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Study of Non-Genetic Factors Affecting Dairy Cow's Milk Production and the Development of Correction Factors for Selection of FH Cattle in Indonesia

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Abstract. The purpose of this study is to identify the non-genetic variables that have a substantial impact on the milk output per lactation of FH dairy cows at BBPTUHPT Baturraden and to construct variables' correction factors. The National Dairy Cow and Forage Breeding Center (BBPTUHPT) of Baturraden provided the secondary data for the study, which included 1,942 unique records of the amount of milk produced per lactation by 1,015 FH dairy cows born between 2000 and 2014 (a total of 1,015 lactation records). Milk output per lactation, the number of milking days (100–600), the age at calving (575–2,993 days), the lactation phase (lactation 1-6), and the season of birth were among the studied variables. The F test was used to examine the impact of non-genetic factors on the amount of milk cows produce per lactation (ANOVA). The impact of season on milk output per lactation was examined using a student t-test. Utilizing the multivariate least squares method, correction factors were created. Age at calving, which ranges from 1750 to 2000 days, milking days, which range from 300 to 350, and the dry season serve as the primary benchmarks for constructing correction factors. The R program was used to generate and run statistical tests and graphic representation. The findings indicated that the age of calving and lactation period had a very strong correlation (r= 0.94). The number of milking days, age at calving, and season at birth all significantly affected milk output per lactation, with the variance contributing 84.16 percent to the overall variation, according to the results of multivariate analysis ($P < 0.01$). Actual milk production had a mean (standard deviation) of 3710.55 kg, while adjusted milk production had a mean (standard deviation) of 5167.91 kg. The adjustment parameters can lower the variation in milk production each lactation by 57.92%. (43.00 percent vs 18.09 percent). Conclusion: Non-genetic variability was successfully reduced by correcting milk production data on the number of days of milking, age at calving, and season at birth.

Keywords: Dairy cows, environmental factors, production, reproduction, non-genetic

Abstrak. Penelitian ini bertujuan untuk mengetahui faktor-faktor non-genetik yang berpengaruh terhadap produksi susu per laktasi sapi perah FH di BBPTUHPT Baturraden dan menyusun faktor koreksi untuk faktor-faktor tersebut. Penelitian menggunakan data sekunder dari BBPTUHPT Baturraden yang terdiri dari 1.942 catatan individu produksi susu per laktasi dari 1.015 ekor sapi perah FH yang lahir pada tahun 2000-2014. Variabel penelitian meliputi produksi susu per laktasi, jumlah hari pemerahan, umur saat beranak, periode laktasi, dan musim saat ternak lahir. Pengaruh faktor non-genetik terhadap produksi susu per laktasi induk sapi diuji menggunakan uji F (ANOVA). Pengaruh musim terhadap produksi susu per laktasi sapi FH dianalisis menggunakan uji t. Hubungan antar peubah kategorikal (bulan, musim) dianalisis menggunakan uji Chi-Square. Angka koreksi disusun menggunakan metode kuadrat terkecil. Pengujian statistik dan grafik visualisasi data dilakukan dan dibuat menggunakan program R antar muka RStudio. Uji F secara terpisah terhadap semua peubah independen diperoleh adanya pengaruh yang sangat signifkan terhadap produksi susu per laktasi. Hasil analisis menunjukkan hubungan yang sangat erat (r=0.94) antara umur saat beranak dengan periode laktasi. Hasil analisis multivariate linear model menunjukkan bahwa jumlah hari pemerahan, umur saat beranak dan musim saat ternak lahir memiliki pengaruh yang sangat-sangat nyata ($P < 0.01$) terhadap produksi susu per laktasi dengan sumbangan variansi terhadap variasi total sebesar 84,16 %. Rata-rata (simpang baku) produksi susu aktual dan terkoreksi berturut-turut adalah 3710,55 (1595,64) dan 5167.91 (935.11) kg. Faktor koreksi yang disusun dapat menurunkan 57,92 % ragam produksi susu per laktasi (43,00 % vs 18,09 %). Dapat disimpulkan bahwa produksi susu per laktasi dipengaruhi oleh jumlah hari pemerahan, umur saat beranak dan musim saat ternak lahir. Faktor koreksi yang disusun untuk faktor non-genetik tersebut berhasil menurunkan keragaman produksi susu per laktasi.

