

GENETIC GAINS OF MILK YIELD AND MILK COMPOSITION AS REALIZED RESPONSE TO DAIRY COW SELECTION IN BBPTU-HPT BATURRADEN, INDONESIA

A. P. Rahayu*, S. Johari and E. Kurnianto

Faculty of Animal and Agricultural Sciences, Diponegoro University,
Tembalang Campus, Semarang 50275 - Indonesia

*Permanent address: Animal Husbandry and Fisheries Center of Semarang Regency,
Jl. Letjend Suprpto 7, Ungaran 50514 - Indonesia
Corresponding E-mail: kurniantoedy17@gmail.com

Received April 03, 2015; Accepted May 26, 2015

ABSTRAK

Penelitian ini bertujuan untuk menaksir heritabilitas, mengetahui pengaruh seleksi sapi perah betina, dan menganalisis kemajuan genetik pada produksi dan komposisi susu di Balai Besar Perbibitan Ternak Unggul dan Hijauan Pakan Ternak (BBPTU-HPT) Baturraden, Indonesia. Penelitian menggunakan 221 catatan laktasi pertama periode 2006-2014. Heritabilitas ditaksir dengan korelasi saudara tiri seapak. Perbandingan antara rata-rata penampilan pada populasi anak (\bar{A}) dengan populasi awal induk sebelum seleksi (\bar{P}) dilakukan dengan menggunakan uji Z. Kemajuan genetik per tahun merupakan kemajuan genetik per generasi (selisih antara \bar{A} dan \bar{P}) dibagi dengan interval generasi. Hasil penelitian menunjukkan heritabilitas kadar lemak, produksi lemak, kadar protein dan produksi protein susu masing-masing 0,46; 0,30; 0,28 dan 0,17. Produksi susu generasi ke-2 (G_2) yang nyata lebih tinggi ($P=0,025$) dari generasi pertama (G_1) menghasilkan kadar lemak yang sangat nyata lebih rendah ($P=0,004$). Kemajuan genetik untuk produksi, kadar lemak dan protein susu masing-masing 9,76 kg; -0,04% dan -0,01% per tahun. Kesimpulan penelitian adalah seleksi yang hanya diarahkan untuk produksi susu berdampak negatif terhadap kadar lemak dan protein susu. Seleksi dapat dilakukan berdasarkan produksi lemak susu untuk mencegah penurunan kadar lemak susu. Pengaruh negatif interaksi genetik-lingkungan menyebabkan kemajuan genetik menjadi lambat akibat sapi impor membutuhkan waktu untuk beradaptasi dengan lingkungan lokal.

Kata kunci: heritabilitas, produksi susu, komposisi susu, respon seleksi, kemajuan genetik

ABSTRACT

The aims of this study were to estimate the heritabilities, examine the effects of dairy female selection and calculate the genetic gains on milk yield and milk composition in Baturraden Dairy Cattle Breeding and Forage Centre (Balai Besar Perbibitan Ternak Unggul dan Hijauan Pakan Ternak / BBPTU-HPT Baturraden), Indonesia. The first lactation records of 221 dairy cows from 2006 to 2014 were used. Heritabilities were estimated by paternal half-sib correlation. Comparison of average performances between daughter population (\bar{A}) and initial dam population before selection (\bar{P}) were conducted by Z-test. Annual genetic gain was calculated as genetic gain per generation (the differences between \bar{A} dan \bar{P}) divided by generation interval. Heritabilities for milk fat percentage (FP), milk fat yield (FY), milk protein percentage (PP) and milk protein yield (PY) were 0.46, 0.30, 0.28 and 0.17, respectively. A significant increase ($P=0.025$) in the total milk yield (TMY) from the first generation (G_1) to the second generation (G_2) resulted in a high significant decrease in the FP ($P=0.004$). Genetic gains of TMY, FP and PP were 9.76 kg, -0.04% and -0.01% per year, respectively. It is concluded that selection for higher TMY only negatively affect FP and PP. Selection can be applied based on FY to

avoid the decrease of FP. Negative effects of genetic-environmental interaction resulted in slower genetic gain because the imported cows needed time to adapt to the local environment.

