OPTIMASI PROSES FERMENTASI TEMPE KEDELAI (Glycine max (L.) Merr.) BERBASIS SISTEM PENGENDALIAN CERDAS BERDASARKAN STANDAR MUTU CODEX CXS 313R-2013

INTISARI

Fermentasi tempe kedelai (*Glycine max* (L.) Merr.) sangat dipengaruhi oleh variasi cuaca, sehingga sulit mempertahankan mutu produk yang konsisten. Penelitian ini merancang dan membangun sistem inkubator berbasis *Internet of Things* (IoT) yang memantau suhu dan kelembapan relatif secara *Near Real-time*, menganalisis pengaruh jenis dan dosis inokulum serta posisi rak terhadap mutu tempe berdasarkan penilaian sensoris warna dan bau, serta membangun model prediktif mutu tempe menggunakan jaringan saraf tiruan (JST) dengan kondisi fermentasi dioptimasi melalui algoritma genetika (AG). Model JST memprediksi mutu sensoris dengan baik (R^2 = 0,78; RMSE = 0,13), dan optimasi AG meningkatkan mutu tempe sebesar 42,5% dengan variasi lebih konsisten. *Total Cost of Poor Quality* (CoPQ) per *batch* 100 kg turun dari Rp 209.000 menjadi Rp 124.342, terutama akibat penurunan biaya kegagalan internal. Dengan asumsi produksi 30 *batch* per bulan, penghematan CoPQ bulanan diperkirakan mencapai Rp 2.539.740. Skor warna dan bau tempe pasca optimasi masing-masing mencapai 1,00 ± 0,21 dan 1,29 ± 0,08, dengan probabilitas pemenuhan *threshold* konservatif 1,5 sekitar 86,7% (CI 95%: 82,8%–90,5%) untuk kedua atribut sensoris tersebut. Hasil ini menunjukkan bahwa pendekatan IoT–JST–AG efektif meningkatkan konsistensi mutu sensoris yang relevan dengan beberapa kriteria standar CODEX CXS 313R-2013, meskipun verifikasi menyeluruh terhadap seluruh parameter standar diperlukan pada studi lanjutan.

Kata kunci: algoritma genetika, fermentasi, IoT, jaringan saraf tiruan, optimasi mutu, tempe

OPTIMIZATION OF THE SOYBEAN TEMPEH (*Glycine max* (L.) Merr.) FERMENTATION PROCESS USING AN INTELLIGENT CONTROL SYSTEM BASED ON THE CODEX CXS 313R-2013 QUALITY STANDARD

ABSTRACT

Soybean tempeh (*Glycine max* (L.) Merr.) fermentation is highly influenced by weather variations, making it challenging to maintain consistent product quality. This study designed and developed an Internet of Things (IoT)-based incubator system to monitor temperature and relative humidity in *Near Real-time*, analyze the effects of inoculum type and dosage as well as rack position on tempeh quality based on sensory evaluation of color and odor, and construct a predictive quality model using artificial neural networks (ANN) with fermentation conditions optimized via a genetic algorithm (GA). The ANN model effectively predicted sensory quality ($R^2 = 0.78$; RMSE = 0.13), and GA optimization improved tempeh quality by 42.5% with reduced variability. Total *Cost of Poor Quality* (CoPQ) per 100 kg batch decreased from IDR 209,000 to IDR 124,342, primarily due to lower internal failure costs. Assuming production of 30 batches per month, monthly CoPQ savings are estimated at IDR 2,539,740. Post-optimization color and odor scores reached 1.00 ± 0.21 and 1.29 ± 0.08, with a conservative threshold of 1.5 achieved in approximately 86.7% of simulations (95% CI: 82.8%–90.5%) for both sensory attributes. These results indicate that the IoT–ANN–GA approach effectively enhances the consistency of sensory quality relevant to several criteria of CODEX CXS 313R-2013, although comprehensive verification against all standard parameters is recommended for further studies.

Keywords: artificial neural networks, fermentation, genetic algorithm, IoT, quality optimization, tempeh