

Fermentation Process Modeling Using Takagi-Sugeno Fuzzy Model

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Abstract: Fermentation process is vital and important in many biotechnological applications. However modeling the fermentation process is considered a challenging and complex problem. The complexity of the problem is driven by the need of efficient, accurate, not expensive, and reliable predictive models. In this paper, we apply a Takagi-Sugeno Fuzzy Logic technique for modeling the lipase activity production based on nutritional and physico-chemical factors to estimate the lipase activities. The accuracy of the developed fuzzy model is measured, validated and compared with both the multiple regression and artificial neural network models. The fuzzy model successfully showed competitive and promising modeling results.

Key- Words: Fermentation process, Lipase activity production, Takagi-Sugeno Fuzzy Model.

1 Introduction

Lipase production is getting more and more attention in the industry and business field recently due to their biotechnological applications [1]. Lipases have a wide range of uses in industry productions such as dairy-based products, detergents, drugs, cosmetics and leather processes [2]. On the other side, Lipase production is a challenging, complex and not easy to model or monitor [2]. The complexity is due to the nature of lipase production which is highly dependent on its operating conditions that affect its growth. These operating conditions include nutritional and physico-chemical factors such as temperature, initial pH, incubation period, time, inoculum size and agitation rate [1–3]. Consequently, deciding upon an optimization method and choosing a modeling technique are vital issues in the process of producing reliable lipase products with high standards. Efficient optimization and modeling can dramatically improve the system performance and reduce the costs [3].

In biological research, response surface methodology (RSM) is one of the most applied methods in modeling the biological processes. RSM is a statistical and mathematical based system for modeling and optimizing complex processes. RSM explores the relationships between the response (output variable) and the independent variables (input variables). RSM has many advantages such as it reflects the significance of the input variables, alone or in combination, in a given model. Moreover, it reduces the cost of analysis by minimizing the number of experimental trials needed to evaluate input variables and their interactions [4].

Though, RSA is not applicable in all biological applications [3].

In many cases, output results are out of expectations when modeling and predicting systems based on mathematical equations are used for controlling the interactions between the input variables in the process for lipase fermentation. Therefore, a considerable number of previous studies employed empirical models based on artificial intelligence and machine learning approaches. By the following paragraphs we give an insight into some important studies in the field.

Among artificial intelligence and machine learning approaches, Artificial Neural Networks (ANNs) are the most applied in lipase modeling and prediction. In [3] authors used the best composition of production medium among the best previously published media, then they made a comparison by applying both RSM and ANN for optimizing the physical factors for extracellular thermostable lipase production. Although both techniques gave good predictions, the ANN showed better performance in data fitting and estimation capabilities. However ANN in general suffers some disadvantages; ANNs relatively need large amounts of data for training and they work as black input/output box, it is hard to interpret their results.

In [5] ANN model, based on feed forward architecture and back propagation as training algorithm was applied to predict the state of batch fermentations with grape juice extracted from grape waste. The Levenberg- Marquardt optimization technique has been used to upgrade the network by minimizing the sum square error (SSE). Authors found that the best performance of the model for predicting cell

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Table of Contents Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model

1. Understanding the eBook Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - The Rise of Digital Reading Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Advantages of eBooks Over Traditional Books
2. Identifying Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - User-Friendly Interface
4. Exploring eBook Recommendations from Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Personalized Recommendations

- Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model User Reviews and Ratings
- Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model and Bestseller Lists
- 5. Accessing Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model Free and Paid eBooks
 - Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model Public Domain eBooks
 - Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model eBook Subscription Services
 - Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model Budget-Friendly Options
- 6. Navigating Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model eBook Formats
 - ePub, PDF, MOBI, and More
 - Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model Compatibility with Devices
 - Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Highlighting and Note-Taking Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Interactive Elements Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
- 8. Staying Engaged with Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
- 9. Balancing eBooks and Physical Books Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Setting Reading Goals Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model
 - Fact-Checking eBook Content of Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model

- Distinguishing Credible Sources
13. Promoting Lifelong Learning
- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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