Keywords: heritability, milk yield, milk composition, selection response, genetic gain

INTRODUCTION

Dairy cow population in Indonesia increased only in small quantities from year to year, even decreased by 27% in 2013. National dairy cow population from 2009 to 2014 were 474,701; 488,448; 597,213; 611,939; 636,064 (Ditjen PKH, 2013); 444,000 and 483,000 heads (BPS, 2015), respectively. The needs of domestic milk reached 3.2 million tons per year, but domestic milk only able to supply about $\pm 25\%$, while about $\pm 75\%$ is imported. Therefore, it is necessary to improve dairy cattle productivity, one of which with genetic quality improvement through selection to provide more permanent impact on its productivity.

Baturraden Dairy Cattle Breeding and Forage Centre (*Balai Besar Perbibitan Ternak Unggul dan Hijauan Pakan Ternak / BBPTU-HPT Baturraden*) has been doing the dairy female selection program. Kurnianto (2009) described selection as an effort to select animal that are considered to be preserved as a replacement for the next generations and cull the animal that are considered unfavorable by specific criteria. The increase of phenotypic mean after selection compared to the previous generation before selection is called a selection response (Santosa *et al.*, 2011). One of the important factors for the successful selection is heritability. Heritability of milk yield in BBPTU-HPT Baturraden has been widely studied (Kamayanti *et al.*, 2006; Karnaen and Arifin, 2009; Kurniawati *et al.*, 2013), but it was still lack of study on heritabilities of milk composition (Muladno and Astuti, 1985). These values are important because milk composition genetic improvement is also required. Previous studies (Hindratinigrum, 2008; Santosa *et al.*, 2011) have predicted milk yield selection response, but the realized response (also known as genetic gain) and its effect on milk composition as correlated responses have not been studied yet, because it only can be obtained after data of progenies are available. This study was conducted to estimate the heritabilities, examine the effects of dairy female selection, and calculate the genetic gains on milk yield and milk composition in BBPTU-HPT Baturraden.

MATERIALS AND METHODS

Location and Materials

This study was conducted from September to October 2014 in BBPTU-HPT Baturraden, Purwokerto, Central Java, Indonesia. The first lactation daily records of the 0th generation (G₀), 1st generation (G₁) and 2nd generation (G₂) from 2006 to 2014, selection records, and catalogs were used. The criteria of used data were date of birth, records for both dam and daughters (except for culled cows) and 185-425 days of lactation length (LL).

The G₀ were cows imported from New Zealand (NZ) in the year 2005. There were 74 cows of G₀ that met the criteria (61 selected dams, 13 culled cows) and 106 data of their daughters available (G₁). From G₁, 59 cows could not further analyzed because they have no daughter, their daughters were sold as heifers or did not meet the criteria. There were 47 cows (G₁') that met the criteria (38 selected dams, 9 culled cows) and 41 data of their daughters available (G₂). Total amount of data was 221.

Parameters Measured

Studied parameters were the averages of corrected total milk yield (TMY), milk fat percentage (FP), milk fat yield (FY = FP x TMY), milk protein percentage (PP) and milk protein yield (PY = PP x TMY).

Data Analysis

Data were corrected for LL and mature equivalent using local correction factor by Santosa *et al.* (2014). Heritabilities were estimated by unbalanced design of paternal half-sib correlation method using one-way analysis of variance (one-way ANOVA) based on Kurnianto (2009). Performances between the daughters of selected dam and the initial dam population were compared by unpaired Z-test using SPSS 20. The influence of birth year on TMY was analyzed using one-way ANOVA. Simulations were performed for selection based on TMY compared to selection based on FP with 10% to 90% (10% of interval) proportion of selected dams.

The formulas for genetic gains (predicted and realized), annual genetic gain and selection

effectivity were respectively based on Kurnianto (2009), Berry *et al.* (2011) and Hindratiningrum (2008) as follows:

$$\text{Predicted Genetic Gain, } \Delta G = h^2(\bar{P}_s - \bar{P})$$

$$\text{Realized Genetic Gain, } \Delta G = \bar{A} - \bar{P}$$

$$\text{Annual Genetic Gain, } \Delta G/\text{year} = \frac{\Delta G}{L}$$

$$\text{Selection Effectivity, } E_s = \frac{\Delta G}{\bar{P}} \times 100\%$$

ΔG = selection response or genetic gain per generation

\bar{P}_s = average performance of the selected dam population

\bar{P} = average performance of the initial dam population (before selection)