Kata kunci: Sapi perah, faktor lingkungan, produksi, reproduksi, non-genetik

Introduction

Milk production of dairy cows, like other quantitative traits, is influenced by genetic and non-genetic factors throughout the life of the animal. The milk production of dairy cows per lactation has a moderate heritability estimate value, for example as reported by (Cilek and Sahin, 2009) that milk production per lactation in the 1-3 lactation period is 0.47 ± 0.12, 0.38 ± 0. 04 and 0.30 ± 0.06. However, several research reports reported low heritability estimates. (Pickering et al., 2015; Stefani et al., 2018; Ismael et al., 2021) reported estimated heritability values of 0.15, 0.25, and 0.08, respectively. However, high heritability values (>0.4) are also found in the literature, for example (Krisnamurti et al., 2019) reported an estimated heritability value of 0.43 ± 0.19 and (Ali et al., 2019) reported an estimated heritability value heritability 0.46 ± 0.206. This shows that non-genetic factors have an important contribution to livestock expressing their milk production and have various estimated values. The various heritability estimates are reasonable because the heritability estimates are relative values that are influenced by the data population, assessment methods, and environmental factors included in the value assessment (Falconer and Mackay, 1996).

Selection of livestock as seeds must be free from bias due to non-genetic influences so that all non-genetic factors that have a significant effect on a character must be eliminated or minimized. One way to eliminate or minimize the influence of these non-genetic factors is to make corrections to the data on non-genetic factors that have a real influence. The United States Dairy Herd Improvement Association (DHIA) has issued correction factors for several non-genetic factors for dairy cattle (Everett et al., 1968). However, the best correction factor for a livestock population is one that is compiled based on data derived from the livestock population being kept (Santosa et al., 2014). Because the influence of non-genetic factors can change from time to time, ideally correction factors are also compiled based on up-to-date data from a population. However, in the estimation of genetic parameters using animal linear models, the data correction process is carried out simultaneously with the estimation of genetic parameters (Mrode, 2014).

The purpose of this study was to determine the non-genetic factors that have a significant effect on milk production per lactation of FH cattle at BBPTUHPT Baturraden and develop correction factors for non-genetic factors that have a significant effect.

Materials and Methods

The study was conducted using the FH dairy cattle database obtained from the Baturraden Superior Cattle Breeding and Forage Animal Feed Center (BBPTUHPT). The material used in this study was a database of dairy cows born in the period 2000-2014 which consisted of 1,942 individual records of milk production per lactation from 1,015 FH dairy cows. The variables observed were milk production per lactation, month and year of mother's birth, month and year of calving, lactation period, age of mother at calving, and number of milking days (JHP). The age of the dams (days) is calculated using the date of birth and the date of the brood. The brooding season was determined using the month when the mother gave birth which was converted into seasons using the traditional season classification, namely the rainy season (October - March) and the dry season (April - September). The data analyzed in this study were milk production per lactation (lactation 1-6) with JHP 100-600, age at calving 575-2993 days, and lactation period 1-6.

The F test (ANOVA) was used to determine the effect of observed non-genetic factors (month and year of mother's birth, month and year of calving, lactation period, age group of mothers at calving, and JHP) on milk production per lactation. While the effect of season on milk production per lactation of FH cattle was analyzed using the t-test. The independence test for categorical variables (month and season) was carried out using the chi-square test.

Correction factors for non-genetic factors that have a significant effect on milk production per lactation were prepared using the multiplicative technique from the estimation results of the least square method. The reference (base) used in the least square calculation of JHP is class 300-350 days while the age at calving is class 1750-2000 days. The dry season is used as a reference (base) in the least squares calculation to determine the seasonal correction factor.

Corrected milk production per lactation is calculated using the following formula:

$$MY_{corrected} = FK_1\ x\ FK_2 x\ \ldots\ldots x\ FK_j\ x\ MY_{actual}$$

(Warwick et al., 1995)

$MY_{corrected}$: Corrected production per lactation (kg)
MY_{actual} : actual (real) milk production per lactation (kg)
FK_j: The jth correction factor is a non-genetic factor that has a significant effect on milk production per lactation.

Changes in the value of the variance of milk production with the use of correction factors are done by comparing the coefficient of variation of real milk production with the coefficient of variation of corrected production which is calculated using the following formula:

$$VarRed = \frac{(CV_{actual} - CV_{corrected})}{CV_{actual}}\ x\ 100\ \%$$

VarRed: corrected decrease in production variation coefficient compared to real production (%)
CV_{actual}: actual (real) milk production variability coefficient per lactation
$CV_{corrected}$: corrected coefficient of variation in milk production per lactation

Statistical analysis and visualization of research results were carried out using the tidyverse and ggplot2 packages from the R program (R Core Team, 2020) and the Rstudio interface (RStudio Team, 2020).

