MONITORING PEMBENTUKAN KETEBALAN *PELLICLE BACTERIAL CELLULOSE* SELAMA FERMENTASI DENGAN VARIASI SUMBER KARBON BERBASIS *REAL-TIME IMAGE PROCESSING*

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INTISARI

Nata de coco merupakan salah satu produk fermentasi *bacterial cellulose* oleh *Acetobacter xylinum* yang membutuhkan pemantauan ketat selama beberapa hari. Penelitian ini bertujuan untuk evaluasi sebaran data variabel selama fase pembentukan *bacterial cellulose* pada sumber karbon yang berbeda, menganalisis segmen dan korelasi antar variabel berpengaruh, serta penentuan model matematis kinetika sebagai prediktor pembentukan ketebalan *bacterial cellulose* selama fermentasi. Penelitian dimulai dengan pembuatan starter *Acetobacter xylinum*, media fermentasi dengan variasi sumber karbon (5% glukosa, 2% fruktosa, 5% sukrosa, atau 0,83% manitol). Fermentasi dilakukan hingga fase stasioner atau hingga pelikel menutupi bidang kamera. Ketebalan *bacterial cellulose* diamati dengan real-time image processing melalui USB kamera, sementara pH, kekeruhan, dan suhu diukur menggunakan sensor terintegrasi pada Arduino Uno. Analisis statistik terhadap pola pembentukan *bacterial cellulose* meliputi *principal component analysis*, *clustering analysis*, uji korelasi, dan penentuan model kinetika pembentukan *bacterial cellulose* dengan bantuan bahasa pemrograman R. *Cumulative proportion* tertinggi ditemukan pada perlakuan sumber karbon fruktosa (92,64%), diikuti oleh manitol (92,59%), sukrosa (88,65%), dan glukosa (83,80%). Hubungan antar parameter pada sumber karbon glukosa, sukrosa, dan manitol menunjukkan adanya tiga klaster utama, sedangkan sumber karbon fruktosa menunjukkan dua klaster utama. Korelasi antara variabel waktu dan ketebalan menunjukkan korelasi yang sangat kuat pada semua sumber karbon yang digunakan, dengan nilai korelasi lebih dari 0,95. Persamaan model Gompertz terpilih untuk kinetika fermentasi menggunakan glukosa ($y = 178{,}7415e^{(-48{,}09013e^{-0{,}00068111x})}, R^2 = 0{,}9976$) dan sukrosa ($y = 243{,}4395e^{(-6{,}976199e^{-0{,}00039839x})}, R^2 = 0{,}9979$), sedangkan persamaan model Van Bertalanffy terpilih untuk kinetika fermentasi menggunakan fruktosa ($y = 424{,}8781(1 - 1{,}336465e^{-0{,}00022855x})^3, R^2 = 0{,}9974$) dan manitol ($y = 160{,}0605(1 - 0{,}9376942e^{-0{,}00027453x})^3, R^2 = 0{,}9975$).

Kata Kunci: *bacterial cellulose, model kinetika fermentasi, nata de coco, real-time image processing, variasi sumber karbon*.

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MONITORING THE FORMATION OF BACTERIAL CELLULOSE PELLICLE THICKNESS DURING FERMENTATION WITH VARIATION OF CARBON SOURCES BASED ON REAL-TIME IMAGE PROCESSING

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ABSTRACT

Nata de coco is a product of bacterial cellulose fermentation by *Acetobacter xylinum*. The process requires careful monitoring for several days. This study aims to evaluate the distribution of variable data during the formation phase of bacterial cellulose on various carbon sources, to analyse segments and correlations between affected variables, and to determine the mathematical kinetics model as a predictor of the formation of bacterial cellulose thickness during fermentation. The research began with the preparation of *Acetobacter xylinum* starter, fermentation media with different carbon sources (5% glucose, 2% fructose, 5% sucrose, or 0.83% mannitol). Fermentation was carried out until the stationary phase or pellicle covered the camera's field of view. The thickness of the bacterial cellulose was monitored through real-time image processing using a USB camera, while pH, turbidity, and temperature were measured using integrated sensors on an Arduino Uno. The statistical analysis of bacterial cellulose formation patterns was conducted using the R programming language to perform principal component analysis, clustering analysis, correlation test, and determination of the kinetics model for bacterial cellulose formation. The fructose carbon source treatment had the highest cumulative proportion (92.64%), followed by mannitol (92.59%), sucrose (88.65%), and glucose (83.80%). Three main clusters were observed for the parameters on glucose, sucrose, and mannitol carbon sources, while the fructose carbon source showed two main clusters. A very strong correlation (correlation value > 0.95) was observed between time and thickness variables for all carbon sources used. The Gompertz model equation was selected for fermentation kinetics using glucose ($y = 178.7415e^{(-48.09013e^{-0.00068111x})}$, R^2 = 0.9976) and sucrose ($y = 243.4395e^{(-6.976199e^{-0.00039839x})}$, R^2 = 0.9979), while the Van Bertalanffy model equation was selected for fermentation kinetics using fructose ($y = 424.8781(1 - 1.336465e^{-0.00022855x})^3$, R^2 = 0.9974) and mannitol ($y = 160.0605(1 - 0.9376942e^{-0.00027453x})^3$, R^2 = 0.9975).

Keyword: *bacterial cellulose, fermentation kinetics model, nata de coco, real-time image processing, variation of the carbon source.*

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