\bar{A} = average performance of the daughter population

L = generation interval (average age of dams and sires when G_1 and G_2 were born)

RESULTS AND DISCUSSION

Estimated Heritability (h^2)

Estimated heritability for TMY, FP, PP, FY and PY were 0.20 ± 0.26 , 0.46 ± 0.33 , 0.28 ± 0.27 , 0.30 ± 0.29 and 0.17 ± 0.25 , respectively (Table 1). The heritability of TMY was lower than those reported by Harris *et al.* (2006) in NZ (0.308). Ojango and Pollott (2001) reported that heritability of TMY from temperate breeds kept in the tropics were lower than those from similar breeds kept in temperate countries. Lower heritability lead to lower selection accuracy because selection accuracy is equal to square root of heritability. Heritabilities of FY and PY were within the range reported (0.30 to 0.35 for FY and 0.15 to 0.40 for PY) by Cassell (2009). In the other hand, the heritability of PP was lower than generally (0.50). Toghiani (2012) also found lower heritabilities of FP and PP in Holstein-Friesian (HF) cows in Iran (0.23 respectively). Heritability may vary depending on the observation years, breeds, estimation methods, origin and quantity of data (Kurnianto, 2009). Large quantity of data is recommended to minimize standard error (Cassell, 2009).

Total Milk Yield

Selection was done twice a year based on test day analysis. Selected dams belongs to group of grade A (>6,000 kg), B (>5,000-6,000 kg) or C

Table 1. Estimated Heritability of Milk Yield and Milk Composition

Parameter	Heritability*	Standard Error	Category
TMY	0.20	0.26	moderate
FP	0.46	0.33	high
PP	0.28	0.27	moderate
FY	0.30	0.29	moderate
PY	0.17	0.25	moderate

*0.00 to 0.15 = lowly heritable; >0.15 to 0.30 = moderately heritable; 0.30 to 1.00 = highly heritable (Kurnianto, 2009). TMY= total milk yield, FP = milk fat percentage; PP = milk protein percentage; FY = milk fat yield; PY=milk protein yield

(>4,000-5,000 kg) per lactation. Estimated breeding value (EBV) were sorted from the highest. Limited to the data used in this study, the overall percentage of culled cows was 18.18%. This is still below the ideal culling rate (from 20 to 30%) suggested by Radke (2000).

TMY of G_1 ($4,655.78 \pm 848.10$ kg) was significantly lower ($P=0.038$) than G_0 ($4,927.83 \pm 779.02$ kg), as presented in Table 2. This was not in line with expectations (Table 3), it was possible due to the impact of G_0 's native environment. G_0 were imported as heifers, about 5 to 11 months before their first calving. Most dairy farms in NZ are seasonal and grass-based systems. After being imported, the cattle took adaptation period to the local environment. It was indicated from their TMY. According to certificates, TMY of G_0 dams was 5,824.25 kg. G_0 should be near this, but in fact theirs only 4,927.83 kg. Maintenance in NZ supported the growth of G_0 , including body weight and udder affecting TMY. First-lactation TMY increased as prepubertal daily gains increased up to 799 g/d and body weight at calving increased up to 550 kg (Zanton and Heinrichs, 2005). Udder growth has begun since ± 30 days after conception and influence production capabilities with positive correlation value of about 0.32 (Sawa *et al.*, 2013). Thus, although TMY of G_0 was lower than its potential, there were beneficial effects from NZ environment causing it was still higher than G_1 .

As daughters of selected dams, G_1 have good genetic potential, but it could not be maximally

expressed because of the genetic-environmental (GxE) interaction (differences of the genotypic response in different environments). Kiplagat *et al.* (2012) stated that favorable genes in some environments may become unfavorable under other environments. Some alleles may only be expressed in some specific environment due to change in some gene regulations depending on the environment (climate, feed, management, housing, etc). The temperatures in NZ are 10.71 to 17.62 °C (Lal *et al.*, 2013) whereas Baturraden are 18 to 30 °C with humidity of 70 to 80%. HF cows will be comfortable at temperature humidity index (THI) <72. In dry season, Baturraden could reach THI of 73 to 83, causing mild to moderate stress. It resulted in lower consumption and metabolism rates causing decreased TMY (Gantner *et al.*, 2011). Many other studies also showed GxE interaction (Mirkena *et al.*, 2010; Bohlouli and Alijani, 2012). Beside the GxE interaction, lower TMY of G₁ was because the sires of G₁ (80% local frozen semen) had lower average EBV (+258 kg) than the sires of G₀ (imported elite bulls) whose

average EBV was +1,217.73 kg (according to certificates). Sire with higher EBV inherit higher superiority (Kurnianto, 2009).