Results and Discussion

Effect of non-genetic factors

Through the F-test (ANOVA) it can be seen that all the non-genetic factors studied (month and year of mother birth, month and year of calving, lactation period, age of mother at calving, and JHP) have a very, very significant effect (P <0.001) on milk production per lactation of FH dairy cows (Table 1).

The results of the analysis using the F test (ANOVA) show that the month when the mother was born has a very significant effect on milk production per lactation of dairy cows (Table 1). Variations in milk production per lactation based on the month when the cattle were born are shown in Figure 1.

Table 1. Results of analysis of non-genetic factors on milk production per lactation

Non-genetic factors	Method of Analysis	Significance level
Month of birth (MOB)	F-test ANOVA	**
Year of birth	F-test ANOVA	***
Month of calving (MOCalv)	F-test ANOVA	***
Year of calving	F-test ANOVA	***
Lactation period	F-test ANOVA	***
Number of days milked	F-test ANOVA	***
Group age of calving	F-test ANOVA	***
Season of birth (SOB)	T-test Student	***
Season of calving (SOCalv)	T-test Student	*
MOB and MOCalv relationship	Chi-Square test	***
SOB and SOCalv relationship	Chi-Square test	**

Notes: *) P<0,05; **) P<0,01; ***) P<0,001

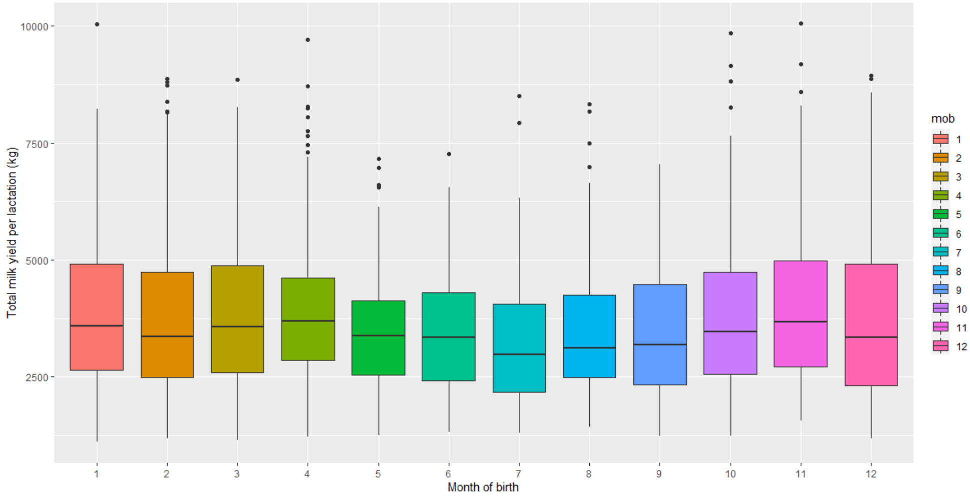

Figure 1. Distribution of milk production per lactation based on the month when the dam was born

The effect of the month when the dams were born on the milk production of cows per lactation is indirect but through a relationship between the month and rainfall and the availability of feed in quantity and quality. Estiningtyas et al. (2007) showed a relationship between the month and rainfall. Through observing monthly rainfall data for the period 1988-2006, Estiningtyas et al. (2007) showed a pattern of high rainfall in October-April and low rainfall in May-September. The availability of feed is influenced by the season (Indrijani, 2008; Suardin et al., 2015). According to Santos and Santos (1979), malnutrition in the postnatal period will have an impact on disrupting the process of multiplication of cells in the forebrain, especially aglia cells. This condition is thought to have a further impact on the development of udder alveoli cells as a center for milk synthesis.

Variations in milk production per lactation of FH dairy cows based on the year when the cows were born are shown in Figure 2. The results of the F test (ANOVA) showed that the year when the cows were born had a very, very significant effect ($P<0.001$) on milk production per lactation of FH cows. Various factors can be the cause of the relationship between the year when the mother was born with milk production per lactation. In general, the influencing factors can be grouped into 2, namely genetic factors and environmental factors. Environmental factors in general, for example, rearing management and rainfall which in turn affect the availability of forage and nutrient content of forage. This environmental factor is the main factor that influences milk production per lactation of dairy cows. Genetic factors that influence milk production per lactation include differences in breeding values (additive genetic values) of dams born in different years.

Differences in livestock breeding values can occur due to livestock selection programs carried out in populations. The selection of livestock causes an increase in the frequency of the desired gene in the population which is then expressed in an increase in the average phenotypic value (Falconer and Mackay, 1996). The selection that commonly occurs in the dairy cattle population is to increase the mother's milk production. Apart from selection, the entry of imported livestock into the population can also affect the average milk production per lactation. The population of dairy cattle at BBPTUHPT Baturraden consists of imported cattle and cattle born at BBPTUHPT Baturraden. The different compositions of local and imported livestock can cause differences in milk production per lactation. Although using a different year of data from this study, Estiningtyas et al. (2007) have shown that there is variation in the amount of rainfall between years.

