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Modeling for determining the superiority of Holstein bulls as frozen semen producer and genetic source for milk production

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ABSTRAK

Tujuan penelitian ini adalah untuk menyusun model dalam memperoleh nilai keunggulan pejantan Holstein sebagai penghasil semen beku dan sumber genetis produksi susu sapi perah. Kemampuan pejantan untuk menghasilkan semen beku per tahun dianalisis secara deskriptif. Nilai efisiensi reproduksi semen beku dalam inseminasi buatan dihitung dengan *service per conception* (S/C). Estimasi nilai pemuliaan pejantan untuk produksi susu dievaluasi melalui metode *contemporary comparison* (CC)**.** Model nilai keunggulan pejantan dianalisis menggunakan *Structural Equation Model-Partial Least Square* (SEM-PLS). Rata-rata produksi semen beku per pejantan adalah 23.109±14.970 dosis/tahun. Nilai rata-rata S/C adalah 2,83. Nilai CC antara -1.865,7 sampai +1.636,3. Potensi produksi susu yang dihasilkan dari betina laktasi keturunan per pejantan yang diuji antara 951.749,2 sampai 52.347.822,9 liter per tahun. Nilai ekonomis pejantan berdasarkan potensi produksi susu betina antara Rp. 4.758.745.999. sampai Rp. 261.739.114.505. Nilai keunggulan pejantan dipengaruhi (P<0,05) oleh koefisien kemampuan pejantan untuk menghasilkan semen beku sebesar 0,59; efisiensi reproduksi sebesar -0,53 dan rata-rata produksi susu anak betinanya sebesar 0,33. Kesimpulan penelitian ini adalah nilai keunggulan pejantan dapat dijelaskan sebesar 78,3% oleh nilai kemampuan pejantan untuk menghasilkan semen beku, efisiensi reproduksi dan produksi susu anaknya.

Kata kunci: produksi semen beku, efisiensi reproduksi, nilai pemuliaan, keunggulan pejantan

ABSTRACT

The objective of this study was to develop models for determination the superiority of Holstein bulls as a producer of frozen semen and inheritance of the genetic traits of milk production. The ability of the bull to produce frozen semen per years was analyzed descriptively. Reproductive efficiency of frozen semen in artificial insemination was calculated by service per conception (S/C). Estimation sire breeding value for milk production was calculated by contemporary comparison (CC) method. Model of superiority bulls was analyzed by Structural Equation Model with Partial Least Square method (SEM-PLS). Total average production of frozen semen was 23,109±14,970 doses/year. The average S/C was 2.83. The CC value ranged from -1,865.7 until +1,636.3. Potency of milk production resulted from lactation cow offspring per bulls ranged from 951,749.2 to 52,347,822.9 liters per year. The economic value of bulls based on the potency milk production of offspring ranges from IDR 4,758,745,999 to IDR 261,739,114,505. The superiority of bulls was affected significantly (P<0.05) by frozen semen production, reproductive efficiency and average milk production of daughter cows (DC) as much as 0.59, -0.53 and 0.33, respectively. In conclusion, the superiority of bull can be explained about 78.3% by the production of frozen semen production, reproductive efficiency and milk production of offspring.

Keywords: frozen semen production, reproductive efficiency, breeding value, superiority of bull

INTRODUCTION

The superiority of Holstein bulls in terms of economic traits are the ability of bull to produce frozen semen, reproductive efficiency and genetic traits of milk production measured simultaneously. This statement was in accordance with Fuerst-Waltl *et al*. (2016) who stated that economical traits should be considered in the breeding objective, included production and functional traits in order to get qualified bull.