Positive selection response appeared in G₂ (Table 3). TMY of G₂ (5,004.22±1,044 kg) was significantly higher (P=0.025) than G₁' (4,535.58±882.70 kg), as presented in Table 2. It was because the cows have been adapted to the environment. G₁ born in 2006-2007 had lower TMY than G₁ born in the year thereafter (Table 4). In that period, G₀ had just imported so that some energy were used for adaptation. As a result, when pregnant, nutrition to support foetus (G₁) growth was less than optimal. Unsignificant influence of birth year in 2008-2011 indicates that the negative effects of GxE interaction have been eliminated, so that potential genetic of G₂ inherited from G₀ and G₁ could be better expressed. As stated by Ayalew *et al.* (2003) and Mirkena *et al.* (2010), the degree of adaptability affected productivity.

Milk Composition

Selection of a trait may affect other traits. It

Table 2. Total Milk Yield (kg), Milk Fat Percentage (%) and Milk Protein Percentage (%) Between Two Generations

Parameter	Generation		Significance
G ₀ vs G ₁	G ₀ (n = 74)	G ₁ (n = 106)	
TMY	4,927.83 ± 779.02 ^a	4,655.78 ± 848.10 ^b	0.038
FP	4.68 ± 0.56	4.76 ± 0.553	0.358
PP	3.01 ± 0.16	3.00 ± 0.12	0.670
G ₁ ' vs G ₂	G ₁ ' (n = 47)	G ₂ (n = 41)	
TMY	4,535.58 ± 882.70 ^b	5,004.22 ± 1,044.00 ^a	0.025
FP	4.70 ± 0.42 ^a	4.35 ± 0.63 ^b	0.004
PP	2.97 ± 0.17	2.93 ± 0.13	0.231
G ₀ vs G ₂	G ₀	G ₂	
TMY	4,927.83 ± 779.02	5,004.22 ± 1,044.00	0.658
FP	4.68 ± 0.56 ^a	4.35 ± 0.63 ^b	0.009
PP	3.01 ± 0.16 ^a	2.93 ± 0.13 ^b	0.009

Means with different superscripts within same row differ significantly (P<0.05); G₀ = initial population of dams; G₁ = daughters population of selected G₀; G₁' = G₁ that met the criteria for further analysis; G₂ = daughters population of selected G₁, TMY= total milk yield, FP = fat percentage; PP = protein percentage

Table 3. Predicted and Realized Selection Response

Parameters	G ₁	G ₂
 (kg)	
TMY of initial population of dams	4,927.83	4,535.58
TMY of selected dams	5,184.43	4,785.80
Selection differential	256.59	250.22
Predicted selection response	51.32	50.04
Expected TMY of daughter	4,979.15	4,585.63
Realized TMY of daughter	4,655.78	5,004.22
Realized response to selection	- 272.05	468.64
Differences between predicted and realized response	- 323.37	418.59

Table 4. Average of Total Milk Yield Based on the Birth Year

Birth Year	G ₁		G ₂	
	n	Milk Yield (kg)	n	Milk Yield (kg)
2006	17	3,868.34 ± 613.02 ^b	-	-
2007	32	4,472.41 ± 852.24 ^b	-	-
2008	30	5,037.71 ± 665.36 ^a	4	4,784.04 ± 471.43
2009	14	5,081.81 ± 636.70 ^a	9	5,008.70 ± 725.85
2010	8	4,915.30 ± 879.19 ^a	13	5,206.41 ± 771.73
2011	5	4,839.11 ± 1,224.30 ^a	15	4,885.01 ± 1,479.15

Means with different superscripts within same column differ significantly (P<0.05)