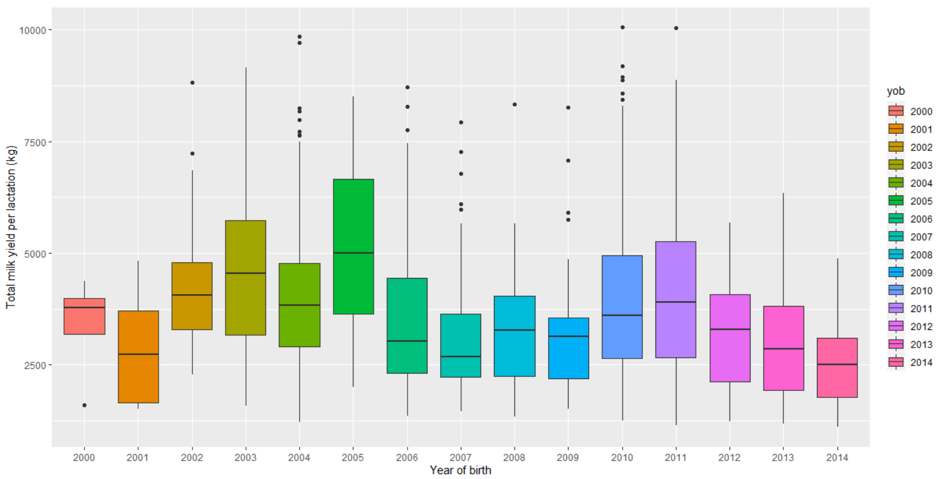

Figure 2. Distribution of milk production per lactation based on the year when the dam was born

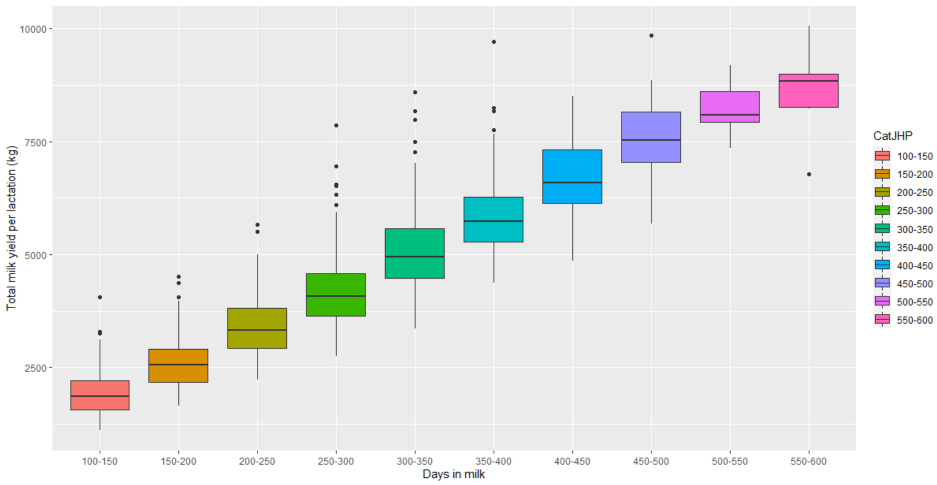

Figure 3. Distribution of milk production per lactation based on the number of milking days

The month and year when the dams also affect the cow's milk production per lactation (Table 1). Van Eetvelde et al. (2020) stated that the month of calving is more important than the month of birth concerning the mother's milk production. The results of this study reported that the variation in milk production per lactation caused by the month when the mother gave birth was five times greater than the variation caused by the month when the mother was born. Through experiments on limiting feed nutrition, in this case, protein, 1-3 days before calving, Santos and Santos (1979) have shown a decrease in dams milk production. The effect of month and year on milk production per lactation is thought to occur indirectly but through a relationship between the availability of both the quality and quantity of feed when the cattle are born. Milk production is strongly influenced by feed (Astuti et al., 2016).

The very, very significant effect of the mother's lactation period on the cow's milk production per lactation (Table 1) is thought to also occur directly through the relationship between the age of the cattle at lactation. In general, it can be described that there is an increase in milk production after the initial period of lactation which is then followed by a decrease in production after passing the peak production period which is usually achieved in the 5th lactation (Wondiraw, 2013). Meanwhile, the pattern of milk production in cows for each lactation period generally follows a pattern known as the lactation curve (Cziszter et al., 2013; Jingar et al., 2014). In general, the lactation curve is known for short lactation periods (Narwaria et al., 2015) and long lactation periods (Cole et al., 2009).

