used in this study is suitable for capturing nonlinear characteristics of bacterial growth that is inhibited by lemon basil waste extract.

## 1. Introduction

Quantitative mathematical modeling to predict the growth of microorganism becomes crucial due to the impact for food industry and food safety. The growth factors of microorganism were categorized as intrinsic, explicit, implicit and processing factors [1]. It has been reported that microbial growth kinetics was not linier [2] and consisted of four phases, namely lag, exponential, stationary and death phases [3]. Moreover, the presence of antimicrobial may inhibit some microorganism and at the same time may not inhibit other microorganism because of different resistance [4]. Yet, despite its importance, the relations between those phase, antimicrobial and growth factors remain complex when



it describe in quantitative mathematical modeling. Nowadays, neural networks have been utilized to build some complex model and it shown that it capability to approximate nonlinear functions up to high level of accuracy [5].

The accuracy of mathematical modeling is important to ensure food safety which may affect to human health. There has been reported that some pathogenic have caused food contamination during food supply chain and introduced foodborne illness [6,7]. It became concern when ready-to-eat food, such as smoked fish, were consumed without further heating or process There were many cases of outbreak due to smoked fish consumption [8,9,10]. Some pathogenic bacteria such as *Salmonella* Typhimurium, *Bacillus cereus* and *Staphilococcus aureus* has been isolated from fish and smoked fish [11,12,13]. To do so, antimicrobial were used to be applied in food processing. Singh (2016) reported that natural antimicrobial such as essential oil has been incorporated into edible film to against the growth of pathogenic bacteria [14].

Artificial Neural Network (ANN) has been used to predict the growth of bacteria in quantitative mathematical modeling [15,16]. The neural networks are also robust in inadequate data than other mathematical modeling such as the empirical models and correlations. Fast and accurate bacterial growth prediction by using the neural networks model is an additional advantage value with less computational load. Prediction of bacterial growth that is fast and accurate by using neural network models is a benefit with less computational load. In this study, a Multi Layer Perceptron (MLP) neural networks with Finite Impulse Response (FIR) structure was used to model bacterial growth, in order to predict the growth of bacteria by using the model of data for three pathogenic bacteria (*Salmonella* Typhimurium, *Bacillus cereus*, and *Staphillococcus aureus*) which has been inhibited by natural antimicrobial (lemon basil extract) on edible film of smoked fish.

## 2. Neural Network Architectures and Training

The system under study is some bacterial growth over the time. In this study used a type of artificial neural network (ANN) based Multilayer perceptron. ANN can be described as follows:

- Input and output of data sets stored in MS Excel were divide into two parts, 75% for training and 25% for validation purpose.
- Activation function in multilayer perceptron use logsig for hidden layer and i purelin for output layer.
- Initial weights of the ANN are determined randomly.
- The Levenberg Marquart learning algorithm is used to optimize the weigth ofthe networks. The different learning algorithms are available in literatures [2,5].

$$y_i = F_i \left[ \sum_{j=1}^{n_h} W_{i,j} \cdot f_j \left( \sum_{l=1}^{n_p} w_{j,l} \phi_l + w_{j,0} \right) + W_{i,0} \right] \quad (1)$$

where :

- J = external input
- nqJ = number of input in an input layer,
- nh = number of hidden neurons in a hidden layer,
- W = ware weights,
- f = activation functions for hidden layer
- F = activation functions for output layer

- e. The performance of the neural network is expressed by MSE (Mean Square Error). The smaller the MSE value, the better the performance of the neural network. MSE is calculated based on the equation:

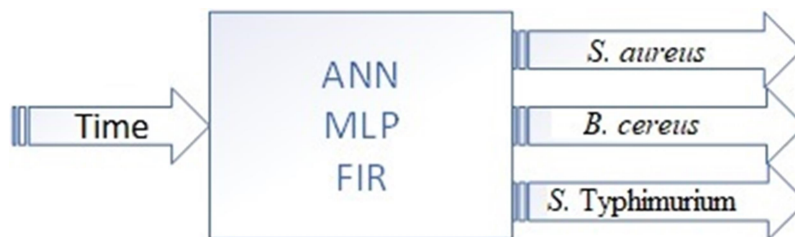
$$MSE = \frac{1}{n} \sum_{i=1}^n (P_i - m_i)^2 \tag{2}$$