Study on the superiority of bulls have been conducted separately based on economic traits like bull breeding soundness evaluation (BBSE) and semen quality (Purwantara *et al*., 2010; Chenoweth and McPherson, 2016; Penitente-Filho *et al.,* 2018); reproductive efficiency (Pecsok *et al.,* 1994; Plaizier *et al.,* 1996; Fernando *et al*., 2016); breeding value (Wilder and Van Vleck, 1988; Groen and Steine, 1997; El-Bayoumi *et al*., 2015). Chenoweth and McPherson (2016) stated that bull breeding soundness evaluation (BBSE) is able to describe the superiority of bulls based on their ability to produce frozen semen by 65-85%. Quality semen is one of four factors (25%) affecting successful service of insemination such as skill of inseminator, timing of insemination and status reproduction cows (Fernando *et al*., 2016). Heritability of milk production was medium, being 0.34±0.02 (scale 0-1), so that it has little effect on the measurement of bull superiority (El-Bayoumi *et al*., 2015). The problem is if the evaluation of superiority bull was limited on one trait separately, then it would unable to describe and measure interactions among traits and would have an impact in the mistaken decision in the bull selection. To obtain more accurate overview, it was important to evaluate the economic traits affecting the bull superiority thoroughly and simultaneously by using more comprehensive model. The objective of this study was to develop model for determination the superiority of Holstein's bull as a producer of frozen semen and inheritance of the genetic traits of milk production.

MATERIALS AND METHODS

The Ability of the Holstein Bull to Produce Frozen Semen

The study was conducted at Lembang and Singosari Artificial Insemination Center (AIC), Indonesia. Data used in this study were 24,634 data of frozen semen production from 67 Holsteins bulls (2-9 years old) as producer of frozen semen during the production period from 2008 to 2016. Data were analyzed descriptively.

Determination of Reproductive Efficiency of Frozen Semen of Holstein Bull in AI Activities

Reproductive efficiency of frozen semen in artificial insemination (AI) was used service per conception (S/C) value calculated from reproduction record of AI acceptor at the dairy farmer located in Java Island that used frozen semen produced by Lembang and Singosari AIC. The Java Island was selected as the location of the study based on a report of Anggraeni (2012) which stated that the Java Island has 97.2% of the Holstein population s in Indonesia. The S/C was calculated by formula of Atabany *et al.* (2011).

Prediction numbers potential calving of lactation cows was calculated using frozen semen production (dose/year), S/C and reproductive technique coefficient on dairy cows according to Sadeghi *et al.* (2012) including embryo mortality (5%); calf mortality (10%); sex ratio (1:1) cow mortality (8%) and percentage of lactation cow (80%).

Determination of Genetic Superiority

The observed data were milk production record of daughter cows (DC) of Lembang and Singosari bulls and milk production records of contemporary cows at the same location and age at period 2011-2017. The full milk production per lactation was estimated using test-day method, standardized to 305 days milk production, milking twice daily and mature age based on DHIA-USDA correction factors (Hardjosubroto, 1994). Estimation of sire breeding value for milk production was calculated by Contemporary Comparison (CC) method described by Kurnianto (2012) which fit to smallholder farmer with ownership of less than 5 cows. The formula of CC was:

$$CC = \frac{\Sigma[W_i(\bar{Y}_1 - \bar{Y}_c)]}{\Sigma W_i}$$

$$W_i = \frac{n_1 \times n_2}{n_1 + n_2}$$

Where:

CC = CC value

W_i : Weighted factor

n_1 : Number of daughter cows

n_2 : Numbers of contemporary

$\overline{Y}_i$: Milk production average of daugter

$\overline{Y}_c$: Milk production average of contemporary

The potency of milk production per bulls was calculated based on the potency of the number of the lactation DC multiplied by average of milk production from DC of bull's offspring tested. The economic value of bull was calculated based on milk price assumption of IDR 5,000/liter.