Based on the analysis of variance using the F test, it can be seen that the effect of JHP, age at calving, and calving season on milk production per lactation separately was very, very significant (P<0.001). The effect of JHP on milk production per lactation is very easy to understand, namely increasing the number of milking days will increase the amount of milk production per lactation. Variations in milk production per lactation based on the number of milking days are visualized in Figure 3.

Milk production per lactation of cow's milk is affected by age at calving (Table 1). This phenomenon has been widely reported by previous studies, for example. The effect of sow age at calving on milk production per lactation is thought to be related to the status of physiological changes in livestock due to the process of increasing age during lactation. The regression of milk production on the age of livestock at lactation is in the form of a curvilinear, however, the nature and amount of curvature (curvature) vary widely (López et al., 2015). Figure 6 shows the variations in milk production per lactation of cows based on the age at calving.

The age at which the mother gives birth to the lactation period has a very close relationship. The results of the correlation analysis between the two resulted in a very large correlation coefficient of 0.94 (P < 0.01). The increasing age of livestock will also increase the period of lactation of the mother or vice versa. A very large correlation coefficient indicates a very close relationship between the two. In statistical analysis using least squares, the use of 2 variables that have a very strong correlation can reduce the accuracy of the resulting estimation results due to the collinearity of these variables. Collinearity is always avoided in multiple regression analysis (Shafii et al., 1996; Tisman and Putra, 2015). Because there is a very close relationship between the lactation period and the age at which the mother gives birth, the influence of these environmental factors on milk production in this study is represented by one of them, namely the age factor at the time the mother gives birth so that the estimation results of linear regression in estimating the correction factor are free from the influence of collinearity. between the two.

Testing the effect of the season when the cows were born and when the cows calved on milk production per lactation was carried out using the Student's t-test. The results of the Student's t-test for the average milk production based on the season when the mothers gave birth showed a very significant difference (P<0.05) (Table 1). The results of the Student's t-test analysis for the average milk production based on the season when the dams were born showed a very, very significant difference (P<0.001). The season when the dams calve and the season when the dams are born is thought to have an indirect effect on milk production per lactation through the relationship between the availability of both quantity and quality of feed on milk production per lactation of dams in different seasons. Forage production in the tropics fluctuates throughout the year and depends on the season (rainfall) (Nasrullah et al., 2003).

The test results on the independence between categorical variables (month and season) using chi-square showed that the season when the mother gave birth and the season when the mother was born had a very significant relationship (P<0.01). Likewise, the month when the mother gave birth and the month when the mother was born also showed a significant relationship (P<0.01).

Differences between the factors of the season when the mother calves and the season when the mother is born on the milk production of cows per lactation are shown in Figures 5 and Figure 6. The average milk production per lactation of mothers who calve during the dry season is lower than the milk production of cows per lactation of the cows. giving birth during the rainy season (3,543.23 vs 3,807.84 kg). The same is observed in the milk production of dams born in different seasons. The average milk production of mothers born in the dry season was lower than that of born in the rainy season (3623.98 vs 3797.48 kg).

