RINGKASAN

KARAKTERISASI PRODUKSI, KUALITAS TELUR DAN POLIMORFISME GEN *GnRH* SERTA MODEL MATEMATIKA PRODUKSI TELUR AYAM LOKAL DAN KOMERSIAL

Setya Agus Santosa (NIM. D3A022003)

Tujuan penelitian adalah 1) menganalisis karakteristik produksi dan kualitas telur ayam lokal (Sentul) dan komersial (*Hy-Line Brown*); 2) menganalisis polimorfisme gen *GnRH* pada kedua jenis ayam lokal (Sentul) dan komersial (*Hy-Line Brown*); 3) menganalisis hubungan atau asosiasi *single nucleotide polymorphism* (SNP) pada gen *GnRH* dengan produksi dan kualitas telur ayam lokal dan komersial; 4) mengembangkan model matematika yang akurat untuk memprediksi kurva produksi telur pada ayam lokal dan komersial. **Orisinalitas dan kebaruan penelitian** meliputi 1) terdeteksinya marka genetik SNP pada gen *Gonadotrophin Releasing Hormone* (*GnRH*) yang berasosiasi dengan produksi dan kualitas telur pada ayam lokal dan komersial; 2) didapatkan model matematika produksi telur yang akurat untuk memprediksi kinerja produksi telur ayam lokal dan komersial.

Penelitian menggunakan 100 ekor ayam lokal (Sentul) dan 100 ekor ayam komersial (*Hy-Line Brown*). Ayam dipelihara hingga umur 80 minggu dalam kandang *closed house*. Materi penelitian meliputi telur, catatan produksi, dan sampel darah untuk analisis DNA. Pengamatan kualitas telur dilakukan pada umur 28 minggu. **Variabel** yang diamati adalah bobot telur, kekuatan kerabang, warna kuning telur, (Alig et al., 2023)bot kuning telur, bobot putih telur, *haugh unit* dan bobot kerabang. Pengambilan sampel darah untuk analisis polimorfisme gen *GnRH* dilakukan pada umur 31 minggu. **Analisis molekuler** menggunakan teknik PCR dan sekuensing DNA untuk mengidentifikasi polimorfisme gen *GnRH*. *Single nucleotide polymorphism* (SNP) yang teridentifikasi kemudian dianalisis asosiasinya dengan produksi dan kualitas telur. Data produksi telur hingga umur 80 minggu digunakan untuk pemodelan matematika. **Tujuan pemodelan** adalah untuk mengetahui pola produksi dengan pediksi model terbaik. Data yang digunakan untuk pemodelan matematika adalah *hen day production* (HDP) setiap minggu. Model matematika yang diuji meliputi fungsi Gamma Wood, kuadratik, kubik, dan kuartik. **Kecermatan model** matematika diuji dengan *adjust* R^2, *Mean Absolut Error (MAE), Root Mean Square Error (RMSE), Akaike Information Criterion (AIC)* dan *Bayesian Information Creterion (BIC).*

Berdasarkan **hasil penelitian** didapatkan ayam komersial (*Hy-Line Brown*) lebih unggul dalam hampir semua parameter produksi dan kualitas telur dibandingkan ayam lokal (Sentul). **Produksi telur** ayam *Hy-Line Brown* mencapai 97,87%, lebih tinggi dari Sentul (67,98%). **Bobot telur** ayam *Hy-Line Brown* lebih berat (62,42 g) dibandingkan Sentul (50,72 g). **Komponen telur**: bobot putih telur (32,40 vs 26,19 g), bobot kuning telur (21,60 vs 17,62 g), dan bobot kerabang (8,26 vs 6,83 g) pada *Hy-Line Brown* secara signifikan lebih berat. **Kualitas internal**: *haugh unit* (HU) pada *Hy-Line Brown* lebih tinggi (95,55) dibandingkan Sentul (86,71). **Kualitas eksternal**: kerabang telur *Hy-Line Brown* lebih tebal (0,38 mm vs 0,37 mm), lebih kuat (0,42 kgf vs 0,34 kgf), dan warnanya lebih gelap serta seragam (skala 13,90 vs 8,62). **Warna kuning telur**: tidak ada perbedaan signifikan antara ayam lokal dan komersial.

