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ASSOCIATIONS BETWEEN FUNCTIONAL TRAITS AND MILK PRODUCTION IN FRIESIAN CATTLE USING THRESHOLD AND LINEAR MODELS.

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SUMMARY

Recently, functional traits are of interest to dairy cattle breeders as their breeding goals consist of milk production traits as well as functional traits (FT). Thus, the main objective of the present study was to estimate (co)variance components, genetic and phenotypic parameters of functional traits and their associations with milk production trait. There were 3674 records collected from 1230 cows, daughters of 160 sires and 857 dams of a Friesian herd raised at Sakha experimental farm belonging to Animal Production Research Institute (APRI) in Egypt.

Analyzing 305-day milk yield (M305) with FT (retained placenta (RP), stillbirth (SB), gestation length (GL) and days open (DO)) was carried out using two types of models. Bivariate threshold repeatability animal models were used to analyze binary functional traits (RP and SB) with M305 and other continuous FT (GL and DO). Bivariate Linear repeatability animal models were used to analyze continuous traits: M305, GL and DO. Estimates of heritability (h^2) ranged between 0.19 to 0.24 for M305; from 0.23 to 0.26 for RP; from 0.18 to 0.32 for SB; 0.07 for GL and around 0.01 for DO. The corresponding repeatability (t) estimates for M305 was 0.39; from 0.45 to 0.53 for RP; 0.99 for SB; from 0.08 to 0.11 for GL and from 0.01 to 0.26 for DO, respectively. Moderate h^2 and high t estimates of SB with antagonistic moderate genetic correlations (r_G) with M305 in addition to the moderate positive r_G with both of GL and DO suggest that genetic improvement can be achieved for M305 and against SB occurrences through direct selection than indirect selection.

Moreover, moderate h^2 estimates of RP with positive r_G with reproductive traits (GL and DO) were desirable in the sense that direct selection for minimizing the incidence and the risks of RP would result in progress of selection response against extended or prolonging both DO and GL in subsequent lactations.

Selecting cows that have more milk could decrease SB cases in later lactations, but should be done with caution due to the unfavorable moderate r_G between M305 and DO. Moderate positive r_G estimates between GL and both of RP and SB emphasized that GL were genetically associated with SB and RP incidences.

Keywords: Friesian, Functional Traits, 305-day Milk yield, Variance components, Genetic Parameters

INTRODUCTION

Growing emphasis on functional traits indicates that they are more important now than in the past with a future trend during reducing the costs of labor and veterinary care, with better fertility, fewer diseases and reducing culling rates, then increasing income. Profitability of dairy cattle does not only depend on milk production traits but also on other traits such as fertility and health traits. Selection for functional traits is increasing for most dairy breeds and in several countries (Luo *et al*., 2002 and Mark, 2004). Thus inclusion of functional traits in genetic improvement programs is important for the long-term development of dairy populations.

Eaglen *et al.* (2013) documented that an emphasis on the genetic merit for FT is needed when selection decisions are made. Furthermore, negative genetic relationships were observed between production and FT. Then, it is essential to be included in national breeding programs to stop undesirable genetic trends on correlated traits.

Reproductive problems such as retained placenta (RP) and stillbirth (SB) are occurring frequently in lactating dairy cows and can dramatically affect reproductive efficiency in a dairy herd with impairing reproductive function (Ghavi Hossein-Zadeh, 2013).

Retained placenta (RP) is considered as the third most common health hazard in dairy cows (Goff, 2006) as a calving disorder and disease in cattle. Also, it is from the main causes of the sub fertility including longer days open (DO) and days to first service among the dairy herds, (Han and Kim, 2005).

Stillbirth (SB) in dairy cattle has been shown to be heritable (Weller *et al*., 1988 and Luo *et al*., 1999). Atashi *et al*. (2012) evidenced that SB has considerable effects on the dairy industry through reducing number of calves, lactation performance and increasing risks of developing metritis and RP.

Gestation length (GL) is one of the most important traits in cow-calf operations and significantly affects cattle breeding and production (Nogalski and Piwczynski (2012) and Kumar *et al*., 2016). Jenkins *et al*. (2016) showed that the net effects of any genetic selection that results in shorter GL were likely to be economically positive.

The objective of the present study was to estimate (co)variance components, genetic and phenotypic parameters and correlation coefficients among functional traits and milk production in Friesian cattle using threshold and linear animal models.

MATERIALS AND METHODS

Data and Studied Traits:

Data utilized in this study were obtained from a Friesian herd raised at Sakha experimental farm, which belongs to the Animal Production Research Institute, Ministry of Agriculture. A Thirty nine years data set making a total of 3674 records including 1230 cows daughters of 160 sires and 857 dams which covered the period from 1976 to 2014 were included in the analyses. Data consisted of eight parities with number of records of 1069, 866, 613, 458, 295, 202, 105 and 66, respectively distributed on two seasons. Cold weather season was from November to April and hot weather season was from May to October. Numbers of male calves were 1645 and of female calves were 1684. Available data on 305-day milk yield as a production trait and some functional traits such as retained placenta and stillbirth as binary (0,1) disorders and gestation length and days open as fertility continuous traits were utilized. Table (1) presents description of data with some descriptive statistics for the utilized traits.