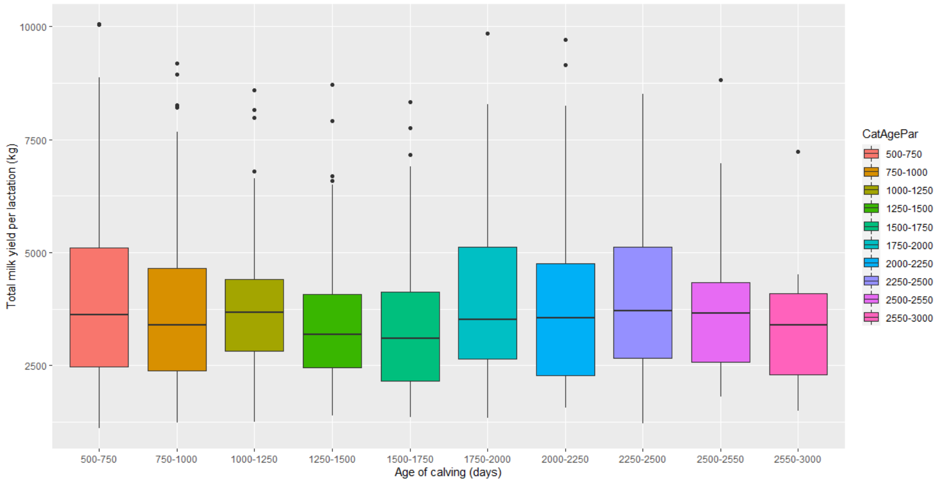

Figure 4. Distribution of milk production per lactation based on age at calving

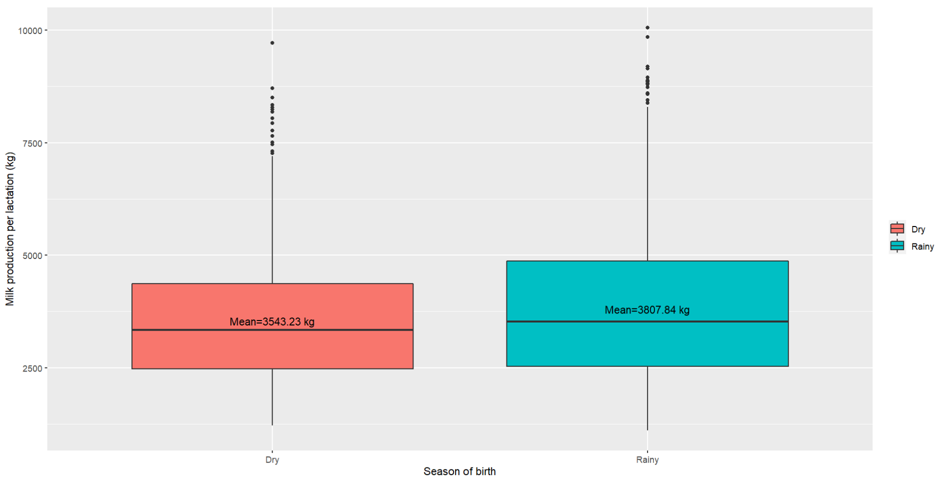

Figure 5. Milk production per lactation based on the season when the dams were born

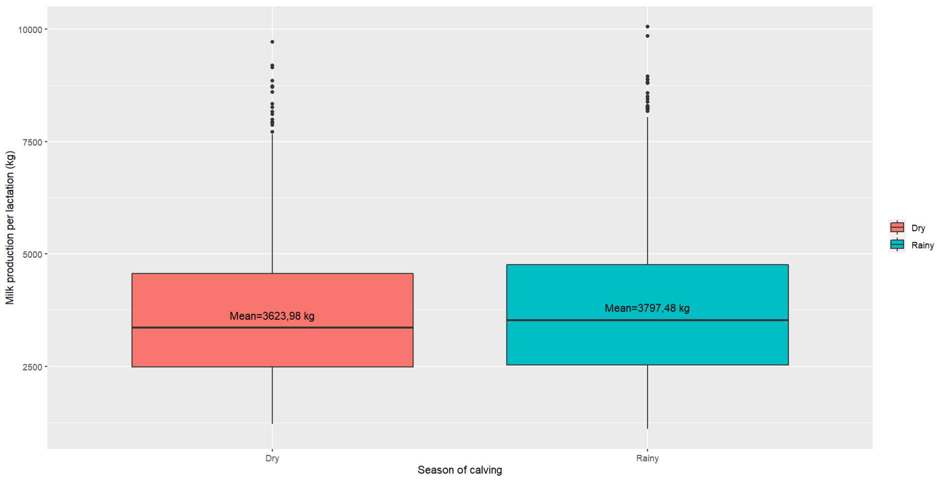

Figure 6. Milk production per lactation based on the season of calving

Table 2. Basic statistics on real, corrected milk production and age and number of milking days

Statitistik	MY_a (kg)	Umur (hari)	JHP (hari)	MY_c (kg)
Minimum	1,107.50	575.00	100.00	2,839.44
Mean	3,710.55	1,251.60	233.50	5,167.91
Maximum	10,052.80	2,993.00	571.00	9,941.49
Standard deviation	1,595.64	534.27	86.11	935.11
Coefficient of variation (%)	43.00	36.88	42.69	18.09

Notes:
MY_a : milk production per lactation real (actual)
MY_c : corrected milk production per lactation
JHP : Number of milking days during one lactation period
Coefficient of variation = $\frac{\sigma}{\bar{X}} x100$ %

The results of statistical analysis in this study showed that the average corrected milk production per lactation was higher than the real (actual) production per lactation. The average actual milk production from the results of this study (Table 2) is relatively not different from that reported by (Santosa et al., 2014). Using 324 milk production records from 108 dairy cows, (Santosa et al., 2014) reported the mean, standard deviation, and coefficient of variation of milk production per lactation of 3,847.6 kg, 1,142.8 kg, and 29.7 %, respectively. The average milk production per lactation obtained in this study is different from the average milk production reported by other studies (Anggraeni et al., 2008; Rokhayati, 2010; Pasaribu et al., 2015; Anggraeni et al., 2008) who reported the average milk production per year and full lactation from BPPT-SP Cikole Lembang, namely between 4,058 - 4,558 kg.

