# ABSTRAK

Kelapa sawit merupakan komoditas perkebunan strategis di Indonesia yang memiliki peran penting dalam sektor ekonomi. Salah satu faktor krusial dalam rantai produksinya adalah penentuan tingkat kematangan tandan buah segar (TBS), karena kualitas hasil minyak sawit sangat dipengaruhi oleh ketepatan panen. Namun, proses penentuan kematangan TBS di lapangan masih mengandalkan penilaian visual oleh manusia, yang rentan terhadap subjektivitas dan inkonsistensi. Hal ini dapat menurunkan efisiensi panen serta mutu produksi. Oleh karena itu, penelitian ini berupaya merancang Model berbasis kecerdasan buatan yang mampu melakukan klasifikasi tingkat kematangan TBS secara lebih objektif, akurat, dan konsisten.

Penelitian ini menggunakan metode *Convolutional Neural Network* (CNN) dengan pendekatan *transfer learning* pada dua arsitektur populer, yaitu ResNet-50 dan VGG16. Dataset penelitian terdiri dari 852 citra buah sawit tunggal hasil proses cleaning dari gabungan dua sumber terbuka *(Kaggle dan Roboflow)*. Dataset kemudian dibagi menjadi data latih, validasi, dan uji, dengan empat kelas tingkat kematangan: mentah, mengkal, matang, dan busuk. Model dilatih dalam empat skenario eksperimen (A1, A2, B1, dan B2) dengan variasi *hyperparameter learning rate*, sementara parameter lain seperti *optimizer, batch size*, dan jumlah *epoch* dijaga konstan. Proses pelatihan dilakukan melalui dua tahap, yaitu *feature extraction* dan *fine-tuning*. Evaluasi Model dilakukan menggunakan metrik akurasi, presisi, *recall, F1-score*, serta visualisasi *confusion matrix* dan *learning curve*. Untuk memperkuat validitas hasil, dilakukan pula uji statistik menggunakan *ANOVA* dan *Tukey HSD* untuk mengidentifikasi perbedaan signifikan antar skenario.

Hasil penelitian menunjukkan bahwa arsitektur ResNet-50 pada skenario A2 dengan *learning rate kecil (0.0001 pada feature extraction dan 1e-5 pada fine-tuning)* menghasilkan performa terbaik, dengan akurasi uji mencapai 92.97% dan rata-rata *F1-score* 0.93. Hasil uji *ANOVA* memperlihatkan adanya perbedaan signifikan antar skenario, sementara uji *Tukey HSD* mengonfirmasi bahwa perbedaan paling mencolok terdapat antara ResNet-50 A2 dengan VGG16 B2. Temuan ini membuktikan bahwa pemilihan *learning rate* yang lebih kecil mampu meningkatkan stabilitas konvergensi dan generalisasi Model, serta mengurangi risiko *overfitting*. Penelitian ini berkontribusi dalam menyediakan pendekatan berbasis CNN yang efektif untuk klasifikasi tingkat kematangan TBS, sekaligus memperkuat dasar pengembangan sistem panen berbasis kecerdasan buatan yang lebih objektif dan efisien.



**Kata Kunci:** *Convolutional Neural Network*, ResNet-50, VGG16, klasifikasi citra, kelapa sawit

## *ABSTRACT*

*Oil palm is one of the most strategic plantation commodities in Indonesia, playing a vital role in the national economy. A critical factor in the production chain is the determination of the ripeness level of fresh fruit bunches (FFB), as harvesting accuracy directly affects the quality and yield of palm oil. However, in practice, the determination of ripeness is still largely based on manual visual inspection, which is prone to subjectivity and inconsistency. This condition may lead to inefficient harvesting and decreased product quality. Therefore, this study aims to design an artificial intelligence-based* Model *capable of classifying oil palm fruit ripeness levels more objectively, accurately, and consistently.*

*This research employs the Convolutional Neural Network (CNN) method with a transfer learning approach using two popular architectures, ResNet-50 and VGG16. The dataset consists of 852 single-fruit images that were cleaned and compiled from two open sources (Kaggle and Roboflow). The dataset is divided into training, validation, and testing sets, with four ripeness categories: unripe, under-ripe, ripe, and overripe. Four experimental scenarios (A1, A2, B1, and B2) were designed by varying the learning rate, while other hyperparameters such as optimizer, batch size, and number of epochs were kept constant. The training process was carried out in two stages: feature extraction and fine-tuning.* Model *performance was evaluated using accuracy, precision, recall, and F1-score, along with confusion matrix and learning curve visualizations. To ensure the statistical validity of the results, ANOVA and Tukey HSD post-hoc tests were applied to examine significant differences between scenarios.*

*The results show that the ResNet-50 architecture in scenario A2, with a smaller learning rate (0.0001 in feature extraction and 1e-5 in fine-tuning), achieved the best performance, with a test accuracy of 92.97% and an average F1-score of 0.93. The ANOVA test indicated significant differences among scenarios, while the Tukey HSD confirmed that the most significant differences occurred between ResNet-50 A2 and VGG16 B2. These findings highlight that using a smaller learning rate enhances convergence stability and* Model *generalization while reducing the risk of overfitting. This study contributes by providing an effective CNN-based approach for oil palm fruit ripeness classification, reinforcing the foundation for developing AI-assisted harvesting systems that are more objective and efficient.*



***Keywords:*** *Convolutional Neural Network, ResNet-50, VGG16, image classification, oil palm*