Where n is the number of data, P<sub>i</sub> is the value predicted by the neural network or the output value, and m<sub>i</sub> is a target value

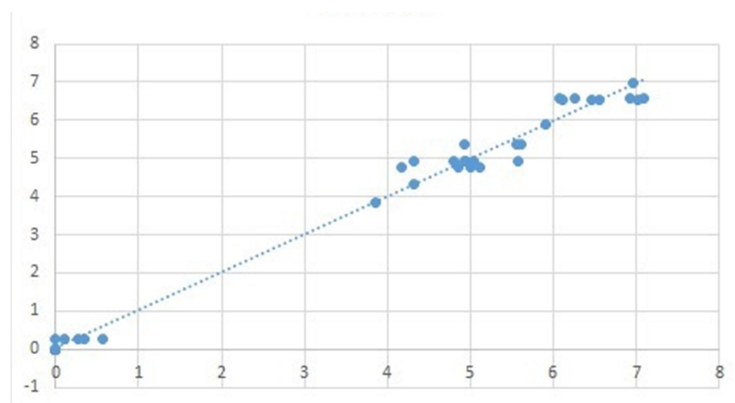
- f. The relationship between the output value and the target determined by regression curves vs. output targets to get correlation coefficient R. R value close to unity showed a good correlation between the value predicted by the neural network (output) and the target value. The correlation coefficient R is calculated using the following equation :

$$R = \frac{\sum_{i=1}^n (m_i - \bar{m})(p_i - \bar{p})}{\sqrt{\sum_{i=1}^n (m_i - \bar{m})^2 \sum_{i=1}^n (p_i - \bar{p})^2}} \tag{3}$$

The proposed ANN bacterial growth is shown in Fig 1



**Figure 1.** Proposed ANN for bacterial growth prediction

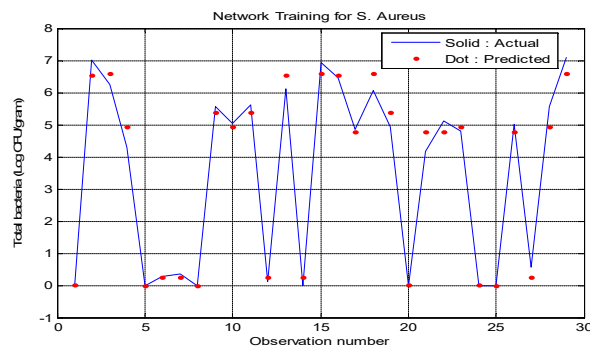


**Figure 2.** Actual data and ANN prediction for all bacterial growth

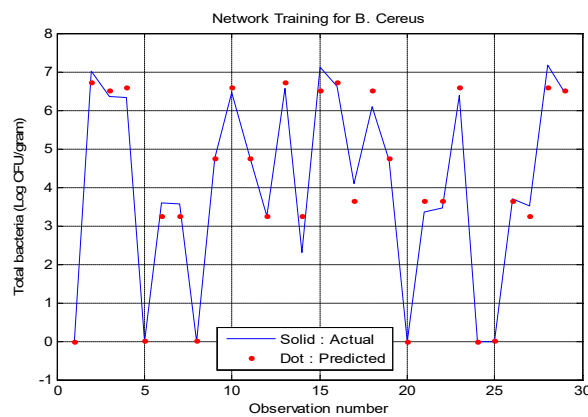
### 3. Result and Discussion

In this modeling, the results of the trained model's performance in predicting outputs as well as the results of providing new input data sets must go through a verification process in the validation phase.

In the validation phase, a new data set is used as input data and new output data for the growth of the three predicted bacteria. Data visualization and prediction as a whole are shown in the fig. 2. A comparison of the actual and predicted output values for the bacterial growth was shown in fig. 3-8. In general, the number of bacteria predicted by the neural networks model in this study was matched with the actual values. Mathematical modelling using MLP neural networks with the structure of Finite Impulse Response (FIR) can be suggested and developed to describe the nonlinear bacterial growth. It was observed that the model developed in this study was capable to predict the number of bacteria during its growth.