Rokhayati (2010) reported milk production of 15.42 kg per day (equivalent to 4,703.1 kg per 305 days) while Pasaribu et al. (2015) reported an average milk production of 6.828 liters per day (equivalent to 2,082.54 liters per 305 days). The difference in average milk production can be caused by several things, including the general maintenance management system, the breed of cattle, and the environmental factors that influence it. Comparing milk production between populations will be more meaningful if the milk production being compared is milk production that has been corrected for the influence of existing environmental factors so that the results of the comparison will be more objective. Comparison of corrected milk production between populations will be able to provide a better picture of the genetic potential of the animals in these different populations. Environmental factors that are commonly used for uniformity (correction) in determining the milk production of dairy cows are the equivalent age of an adult, the amount of milking, and the season when the mother calves (Warwick et al., 1995).

Milk Production Correction Factor

Based on the results of the analysis, milk production per lactation of dairy cows was influenced by all non-genetic factors in the study, namely the month and year of mother's birth, month and year of calving, lactation period, age of mother at calving, and number of milking days (JHP). There is a correlation or relationship between several non-genetic factors as discussed in the previous section, the correction factor for milk production per lactation is calculated using a linear equation by including the number of milking days, age at calving, and season when the mother is born as an independent factor. The results of the linear equation of the model are as follows:

$$\mathrm{MY}_{i,j,k} = 5245.84 + \mathrm{JHP}_i + \mathrm{AgePar}_j + \mathrm{SOB}_k$$

Notes:
MY : milk production per lactation (kg)
JHP : number of milking days in one lactation period
AgePar : dams' age at calving
SOB : season when the dam was born
with a coefficient of determination (R^2) of 84.16%.

Correction factors for the number of milking days, age at calving and season at birth are presented in Table 3, Table 4, and Table 5 respectively.

The coefficient of variation in milk production per lactation after correction for the number of milking days, the age at calving, and the season when the dams were born decreased from 43.00% to 18.09%. If measured from the percent decrease, the data correction in this study causes a decrease in the coefficient of variance by 57.93%. This shows that the correction factors compiled based on the data obtained have succeeded in significantly reducing the variation caused by non-genetic factors, in this case, the number of days of milking and age at calving. In addition, grouping the month when the mother was born into the dry and rainy seasons based on the traditional season grouping has the benefit of reducing the diversity of cow's milk production.

In livestock genetic quality improvement programs through individual selection, livestock selection bias due to non-genetic (environmental) influences will disrupt the accuracy of the selection. Efforts that can be made to minimize bias in choosing livestock as parents include data correction. The order (ranking) of livestock based on phenotypic data that has been corrected for non-genetic factors will better reflect the order of genetic quality than without data correction. In the estimation of livestock genetic quality using the BLUP animal model (Best Linear Unbiased Prediction; (Henderson, 1984; Susanto et al., 2018), the data correction process is carried out simultaneously with the process of estimating the variance component.

Table 3. The correction factor for each class is the number of milking days

No	Class number of milking days	Correction factor
1	100-150	2.5592
2	150-200	1.9162
3	200-250	1.4836
4	250-300	1.2054
5	300-350	1.0000
6	350-400	0.8656
7	400-450	0.7508
8	450-500	0.6755
9	500-550	0.6115
10	550-600	0.5797

Table 4. Correction Factor for age class at calving

No	Class of dam at calving	Correction Factors
1	500-750	1.0586
2	750-1000	1.0438
3	1000-1250	0.9947
4	1250-1500	1.0113
5	1500-1750	1.0301
6	1750-2000	1.0000
7	2000-2250	0.9331
8	2250-2500	0.9140
9	2500-2550	0.9549
10	2550-3000	0.9556