Hasil analisis **polimorfisme gen *GnRH*** menunjukkan perbedaan antara kedua jenis ayam. **Ayam *Hy-Line Brown* bersifat monomorfik**, artinya tidak ditemukan variasi genetik (polimorfisme) pada semua individu yang diuji. **Ayam Sentul bersifat polimorfik**, dengan ditemukannya tiga *Single Nucleotide Polymorphism* (SNP), yaitu **g.2416 C>G, g.2424 T>C,**

dan g.2425 A>G. Setiap SNP memperlihatkan dua varian genotipik yang berbeda, yaitu: 1) SNP g.2416 C>G menghasilkan genotipe heterozigot CG dan homozigot CC, 2) SNP g.2424 T>C teridentifikasi hanya dalam bentuk homozigot, yaitu TT dan CC, sedangkan 3) SNP g.2425 A>G menghasilkan genotipe homozigot AA dan homozigot GG.

Hukum **keseimbangan Hardy-Wienberg** digunakan untuk menguji *goodness-of-fit* distribusi frekuensi genotipe dalam populasi ideal. Berdasarkan **distribusi alel dan genotipe**, pada ayam Sentul menunjukkan penyimpangan dari keseimbangan Hardy-Weinberg, mengindikasikan adanya pengaruh seleksi atau faktor evolusioner lainnya. **SNP g.2416 C>G**: frekuensi alel C (0,825) lebih dominan daripada alel G (0,175). Hanya ditemukan genotipe CC dan CG. **SNP g.2424 T>C**: frekuensi alel T (0,65) lebih tinggi dari alel C (0,35). Tidak ditemukan individu heterozigot (TC), hanya homozigot TT dan CC. **SNP g.2425 A>G**: frekuensi alel A (0,65) lebih tinggi dari alel G (0,35). Tidak ditemukan individu heterozigot (AG).

Analisis asosiasi produksi dan kualitas telur pada **ayam *Hy-Line Brown* tidak dapat dilakukan** karena **bersifat monomorfik. Analisis asosiasi** produksi dan kualitas telur hanya dilakukan pada **ayam Sentul karena adanya variasi genetik**. Hasilnya menunjukkan bahwa setiap SNP memiliki pengaruh spesifik: **SNP g.2416 C>G:** berasosiasi signifikan dengan **produksi telur dan ketebalan kerabang** ($P<0,05$). Alel C cenderung memberikan efek positif pada kedua sifat tersebut. **SNP g.2424 T>C**: berasosiasi sangat signifikan dengan **bobot putih telur, bobot kerabang, dan ketebalan kerabang** ($P<0,01$). Alel T unggul dalam meningkatkan kualitas fisik kerabang. **SNP g.2425 A>G**: berasosiasi signifikan terhadap **produksi telur** ($P<0,01$) dan bobot kuning telur ($P<0,05$). **Ayam dengan genotipe GG menghasilkan telur secara signifikan lebih banyak (72,04%) dibandingkan genotipe AA (65,80%)**. Hasil identifikasi ini memungkinkan **SNP g.2425 A>G** sebagai **marker genetik potensial** untuk seleksi **peningkatan produksi telur ayam Sentul**.

Hasil analisis **parameter komponen genetik** pada ayam Sentul mendapatkan dasar pewarisan sifat-sifat yang terkait dengan SNP yang teridentifikasi. **SNP g.2416 C>G**: alel C menunjukkan efek aditif yang lebih unggul untuk produksi telur dan kualitas kerabang. Namun, variansi dominan (VD) lebih besar daripada variansi aditif (VA), menunjukkan bahwa **efek dominansi membuat seleksi tidak efektif**. **SNP g.2424 T>C**: alel T unggul secara aditif untuk bobot putih telur dan kualitas kerabang, sedangkan alel C unggul untuk *haugh unit*. Variasi genetik pada lokus ini murni disebabkan oleh efek aditif (**VD=0**), sehingga **ideal untuk program seleksi**. **SNP g.2425 A>G**: **alel G memiliki efek aditif positif yang kuat terhadap produksi telur**, sedangkan alel A berefek positif pada bobot kuning telur. Pewarisan sifat pada lokus ini sepenuhnya bersifat aditif (**VD=**0), sehingga **menguntungkan untuk seleksi** karena responnya dapat diprediksi dengan baik.

Model matematika kurva produksi telur. Empat model matematika (Gamma Wood, kuadratik, kubik, dan kuartik) telah dihitung untuk memprediksi kurva produksi telur hingga umur 80 minggu. Hasil uji *goodness of fit* (meliputi *Adjusted* R^2, MAE, RMSE, AIC, dan BIC) secara konsisten menunjukkan bahwa **model kuartik adalah yang terbaik dan paling akurat** untuk memprediksi produksi telur pada ayam Sentul dan *Hy-Line Brown*. Model kuartik ayam Sentul memiliki *Adjusted* R^2 sebesar 96,25%, sedang ayam *Hy-Line Brown* 92,07%. Uji kesesuaian menggunakan metode MAE, RSME, AIC dan BIC menunjukkan bahwa model persamaan penaksir produksi telur semakin baik atau valid dengan nilai yang didapat semakin kecil. Model kuartik mampu menggambarkan puncak produksi dan persistensi lebih baik, terutama pada ayam komersial yang memiliki pola produksi intensif.