Statistical Methods

Effect of age and bulls in frozen semen production were analyzed by nested design. Statistical model was:

$$Y_{ijk} = \mu + A_i + B_{j(i)} + \varepsilon_{(ij)k}$$

i = 1,2,3,..,a
j = 1,2,3,..b
k = 1,2,3,..c

Where

Y_{ijkl} : The k^{th} observation, the j^{th} age factor and the i^{th} bull factor

μ : Overall mean

A_i : Effect of i^{th} bull

$B_{j(i)}$: Effect of j^{th} age factor of i^{th} bull

$\varepsilon_{(ij)k}$: Effect of error

The model of superiority bulls was analyzed by SEM-PLS 3.0. According to Sholihin and Ratmono (2013), partial least square (PLS) was a variance-based structural equation analysis (SEM) that can simultaneously perform testing of measurement models as well as structural model testing. SEM-PLS can estimate p values for path coefficients and can provide an indicator criteria of fit model in the form of average R-squared (ARS), average path coefficient (APC) and average variance inflation factor (AVIF). The statistical model is:

$$Y = \beta_1 X_i + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where

Y : Superiority bulls based on the potential of milk production

β_1 : The coefficient value of frozen semen production path

β_2 : The coefficient value of the reproductive efficiency path

β_3 : The coefficient value of milk production path

X_1 : Average production of frozen semen per bulls

X_2 : Average reproductive efficiency per bulls (S/C)

X_3 : Average milk production of daughter cows per bulls

ε : Error

RESULTS AND DISCUSSIONS

Ability of the Holstein Bull to Produce Frozen Semen

The average total production of frozen semen per bull per years is presented in Table 1. The total production of frozen semen per bull ranged from 1,270±1,124 until 70,577±2,492 doses/year. Total average production of frozen semen was 23,109±14,970 doses/year. The production of frozen semen per year was varying greatly due to the bull's condition, the frequency of semen collection, the quality of fresh semen and the frozen semen processing. The average production of frozen semen per year is lower than that reported by Tiwari *et al*. (2012) amounting to 39,536 doses/year on Sahiwal bulls but higher than the report of Bhosrekar *et al*. (1980) 10,458 doses/year of Holstein bulls in Sri Lanka. This low amount of frozen semen production was caused by poor health conditions of bulls, which affected the frequency of collection and quality of semen produced. The high variation coefficient showed that the average production of frozen semen per year was influenced by the age of bull (P<0.01). It is in accordance with Fuerst-Waltl *et al.* (2016) which stated that the age had a significant influence on semen traits of semen Simmental bulls in Austria.

Determination of reproductive efficiency of frozen semen of Holstein bulls in AI activities

Qualified frozen semen improves the reproductive efficiency of AI activities. The reproductive efficiency data per bulls is presented in Table 2. The reproduction data records in this study were 100,564 acceptors with the use of frozen semen as many as 149,215 doses from 52 Holsteins bull. Numbers of pregnancies were 59.67% indicating that the pregnancy rate was

Table 1. The Average Production of Frozen Semen per Bull per Years

No	Bull Name	Frozen Semen (dose)	Coefficient of Variation (%)
1	Maxwell	1,270±1,124	88.53
2	Fluto	2,581±2,306	89.36
3	Jaysy	2,933±1,232	41.98
4	Fortuner	3,842±3,179	82.74
5	Florean	3,899±2,128	54.57
	……	……	……
	……	……	……
61	……	……	……
62	……	……	……
63	Pland	46,828±26,545	56.69
64	Astry	47,268±20,086	42.49
65	Rodgard	53,504±32,189	60.16
66	Jodan	56,386±27,597	48.94
67	Starko	70,577± 2,493	3.53
Average		23,109±14,970	64,78

Table 2. Reproductive Efficiency per Bull

No.	Bull	Acceptor	Dose	Pregnancy	S/C
1.	Dunde	410	439	410	1.07
2.	Valley	5,880	8,078	5,875	1.37
3.	Heroe	171	244	166	1.47
4.	Mohze	3	3	2	1.50
5.	Astry	6,089	8,698	5,694	1.53
…	…	…	…	…	…
…	…	…	…	…	…
48	Bayu	86	143	35	4.09
49	Tynho	2,262	3,232	771	4.19
50	Sanry P	2,320	3,314	771	4.30
51	Milky	240	343	77	4.45
52	Dean	102	170	37	4.59
		100,564	149,215	60,011	2.83*