Table 5. Correction Factor for Season of Birth

No	Class of the calving season	Correction factors
1	Dry	1.0000
2	Rainy	1.0182

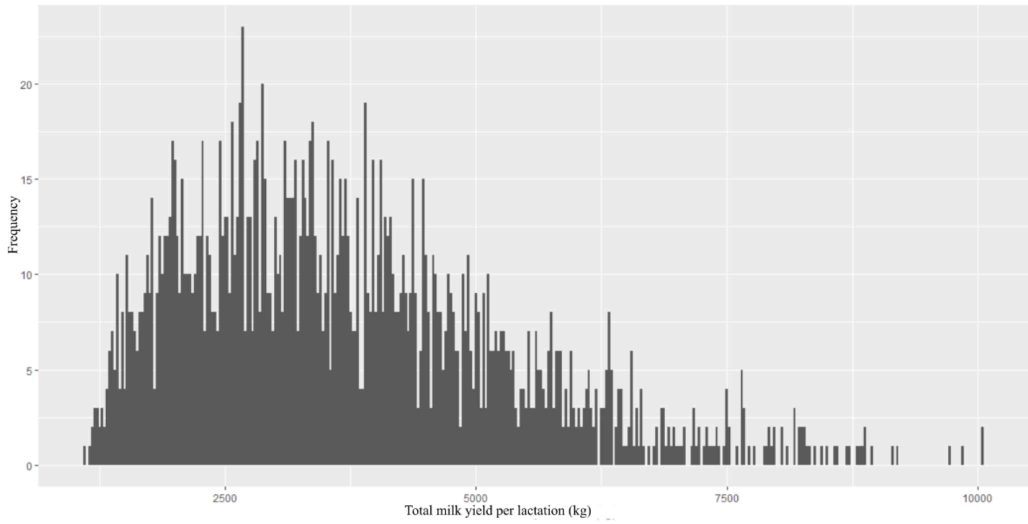

Figure 7. Distribution of actual milk production per lactation

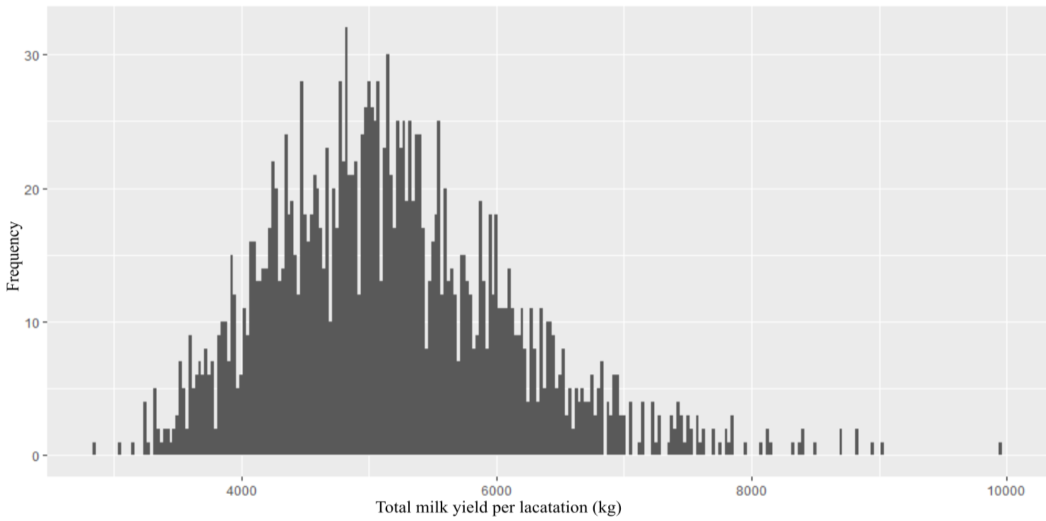

Figure 8. Distribution of corrected milk production per lactation

Selection using the BLUP animal model, in addition to having advantages in the accuracy of estimating livestock breeding values, also has drawbacks in its application because it tends to choose livestock that is related. If not accompanied by a strict program to prevent inbreeding, selection using the BLUP animal model will rapidly increase the average population inbreeding coefficient (Susanto et al., 2011). The decrease in phenotypic diversity due to the influence of non-genetic factors through data correction in the livestock selection program is still relevant because evaluating the genetic quality of livestock using the BLUP animal model requires good pedigree data.

The results showed that the resulting correction factor was more effective in reducing the variation in milk production per lactation compared to the correction factor reported by Santosa et al. (2014) that the decrease in the diversity of milk production due to data correction was 26.60% (from 29.7 to 21.8%). The decrease in the coefficient of variance in this study was 57.92% (from 43.0% to 18.09%). This shows that the process of correcting data on milk production per lactation should be done using the same data and not data obtained from different populations. The distribution of milk production data per lactation from actual data and corrected data is visualized in Figure 7 and Figure 8.

Conclusions

The number of milking days, the age at which the cows calved, and the season when the cows were born had a very significant effect on the milk production per lactation of FH dairy cows. Correction factors compiled based on data from the population can significantly reduce the variation in milk production per lactation of dairy cows. Selection of livestock that is not based on BLUP breeding values is recommended to correct data on milk production per lactation for the number of milking days, age at the time of the dams, and the season at which the dams were born to avoid bias due to the influence of these environmental factors.

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