Modeling Biopolymer and Glucose as Carbon Source Using Artificial Neural Network

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Abstract. Biopolymer is one of the interesting biotechnology products and a promising class of biomaterials, which can be naturally occurred or produced by microorganisms. The production of the biopolymer by bioprocess technology requires the application of chemical engineering principles such as upstream processes, fermentation, and downstream processes. Hyaluronic Acid (HA), also called as hyaluronan is a unique biopolymer. HA is used in exclusive pharmaceutical products such as viscoelastic fluids in ophthalmological surgery. The production alternative of HA from animal tissues is by fermentation. In this study, glucose is used in fermentation as the carbon source for an experiment. Artificial Neural Network (ANN) is used for modeling the use of glucose to produce HA from the experimental study. ANN is a system consisting of many simple processing elements connected in parallel. The mean square error (MSE) in this study is 0.09830%.

1. Introduction

Biopolymer is an attractive biotechnology product and promising biomaterial class, which can occur naturally or produced by microorganisms. It is being widely applied in medicine and in the food and cosmetics industries. Applications include surgical devices, implants, and supporting materials drug delivery systems with a different administration and design routes, carriers for disabling enzymes and cells, biosensors, diagnostic test components, ocular devices, and materials for orthopedic applications. Biopolymers can be synthesized to have the right chemical, physical, biomimetic interface characteristics, which allow a variety of specific applications and can be engineered to meet certain end-use requirements[1]. In recent years, in developing countries such as Japan, Korea, Europe, and the United States, considerable research efforts by several private and public sectors have
been made to produce biopolymers based on bioprocess technology. Biopolymer research has two main focus areas: (i) to produce degradable material that serves as a substitute for traditional commodity plastics and (ii) to develop biomaterials for biomedical applications (US Congress, OTA. 1993).

Biopolymer production by bioprocess technology requires the application of chemical engineering principles such as upstream processes, fermentation and downstream processes (extraction and purification steps). During the fermentation stage, this process is seen in terms of engineering factors such as mass transfer, heat transfer and kinetics [2]. The actual procedure used for downstream processing depends on the nature of the product and broth and can use physical, chemical or biological methods.

Hyaluronic Acid (HA) is used in exclusive pharmaceutical products such as viscoelastic fluids in ophthalmological surgery: eye-surgery, vitreous substitute, and in viscous supplementary products for orthopedic disorders: osteoarthritis therapy and sports medicine [3]. HA and its derivatives have been widely used in various applications including, time-release drug delivery systems, in cosmetics as an anti-aging and moisture-retaining agent, and in neuron and plastic surgery [3]. HA was isolated for the first time from a bovine vitreous body by water-acetone extraction and from human umbilical by chloroform extraction. HA can be commercially produced by two methods: chemical extraction of animal tissues and microbial fermentation [4]. However, HA is produced by the former route, predominantly from rooster combs [5].

This paper is discussed modeling production HA by *StreptococcusZooepidemicus ATTC 39920* using Artificial Neural Network (ANN). Many methods have been created to formulate relationships between two or more variables. In this research, ANN will be used to predict the production of HA against the amount of glucose added. Experimentally, this will take a very long time to do because HA production will continue to change as time changes. This research uses the backpropagation algorithm in ANN. Backpropagation or reverse propagation ANN is the simplest and easiest method to understand from other methods. In backpropagation, the activation function used must fulfill several conditions, namely: continuous, differentiable easily and is a function that does not go down[6]. This algorithm will change the bias weight to reduce the difference between network output and output target. After the training is complete, testing of the network that has been trained is carried out. Learning neural network algorithms requires advanced propagation and is followed by backward propagation. Both are done for all training patterns[7].

2. Research Methodology

Data used in this research is fermentation data of shake flask experiment. There are two types of data used with different glucose inputs. the specification of the experiment carried out is temperature = 37°C, RPM of shaker = 150, culture volume 150 RPM. Data can be seen in table 1 and table 2. The backpropagation algorithm is used in this simulation. The simulation uses "nntool" on the Matlab Toolbox. The parameters used are default. The input used in this experiment is time and output is HA.

3. Results and Discussion

Based on Figure 1, 2 and 3, it can be seen the results of the backpropagation ANN process displayed in graphical form. In Figure 1 shows the learning process at each epoch. In this process, the iteration is stopped at the 7th epoch, because the limit of the desired epoch has been reached and (MSE = 0.000983 <0.001) where this MSE is the MSE that appears when the training is completed in accordance with the specified iteration. The best validation test is in epoch 1. Figure 2 shows the relationship between targets and network output in training data. From testing the training data for the match between network output and target, the correlation coefficient (R) is 0.9363 where the best result is worth 1.
### Table 1. Data 1 for shake flask at an initial glucose concentration of 20 g/l

| Time (h) | Glucose (g/l) | Hyaluronic Acid (g/l) |
|----------|---------------|-----------------------|
| 0        | 21.32         | 0                     |
| 2        | 20.13         | 0.06                  |
| 4        | 17.81         | 0.12                  |
| 6        | 13.61         | 0.25                  |
| 8        | 5.89          | 0.39                  |
| 10       | 0.73          | 0.42                  |
| 12       | 0.53          | 0.44                  |
| 14       | 0.50          | 0.61                  |
| 22       | 0.44          | 0.52                  |
| 24       | 0.36          | 0.52                  |
| 28       | 0.33          | 0.50                  |
| 36       | 0.30          | 0.42                  |

### Table 2. Data 2 for shake flask at an initial glucose concentration of 40 g/l

| Time (h) | Glucose (g/l) | Hyaluronic Acid (g/l) |
|----------|---------------|-----------------------|
| 0        | 41.63         | 0                     |
| 2        | 39.67         | 0.02                  |
| 5        | 36.91         | 0.17                  |
| 7        | 29.27         | 0.30                  |
| 9        | 23.33         | 0.31                  |
| 11       | 15.12         | 0.27                  |
| 13       | 5.04          | 0.28                  |
| 23       | 0.33          | 0.30                  |
| 25       | 0.33          | 0.33                  |
| 27       | 0.24          | 0.26                  |
| 31       | 0.16          | 0.30                  |
| 36       | 0.08          | 0.31                  |

4. Conclusion

Based on the visualization of the given graphs, it can be seen that the results data pattern recognition by backpropagation ANN would be better if you use a smaller error rate and a large amount of data so that the accuracy of the identification is greater. This proves that the ANN is very strong in recognizing the patterns of data provided. This means that the smaller the target error that is desired and the greater the amount of data provided, meaning that the smaller the deviation of identification results with the desired results, so that the accuracy of the forecast results of the network
training forecast will be even higher. The problem that often occurs is that the training process requires a lot of iteration so that further research can use better methods such as genetic algorithm, particle swarm optimization etc.

Figure 3. Regression result of data

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6. Appendix

Figure 4. Best validation of data 1

Figure 5. Training result of data 1
Figure 6. Regression result of data

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