Table 5. Genetic Gains of Milk Yield and Composition

Parameters	Per 2 Generations	Per Generation	Per Year
TMY (kg)	76.39	38.20	9.76
FP (%)	- 0.33	- 0.16	- 0.04
PP (%)	- 0.08	- 0.04	- 0.01

is presented in Table 2, FP (4.35±0.63%) and PP (2.93±0.13%) of G₂ was significantly lower (P<0.01) than G₀ (4.68±0.56% and 3.01±0.16%, respectively). The FP was close to the range of HF cows in NZ (4.42 to 5.03%) reported by Lopez-

Villalobos (2012). A significant increase of TMY from G₁ to G₂ resulted in a significant decrease in the FP. It was because of the negative genetic correlations (caused by pleiotropic or linked genes) between TMY and FP and also between TMY and PP which generally about -0.30 to -0.50 (Gaidarsca *et al.*, 2004; Toghiani, 2012). Previous study by Muladno and Astuti (1985) in BPT Baturraden showed genetic and phenotypic correlations between TMY and FP were -0.76 and -0.26, respectively. Negative correlation indicates a genetic antagonism between traits and its responsible genes for phenotypic expression (Kurnianto, 2009).

Genetic Gain

The genetic gain of TMY was 38.20

kg/generation (Table 5) with 0.85% of selection effectivity. This realized selection response is in between the predicted responses by Hindratiningrum (2008) and Santosa *et al.* (2011), while the effectivity is lower. The generation interval was 3.92 years (3.68 years for female and 4.15 years for male), so that the annual genetic gain was 9.76 kg. TMYs in BBPTU-HPT Baturraden fluctuated from year to year, possibly because the cow 006) and 5,004 kg in this present study, so that the rough average of progress rate was 11.2 kg/year (close to the result of this study). This genetic gain was much lower than those achieved by United States (193 kg), Netherlands (131 kg), Italy (112 kg) and NZ (43 kg) (Sneddon *et al.*, 2014). Higher genetic gain in NZ indicates that NZ cows and their offsprings actually have potential for greater genetic gain than their current achievement in Baturraden. The genetic gain was low because the imported dams and one generation after them took quite a long time to adapt to the local environment. This result was in agreement with Hammami *et al.* (2008) and Kiplagat *et al.* (2012) that the genetic-environmental interaction can reduce the efficiency of genetic quality improvement.

FP and PP, as correlated selection responses, decreased by respectively 0.16% and 0.04% per generation or 0.04% and 0.01% per year (Table 5). Because of the medium to high negative correlation between TMY and FP, it is very difficult to improve TMY and FP simultaneously. The alternative method is applying selection based on FY. Genetic correlation between TMY and FY and between TMY and PY of dairy cows were reported positive from 0.44 to 0.95 (Gaidarsca *et al.*, 2004; Toghiani, 2012). Genetic correlation between FY and PY was from 0.60 to 0.76 so that the selection based on FY also be expected to increase PY.

TMY-based selection resulted in higher TMY response than FY-based selection, but with lower FP (Table 6 and Table 7). If assumed that each 0.1% of increased FP above 3.5% will gain additional sale price, selection based on FY is more profitable. Selection based on FY with 80% selected dams is expected to increase FY by 1.35 kg/year. Predicted genetic gain in NZ was higher than this value (2.22 kg/year). FP and PP will be increase from 4.96% to 4.97% and 3.78% to 3.82%, respectively, in 10 years (Sneddon *et al.*, 2014). It can be seen that although TMY and FP

Table 6. Predicted Response to Selection Based on Total Milk Yield

Proportion	ΔG_{TMY}	\bar{A}_{TMY}	Correlated Responses		\bar{A}_{FY}	\bar{A}_{FP}
			ΔG_{FY}	ΔG_{FP}		
(kg).....	(%)....(%)....	..(%)..	
10%	278.11	5,094.37	14.84	-0.10	238.46	4.54
20%	229.28	5,045.55	13.99	-0.08	237.61	4.56
30%	198.21	5,014.48	12.28	-0.05	235.90	4.59
40%	168.58	4,984.85	11.44	-0.03	235.06	4.61
50%	140.55	4,956.82	9.03	-0.03	232.65	4.61
60%	116.18	4,932.45	8.14	-0.02	231.76	4.62
70%	90.70	4,906.96	6.77	-0.01	230.39	4.63
80%	63.52	4,879.78	4.39	-0.01	228.01	4.63
90%	35.09	4,851.35	2.56	0.00	226.18	4.64

Note for Table 6-7. ΔG = predicted selection response; \bar{A} = predicted performance of daughters population; average performances of initial dam population were 4,816.26 kg for TMY, 223.62 kg for FY and 4.64 % of FP. Estimated h^2 was based on the result of this study (Table 1).