S/C : Service per Conception, *: average

low enough from all acceptors who received AI services. The average S/C value was 2.83. The average S/C value (2.83) showed there was still inefficiency reproduction performance in Indonesia. Nuryadi and Wahjuningsih (2011) reported the normal S/C value was ranged at 1.6-

2.0 in their study on beef cattle in Indonesia. The S/C value (2.83) was also higher than that reported by Fernando *et al.* (2016) 2.1±1.29 observe on Jersey cattle in Sri Lanka. The high S/C in this study was considered as factor of field conditions, i.e. acceptor dispersed on small farms, farmers were late reporting estrus cattle to AI technicians resulting it too late inseminated, reproductive conditions of female cattle, and handling of frozen semen. Another reason was considering on conception of AI depends on the characteristics of the semen provided by AI centers (Ghasemi and Ghorbani, 2014).

Potential number of lactation cow per sire is presented in Table 3. The average number of lactation cows that resulted from 52 sires was 2,863 daughter cows (DC) per bull, it ranged from 296 to 12,228 daughter cows. A smaller value of S/C and greater ability bulls to produce frozen semen affected higher potential numbers of lactation cow per bull's produced with the assumption of the other technical coefficients were constant. This is in accordance with Ferguson and Skidmore (2013) who stated that reproductive efficiency was an outcome of S/C values tthat can be combined with a variable determining pregnancy rate. Decreasing the number of insemination has a positive effect on the profitability and one of the most economically important traits in dairy cattle industry (Ghiasi and Honarvar, 2016; Ghiasi *et al.,* 2016). Improvements in reproductive performance can potentially yield remarkable economic benefits (Fodor *et al*., 2018). Further, Villa-Arcila *et al*. (2018) stated that reproductive performance has also an impact on the economic results of the dairy business, as low reproductive efficiency may cause a decrease in milk production and the number of calves born per year.

Determination of Genetic Superiority

The average milk production and CC estimation is presented in Table 4. The numbers of milk production records that suffice the requirements for use were 1,006 records of DC milk production from 36 bulls tested and 1,019 milk production records of cows as comparative. The average population of milk production was 4,068 liters per lactation or 13.34 liters/day. The average milk production of DC from sires tested was 4,258.7 liters/lactation or 13.96 liters/day with a ranged from 2,320.1 to 7,128.6 liters/lactation. The CC value ranged from -1,865.7 to +1,636.3; these showed that the lowest average milk production per lactation was 1,865.7 liters below the average milk production of

Table 3. Potential Number of Lactation Cow per Sire

No	Bull	Frozen Semen/ years	S/C	Pregnancy	Embryo[1]	Calf[2]	Male[3]	Female[3]	Mature[4]	Lactation[5]
1	Dunde	41,612	1.07	38,863	36,920	33,228	16,614	16,614	15,285	12,228
2	Astry	47,268	1.53	30,944	29,396	26,457	13,228	13,228	12,170	9,736
3	Rodgard	53,504	2.56	20,870	19,826	17,844	8,922	8,922	8,208	6,566
4	Mohze	30,116	1.50	20,077	19,073	17,166	8,583	8,583	7,896	6,317
5	Sg Casir	44,315	2.22	19,993	18,993	17,094	8,547	8,547	7,863	6,291
	…	…	…	…	…	…	…	…	…	…
	…	…	…	…	…	…	…	…	…	…
48	Franko	3,410	2.17	1,569	1,490	1,341	671	671	617	494
49	Heroe	2,290	1.47	1,558	1,480	1,332	666	666	613	490
50	Fortuner	3,842	2.52	1,525	1,449	1,304	652	652	600	480
51	Florean	3,899	3.00	1,302	1,237	1,113	556	556	512	410
52	Milky	4,187	4.45	940	893	804	402	402	370	296

1. Embryo mortality: 5%; 2. Calf mortality: 10%; 3. Sex ratio:50:50; 4. Mature mortality : 8%; 5. Lactation mortality: 20%.