Kesimpulan 1) ayam **komersial** (*Hy-Line Brown*) **lebih unggul** dalam produksi dan kualitas telur dibandingkan ayam lokal (Sentul); 2) Gen *GnRH* pada **ayam Sentul bersifat polimorfik**, sedangkan pada ayam ***Hy-Line Brown*** **bersifat monomorfik**; 3) Terdapat asosiasi antara *Single Nucleotide Polymorphisms* (SNP) g.2416 C>G, g.2424 T>C, dan g.2425 A>G dengan produksi dan kualitas telur pada ayam lokal (Sentul). **SNP g.2416** C>G **berasosiasi** dengan **produksi telur** dan **ketebalan kerabang**. **SNP g.2424** T>C berasosiasi dengan **bobot putih telur, bobot kerabang, dan ketebalan kerabang**. **SNP g.2425** A>G berasosiasi dengan **produksi telur dan bobot kuning telur**. **;** 4) **model matematika kuartik** merupakan model yang **paling akurat** untuk memprediksi kurva produksi telur pada ayam lokal (Sentul) dan komersial (*Hy-Line Brown*).

SUMMARY

CHARACTERIZATION OF PRODUCTION, EGG QUALITY, AND GnRH GENE POLYMORPHISM, AND A MATHEMATICAL MODEL OF EGG PRODUCTION IN LOCAL AND COMMERCIAL CHICKENS

Setya Agus Santosa (Number of Students: D3A022003)

The objectives of this research were: 1) to analyze the characteristics of egg production and quality in local (Sentul) and commercial (Hy-Line Brown) chickens; 2) to analyze GnRH gene polymorphism in both local (Sentul) and commercial (Hy-Line Brown) chickens; 3) to analyze the relationship or association of single nucleotide polymorphisms (SNPs) in the GnRH gene with egg production and quality in local and commercial chickens; and 4) to develop an accurate mathematical model to predict egg production curves in local and commercial chickens. The originality and novelty of the research include 1) the detection of SNP genetic markers in the Gonadotrophin Releasing Hormone (GnRH) gene associated with egg production and quality in local and commercial chickens; 2) the development of an accurate mathematical model of egg production to predict the egg production performance of local and commercial chickens.

The study used 100 local chickens (Sentul) and 100 commercial chickens (Hy-Line Brown). The chickens were raised until 80 weeks of age in a closed house. The research materials included eggs, production records, and blood samples for DNA analysis. Egg quality was monitored at 28 weeks of age. The variables observed were egg weight, shell strength, yolk color, yolk volume, white weight, Haugh unit, and shell weight (Alig et al., 2023). Blood samples were taken for GnRH gene polymorphism analysis at 31 weeks of age. Molecular analysis using PCR and DNA sequencing techniques was performed to identify GnRH gene polymorphisms. The identified single nucleotide polymorphisms (SNPs) were then analyzed for their association with egg production and quality. Egg production data up to 80 weeks of age were used for mathematical modeling. The purpose of the modeling was to determine the production pattern with the best model prediction. The data used for mathematical modeling was weekly hen day production (HDP). The mathematical models tested included Wood's Gamma function, quadratic, cubic, and quartic functions. The accuracy of the mathematical models was tested using adjusted R2, Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC).

Based on the research results, commercial chickens (Hy-Line Brown) were superior in almost all parameters of egg production and quality compared to local chickens (Sentul). Hy-Line Brown chicken egg production reached 97.87%, higher than Sentul (67.98%). Hy-Line Brown chicken egg weight was heavier (62.42 g) than Sentul (50.72 g). Egg components: egg white weight (32.40 vs 26.19 g), yolk weight (21.60 vs 17.62 g), and shell weight (8.26 vs 6.83 g) in Hy-Line Brown were significantly heavier. Internal quality: haugh unit (HU) in Hy-Line Brown was higher (95.55) than Sentul (86.71). External quality: Hy-Line Brown eggshells are thicker (0.38 mm vs. 0.37 mm), stronger (0.42 kgf vs. 0.34 kgf), and darker and more uniform in color (13.90 vs. 8.62). Yolk color: no significant difference between local and commercial chickens.