**Figure 3.** Actual data and ANN prediction under training for *S Aureus*



**Figure 4.** Actual data and ANN prediction under training for *B Cereus*

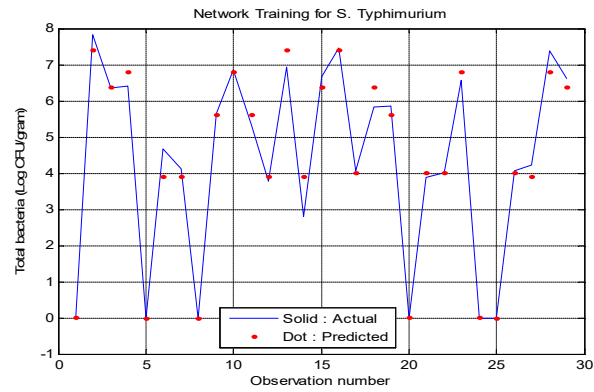


Figure 5. Actual data and ANN prediction under training for *S. Typhimurium*

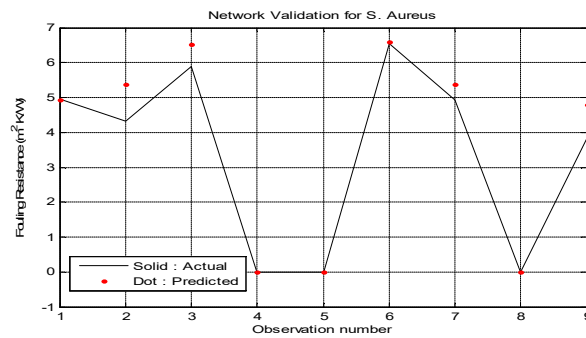


Figure 6. Actual data and ANN prediction under validation for *S. Aureus*

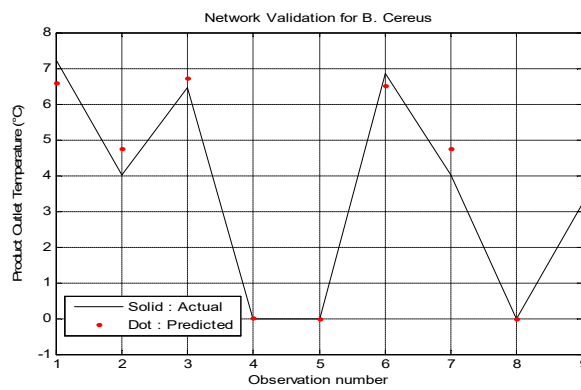
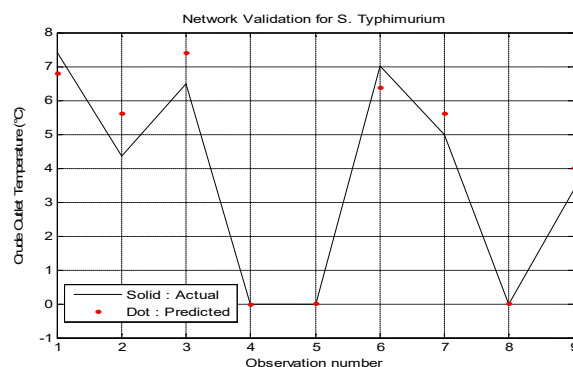


Figure 7. Actual data and ANN prediction under validation for *B. Cereus*



**Figure 8.** Actual data and ANN prediction under validation for *S. Typhimurium*

Mean Square Error (MSE) results during training and validation obtained from this modeling were 0.087 and 0.147, respectively. It means the mathematical modeling approach used in this study is suitable for capturing nonlinear characteristics of bacterial growth which were inhibited by lemon basil extract as natural antimicrobial. This was similar to other study. Marouf *et al.* [17] revealed that ANN model was capable to predict correctly for the susceptibility of microorganism to antimicrobial. Hajmeer *et al* [18] and Jeyamkondan *et al* [19] also reported that the prediction by using neural networks described the real condition of experiment data of microbial growth compared to other prediction by using regression equations.

#### 4. Conclusion

Finite Impulse Response (FIR) type multi layer perceptron artificial neural network model has capability for capturing nonlinear characteristics of bacterial growth. (*S. aureus*, *B. cereus* and *S. Typhimurium*) inhibited by lemon basil extract. In future, it might be applied to predict the dynamic of other pathogenic bacteria growth in food product with more complex condition to figure out the real condition and ensure food safety.

#### Acknowledgments

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