Table 1. Description of data and descriptive statistics of M305 and the studied functional traits

Data	M305(kg)	RP(0,1)	SB(0,1)	GL (day)	DO(day)
Means ±SD	3103±81	0.09±0.2	0.06±0.3	276.8± 6.4	164.0±82.3
No. of records	3462	3674	3674	3674	2605
No. of cows	1163	1046	1077	1168	932
No. of sires	159	154	154	159	145
No. of dams	827	743	764	830	688
C.V.%	26.4	44.4	8.7	2.3	50.2
Incidence percent		8.9	5.7		

M305: 305-day milk yield; RP: retained placenta; SB: stillbirth; GL: gestation length ; DO: days open and C.V.: coefficient of variation.

Statistical Analyses:

Estimation of (Co) variance Components and Genetic Parameters :

Two-trait analyses were performed to estimate (co) variance components, genetic and phenotypic parameters between M305 and each of RP, SB, GL and DO. Also, analyses between GL and DO and other traits were carried out. Analyses that included any of the binary traits (RP or SB) were carried out in bivariate threshold repeatability animal models using GIBBS Sampling Program (Van Tassell and Van Vleck, 1996). A Gibbs sampling chain length of 250000 rounds was run for each analysis with burn in 50000 rounds. Milk yield in 305-day, GL and DO were treated as continuous traits. Fixed effects for RP, SB and GL were parity, season of calving, year of calving and sex of offspring. Age of cow at calving was a covariate effect. M305 and DO had the same fixed effects, except for the sex of offspring. The following model was used:

$$\mathbf{y = X\beta + Z_a a + Z_c c + e}$$

Where,

y is the vector of observations of the traits;

X is the incidence matrix relating the observations to their respective non-genetic fixed effects;

β is the vector of an overall mean and non-genetic fixed effects in the model with association matrix X;

$\mathbf{Z_a}$ is the incidence matrix for random effects of cow;

a is the vector of random direct animal genetic effects with the association matrix $Z_{a;}$

$\mathbf{Z_c}$ is the incidence matrix of random permanent environmental effects;

c is the vector of the random permanent environmental effects with the association matrix $Z_{c;}$ and

e is the vector of the random errors, NID (0, $\sigma^2_e I$).

The analyses between continuous traits (M305, GL and DO) were performed using Multiple-trait derivative-free restricted maximum likelihood program; (MTDFREML, Boldman *et al*., 1996) to estimate (co)variance components, genetic and phenotypic parameters. The analyses were solved iteratively and terminated when the change in the variance of the function values (-2 log likelihood) was below 10^{-9}. The previous model was used.

RESULTS AND DISCUSSION

The overall incidence of RP in the data set was 8.9% and was 5.7% for SB, Table (1).The overall SB rate of 5.7% was in agreement with 6% reported by Atashi (2011) and lower than 9.5% reported by Al-samarai (2012). Whereas, the rate of RP (8.9%) was higher than 6.6 and 6.9% that was found by Bruun *et al*., (2002) and Binabaj *et al*., (2014), respectively but matching with 9% that was obtained by Grohn *et al*., (1990). Gaafar *et al*., (2010) on only eight years of data on the same herd reported 24.9% incidence of RP.

As shown in Figure (1), the occurrence of the RP and SB in this study was very high in heifers 22.7 % and 39.2 % of the cases, respectively, other than later parities. Higher incidence of SB in the first parity cows was reported by Meyer *et al*., (2001) and Hansen *et al.,* (2004b). In general, those incidences were decreased gradually with the advance of parity and thus high risk of both SB and RP were found in heifers (Al Maruf *et al*., 2014 and Yao *et al*., 2014).