The results of the GnRH gene polymorphism analysis showed differences between the two types of chickens. Hy-Line Brown chickens are monomorphic, meaning that no genetic variations (polymorphisms) were found in all individuals tested. Sentul chickens are polymorphic, with the discovery of three Single Nucleotide Polymorphisms (SNPs), namely g.2416 C>G, g.2424 T>C, and g.2425 A>G. Each SNP shows two different genotypic variants, namely: 1) SNP g.2416 C>G produces heterozygous genotypes CG and homozygous CC, 2) SNP g.2424 T>C was identified only in homozygous forms, namely TT and CC, while 3) SNP g.2425 A>G produces homozygous genotypes AA and homozygous GG.

The Hardy-Weinberg equilibrium law is used to test the goodness-of-fit of the genotype frequency distribution in an ideal population. Based on the distribution of alleles and genotypes, Sentul chickens show deviations from Hardy-Weinberg equilibrium, indicating the influence of selection or other evolutionary factors. SNP g.2416 C>G: the frequency of the C allele (0.825) is more dominant than the G allele (0.175). Only CC and CG genotypes were found. SNP g.2424 T>C:

the frequency of the T allele (0.65) is higher than the C allele (0.35). No heterozygous individuals (TC) were found, only TT and CC homozygotes. SNP g.2425 A>G: the frequency of the A allele (0.65) is higher than the G allele (0.35). No heterozygous individuals (AG) were found.

Association analysis of egg production and quality in Hy-Line Brown chickens could not be performed because they are monomorphic. Association analysis of egg production and quality was only performed on Sentul chickens due to genetic variation. The results showed that each SNP has a specific effect: SNP g.2416 C>G: significantly associated with egg production and shell thickness ($P<0.05$). The C allele tends to have a positive effect on both traits. SNP g.2424 T>C: highly significantly associated with egg white weight, shell weight, and shell thickness ($P<0.01$). The T allele is superior in improving the physical quality of the shell. SNP g.2425 A>G: significantly associated with egg production ($P<0.01$) and yolk weight ($P<0.05$). Chickens with the GG genotype produced significantly more eggs (72.04%) than the AA genotype (65.80%). These identification results allow SNP g.2425 A>G to be a potential genetic marker for selection to increase egg production in Sentul chickens.

The results of the analysis of genetic component parameters in Sentul chickens provide the basis for inheritance of traits associated with the identified SNPs. SNP g.2416 C>G: the C allele shows a superior additive effect for egg production and shell quality. However, the dominance variance (VD) is greater than the additive variance (VA), indicating that the dominance effect makes selection ineffective. SNP g.2424 T>C: the T allele is additively superior for egg white weight and shell quality, while the C allele is superior for haugh units. Genetic variation at this locus is purely due to additive effects (VD = 0), making it ideal for selection programs. SNP g.2425 A>G: the G allele has a strong positive additive effect on egg production, while the A allele has a positive effect on yolk weight. Inheritance at this locus is entirely additive (VD = 0), making it advantageous for selection because its response is well predicted.

Mathematical model of egg production curve. Four mathematical models (Wood's Gamma, quadratic, cubic, and quartic) were calculated to predict egg production curves up to 80 weeks of age. The results of goodness of fit tests (including Adjusted R^2, MAE, RMSE, AIC, and BIC) consistently showed that the quartic model was the best and most accurate for predicting egg production in Sentul and Hy-Line Brown chickens. The quartic model for Sentul chickens had an Adjusted R^2 of 96.25%, while for Hy-Line Brown chickens it was 92.07%. The goodness-of-fit test using the MAE, RSME, AIC, and BIC methods showed that the egg production estimator equation model was increasingly valid with smaller values obtained. The quartic model was able to describe peak production and persistence better, especially in commercial chickens with intensive production patterns.

Conclusion 1) Commercial chickens (Hy-Line Brown) are superior in egg production and quality compared to local chickens (Sentul); 2) GnRH gene in Sentul chickens is polymorphic, while in Hy-Line Brown chickens it is monomorphic; 3) There is an association between Single Nucleotide Polymorphisms (SNP) g.2416 C>G, g.2424 T>C, and g.2425 A>G with egg production and quality in local chickens (Sentul). SNP g.2416 C>G is associated with egg production and shell thickness. SNP g.2424 T>C is associated with egg white weight, shell weight, and shell thickness. SNP g.2425 A>G is associated with egg production and yolk weight. ; 4) Quartic mathematical model is the most accurate model to predict egg production curves in local chickens (Sentul) and commercial chickens (Hy-Line Brown).