Table 4. Average Milk Production and Contemporary Comparison of Holstein Bull

No	Bull	Number of		DC	PC	W	CC	EBV
		n_1	n_2					
1	Black	3	7	5929.2	5491.2	2.1	1636.3	3272.5
2	Florean	25	187	5607.5	4506.2	17.5	909.8	1819.5
3	Flaunt	21	238	5369.4	4465.5	16.9	839.6	1679.3
4	Hostormsy	28	320	4041.8	3688.9	23.1	778.5	1557.0
5	Fokker	17	165	5179.4	4505.8	13.2	777.9	1555.7
..	…	…	…	…	…	…	…	…
..	…	…	…	…	…	…	…	…
..	…	…	…	…	…	…	…	…
32	Anata	5	26	2954.7	3593.3	4.1	-745.0	-1490.0
33	Danilsy	19	131	3404.1	4961.5	15.6	-826.7	-1653.4
34	Aryana	50	107	2506.2	3996.2	23.9	-1276.1	-2552.1
35	Bayu	3	69	2320.1	3804.5	2.8	-1411.6	-2823.2
36	Dundee	5	17	4281.0	6146.7	3.9	-1865.7	-3731.5

*) = number of offspring at different farm and time; n_1 = number of daughter ; DC = daughter cow milk production PC = contemporary milk; CC = comtemporary comparison EBV = estimated breeding

population tested while the highest production was 1,636.3 liters above the population. The number of bulls with a positive CC score was 20 bulls or 56% of the total bulls tested and recommended as the bulls donors for the genetic traits of milk production. The difference in CC value was influenced by the average production and the number of DC per sire. The different amount of DC was caused by poor awareness of farmers to record milk production, so it was difficult to obtain a lot of milk production data. Milk production can be increased through genetic and environmental factors. Efforts to increased milk production could be achieved by selecting bulls whose have positive CC values. Identification sire with high genetic potential is a challenge for animal breeding (Rotar *et al.,* 2016). Genetic improvement is one of the main factors responsible for the large increase in milk yield of dairy cow; this success is mainly attributable to the efficient application of AI with semen from proven sire was selected by progeny test (Yang *et al.,* 2018).

The potency of milk production and economic value per bull is presented in Table 5. The potency of milk production resulted from lactation cow offspring per bulls ranged from 951,749.2 to 52,347,822.9 liter/years. The economic value of bulls based on the potency milk production of offspring ranges from IDR 4,758,745,999 to IDR 261,739,114,505. The greater potential for milk production and economic value of the bulls tested will be obtained if the ability of bulls to produce frozen semen was high, the S/C value was low and the milk production of DC was high. The result discussion confirmed the statement of DeJarnette *et al*. (2004) who stated that the AI industry must supply the genetic resources for the dairy industry's with specific breeding objectives; including the emphasis placed on production, type and reproduction in AI sire programs which largely directed to dairy producers through their semen purchasing options.

Model of superiority bulls

The model obtained was declared fit based on the value of average path coefficient (APC), average R-squared (ARS) and average variance inflation factor (AVIF) were 0.481, 0.783, 1.225, which fit the requirements according to Sholihin and Ratmono (2013), being less than 0.05 (P<0.001), 0.05 (P<0.001), 5, respectively. The ARS value showed the variance of the superiority of bull can be explained 78.3% by the production of frozen semen production, reproductive efficiency and milk production of offspring factors and the rest (21.7%) determined by other factors that were not measured.