Table 7. Predicted Response to Selection Based on Milk Fat Yield

Proportion	ΔG_{FY}	\bar{A}_{FY}	Correlated Responses		\bar{A}_{TMY}	\bar{A}_{FP}
			ΔG_{TMY}	ΔG_{FP}		
	(kg).....		...(%)...	...(kg)...(%)...
10%	22.84	246.46	187.00	0.29	5,003.26	4.93
20%	18.98	242.60	171.68	0.22	4,987.95	4.86
30%	16.05	239.67	153.94	0.18	4,970.21	4.82
40%	13.61	237.23	134.70	0.15	4,950.96	4.79
50%	11.49	235.11	113.36	0.12	4,929.62	4.77
60%	9.47	233.09	100.23	0.09	4,916.50	4.74
70%	7.48	231.10	79.16	0.07	4,895.43	4.72
80%	5.28	228.90	53.51	0.05	4,869.78	4.70
90%	2.92	226.54	28.71	0.04	4,844.98	4.68

or PP have antagonistic correlations, FP and PP are still can be improved. It is because NZ consider FY and PY in their breeding worth selection index.

CONCLUSION

In BBPTU-HPT Baturraden, FP was highly heritable, while TMY, PP, FY and PY were moderately heritable. Selection for higher TMY only, negatively affect FP and PP. Selection can be applied based on FY to avoid these decreases. Negative effects of genetic-environmental interaction resulted in slower genetic gain because the imported dams and one generation after them needed time to adapt to the local environment. Adaptive cows (G_2 and the next generations) are recommended to be further selected with high EBV of sires are also considered.

ACKNOWLEDGMENT

This study was fully financed by Indonesia Endowment Fund for Education (*Lembaga Pengelola Dana Pendidikan / LPDP*) through Master Scholarship Program. The authors would like to thank Head of BBPTU-HPT Baturraden for allowing the study and his staffs (especially Head of Information Section) for

gathering data.

REFERENCES

- Ayalew, W., B. Rischkowsky, J.M. King and E. Bruns. 2003. Crossbreed did not generate more net benefits than indigenous goats in Ethiopian smallholdings. *Agric. Systems.* 76:1137-1156
- Badan Pusat Statistik. 2015. *Populasi Ternak.* <http://www.bps.go.id>. [Accessed February 15, 2015].
- Berry, D.P., M.L. Bermingham, M. Good and S.J. More. 2011. Genetics of animal health and disease in cattle. *Irish Vet. J.* 64:5
- Bohlouli, M. and S. Alijani. 2012. Genotype by environment interaction for milk production traits in Iranian Holstein dairy cattle using random regression model. *Livest. Res. Rural Dev.* 24(11):120-124
- Cassell, B. 2009. *Using Heritability for Genetic Improvement.* Virginia Tech, Virginia Cooperative Extension and State University, Virginia.
- Direktorat Jenderal Peternakan dan Kesehatan Hewan. 2013. *Statistik Peternakan dan Kesehatan Hewan 2013.* Kementerian Pertanian RI, Jakarta.
- Gaidarsca, V., N. Rusev and Y. Popova. 2004.