Structural equation model of superiority bulls is presented in Figure 1. The superiority of bulls was affected significantly (P<0.05) by coefficient of frozen semen production, reproductive efficiency and average milk production of DC which found 0.59, -0.53 and 0.33, respectively. The model equation obtained was $Y = 0.59X_i - 0.53X_2 + 0.33X_3 + \varepsilon$. These path coefficients values showed the ability of bulls to produce frozen semen (0.59) and the reproductive efficiency (-0.53) have more considerable value than the genetic potential of milk production (0.33). Therefore, the ability of Holstein bulls to produce qualified frozen semen maximally in an effort to increase reproductive efficiency in AI activities must take the high priority on selection bull in the AIC. This result confirmed the statement of Naha *et al*. (2016) that the primary goal of the AIC is to produce the

Table 5. The Potency of Milk Production and Economic Value per Bull

No	Bull	Number of Lactation Cow (head)	Avg. Daughter cow Milk Production (Lt)	Economic Value of Bull*) (IDR)
1	Dunde	12,228	4,281.01	261,739,114,505
2	Astry	9,736	4,024.35	195,907,004,018
3	Black	5,268	5,929.19	156,181,714,578
4	Prime	4,947	6,007.91	148,600,268,308
5	Rodgard	6,566	3,591.06	117,903,206,549
…				
…				
32	Goldsy	568	4,931.03	14,013,715,041
33	Florean	410	5,607.46	11,482,559,945
34	Fortuner	480	4,514.31	10,828,785,510
35	Franko	494	2,642.72	6,521,499,781
36	Milky	296	3,218.21	4,758,745,999

*) it was assumed that the price of milk/Lt : IDR 5,000

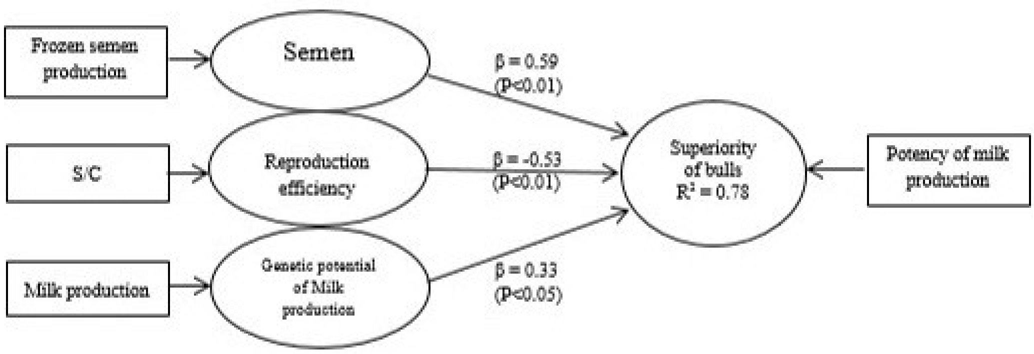

Figure 1. Structural Equation Model of Superiority Bulls

largest quantity of the highest quality semen in a shortest possible time. The path value of genetic potential of milk production (representing heritability value) in this study was found 0.33; it confirmed the statement of Hardjosubroto (1994) that heritability value has a moderate criterion while environmental factors and management have a dominant influence in the milk production process of dairy cattle. Despite milk production has a moderate heritability value; the genetic trait of milk production in Holstein bull has an important role in efforts to improve the genetic quality of their offsprings. Breeders will choose the frozen semen of bull with a higher estimation breeding value (EBV) than a lower one. Kumari and Coudhary (2018) stated that detailed knowledge about raising the bulls was important for better management to support the needs of the AI industry.

CONCLUSION

Frozen semen production, reproductive efficiency and milk production of daughter cows determined the superiority of bulls. The equation of the superiority of bull = 0.59 (semen production) – 0.55 (reproductive efficiency) + 0.33 (milk production) + error. The superiority of bull could be explained about 78.3% by the production of frozen semen production, reproductive efficiency and milk production of offspring.

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