- Correlation between the breeding indicators of black and white cows in Bulgaria. *Biotechnol. Anim. Husb.* 20(1-2):17-21
- Gantner, V., P. Mijić, K. Kuterovac, D. Solić and R. Gantner. 2011. Temperature-humidity index values and their significance on the daily production of dairy cattle. *Mljekarstvo.* 61(1):56-63
- Hammami, H., B. Rekik, H. Soyeurt, A. B. Gara and N. Gengler. 2008. Genetic parameters for Tunisian Holsteins using a test-day random regression model. *J. Dairy. Sci.* 91:2118-2126
- Harris, B.L., J.E. Pryce, Z.Z. Zu and W.A. Montgomerie. 2006. Development of new fertility breeding values in the dairy industry. *N.Z. Soc. Anim. Prod.* 66:107-112
- Hindratiningrum, N. 2008. Respon dan efektivitas seleksi individu sapi perah yang ditaksir menggunakan catatan produksi individu dan tetua betinanya. *J. Ilmiah Inkoma.* 19(1):1-9
- Kamayanti, Y., A. Anggraeni and Pallawarukka. 2006. Pemeriksaan interaksi genetik dan lingkungan dari daya pewarisan produksi susu pejantan Friesian-Holstein impor yang dipakai sebagai sumber bibit pada perkawinan IB. *Proceedings. Lokakarya Nasional Pengelolaan dan Perlindungan Sumber Daya Genetik di Indonesia: Manfaat Ekonomi untuk Mewujudkan Ketahanan Nasional, Bogor, Indonesia, December 20, 2006.* P. 175-181.
- Karnaen and J. Arifin. 2009. Korelasi nilai pemuliaan produksi susu sapi perah berdasarkan test day laktasi 1, laktasi 2, laktasi 3, dengan gabungannya. *Anim. Prod.* 11(2):135-142
- Kiplagat, S.K., I.S. Kosgey and M.K. Limo. 2012. Genetic Improvement of Livestock for Milk Production. In: *Milk Production - Advanced Genetic Traits, Cellular Mechanism, Animal Management and Health* (N. Chaiyabutr, ed.). Intech Publishers, Rijeka. P. 77-96.
- Kurnianto, E. 2009. *Pemuliaan Ternak.* CV. Graha Ilmu, Yogyakarta.
- Kurniawati, D., H. Mulyadi and Adiarto. 2013. Heritability value of milk production of Holstein Friesian imported from New Zealand at Baturraden, Banyumas. *Proceedings. The 6th Conference of Indonesia Students Association in Korea, Daejeon, Korea, July 7, 2013.* CISA 2013-C6/O/70.
- Lal, A., T. Ikeda, N. French, M. G. Baker and S. Hales. 2013. Climate variability, weather and enteric disease incidence in New Zealand: time series analysis. *Plos One.* 8(12):e83484.
- Lopez-Villalobos, N. 2012. Analysing the genetic basis of milk production traits. *CAB Rev.* 7:1-18
- Mirkena, T., G. Duguma, A. Haile, M. Tibbo, A. M. Okeyo, M. Wurzinger and J. Sölkner. 2010. Genetics of adaptation in domestic farm animals: a review. *Livest. Sci.* 132:1-12.
- Muladno and M. Astuti. 1985. Korelasi fenotipa dan genotipa antara produksi susu dengan kadar lemak susu sapi Fries Holland di Balai Pembibitan Ternak Baturraden. *Media Peternakan.* 10(3):39-55
- Ojango, J.M. and G.E. Pollott. 2001. Genetics of milk yield and fertility traits in Holstein-Friesian cattle on large-scale Kenyan farms. *J Anim. Sci.* 79:1742-1750
- Radke, B.R. 2000. Profitable culling and replacement strategies. *Adv. Dairy Technol.* 12:245-256
- Santosa, S.A., A.T.A. Sudewo and A. Susanto. 2014. Penyusunan faktor koreksi produksi susu sapi perah. *Agripet.* 14(1):1-5
- Santosa, S.A., A.T.A. Sudewo, A. Susanto and Iswoyo. 2011. Response, effectiveness and accuracy of different selection methods and intensities in dairy cattle. *Anim. Prod.* 11(1):66-70
- Sawa, A., M. Bogucki, S. Krężel-Czopek, and W. Neja. 2013. Relationship between conformation traits and lifetime production efficiency of cows. *ISRN Vet. Sci.* 2013:124690
- Sneddon, N.W., N. Lopez-Villalobos, R.E. Hickson, L. Shalloo, D.J. Garrick and U. Geary. 2014. Prediction of industry production of milk components, yields of dairy products and lactose deficit under the current breeding objective of New Zealand dairy cattle. *Proceedings. The 10th World Congress of Genetics Applied to Livestock Production, Vancouver, BC, Canada, August 17-22, 2014.* Poster code #398.
- Toghiani, S. 2012. Genetic relationships between production traits and reproductive performance in Holstein dairy cows. *Archiv. Tierzucht.* 55(5):458-468.
- Zanton, G. I. and A. J. Heinrichs. 2005. Meta-analysis to assess effect of prepubertal average daily gain of Holstein heifers on first lactation production. *J. Dairy Sci.* 88:3860-3867