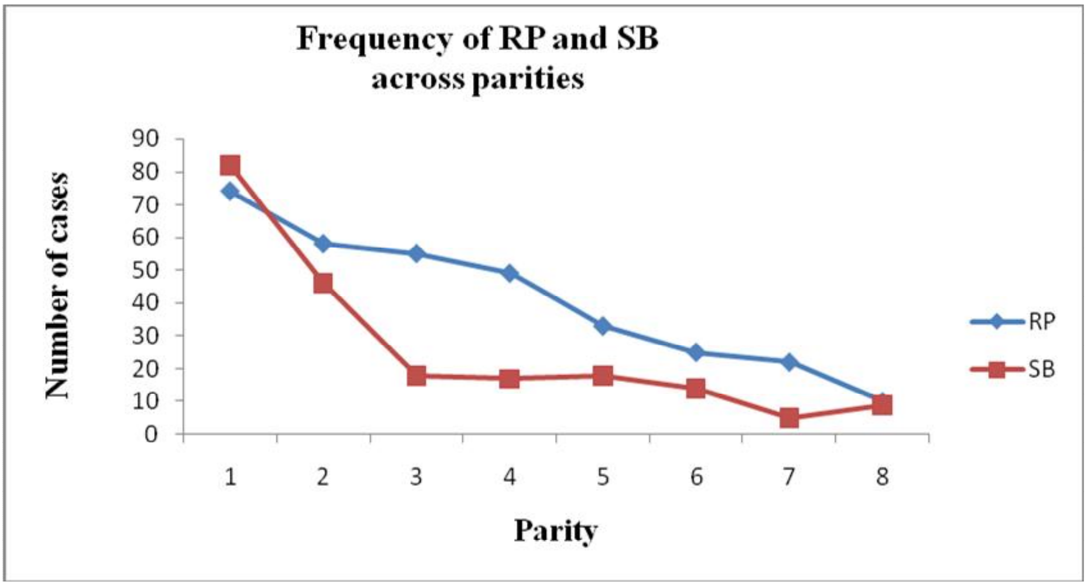

Figure 1. Frequency of RP and SB across the first eight parities

The variation in the incidence of RP may be attributed to variations of influencing factors to which the animals are subjected to such as nutritional status, management and occurrence of infectious diseases that are considered as important, (Al Maruf *et al*., 2014).

Variance Components:

Table (2) shows the estimates of phenotypic variance components and percentages of other variance components relative to the phenotypic variance resulted from analyzing M305 with functional traits (RP, SB, GL and DO). As reported, estimates reflected much greater values of temporary environmental variance ($\sigma^2_{Te\ \%}$) compared with the additive genetic percentage (σ^2_A%), relative to σ^2_P, suggesting greater effects of environmental action on those traits, except with SB where the permanent component was higher and this may explain its high values near unity (0.99) of the t estimate due to its high values of σ^2_{Pe}%. Also, the σ^2_{Pe}% of M305 (14.6 -19.0) were greater than 9.3 that reported by Ben Zaabza *et al*. (2016). Bicalho *et al*. (2008) explained that management practices may influence the incidence of SB calves causing great variation.

Table 2. Estimates of phenotypic variances and percentages of other variance components for M305 and the studied FT and heritability and repeatability estimates

Traits	σ^2_A%	σ^2_{Pe}%	σ^2_{Te}%	σ^2p	h^2	t
M305*	24.19	14.62	61.19	68.78	0.24	0.39
RP	23.41	28.97	47.62	2.11	0.23	0.53
M305*	20.25	18.63	61.12	68.37	0.20	0.39
SB	31.67	67.93	0.40	304.06	0.32	0.99
M305*	19.00	19.00	62.00	67.99	0.19	0.39
GL	7.00	1.00	92.00	43.48	0.07	0.08
M305*	23.00	15.00	62.00	69.18	0.23	0.39
DO	0.65	0.50	98.85	6876.59	0.01	0.01

M305*: variance/10^4 σ^2_A**:** additive genetic variance; σ^2_{Pe} : permanent environmental variance; σ^2_{Te} : temporary environmental variance; σ^2p: phenotypic variance; h^2 : heritability and t: repeatability

The σ^2_p of GL (43.48) were generally much greater than 24.3 and 0.25 that was estimated by Eaglen et al. (2012 and 2013), respectively, and 34.8 by Toghiani (2012). Babaei *et al*. (2015) evidenced that GL was more influenced by non- genetic factors indicating that more various environment variances control this trait. The value of σ^2_{Pe}% 1.0 and 0.5 of GL and DO were higher than 0.05 and 0.04, respectively, reported by Toghiani (2012).

Heritability and repeatability estimates:

Moderate h^2 estimates for M305 (Table 2) were found in normal trend (from 0.19 to 0.24),and this is in agreement with (Zavadilova and Zink, 2013; Faraji-Arough *et al*. 2015 and Ben Zaabza *et al*., 2016). Low estimate for DO (0.01) was nearly matching that of Toghiani, (2012). Low h^2 estimate for DO is caused not only by a low genetic variance but also by random or environmental factors (Khalid *et al*., 2001).

Table (2) shows that h^2 estimate for RP is 0.23 in the analysis with M305 was greater than 0.10 and 0.16 by Nogalski and Piweznski, (2012) and Haugaard and Heringstad (2013), respectively. Moreover, Berry *et al*. (2014) and Koeck *et al*., (2014) reported that the h^2 estimates for RP is between 0.006 and 0.26.

The h^2 estimate of SB (0.32), Table (2) was much higher than 0.12 and 0.15 that reported by Hansen *et al*. (2004a); Beffa *et al*. (2009) and Johanson *et al*. (2011) and lower than 0 .42 that reported by Nogalski and Piweznski (2012). Furthermore, Philipsson, (1976) and Ghavi Hossein-Zadeh (2011) stated that SB has been shown to be heritable and this mean that it is a potential trait to include in a breeding program.

For GL, the h^2 estimate (0.07) was in the range of 0.05 to 0.09 that was obtained by Johanson *et al*. (2011); Toghiani, (2012); Nogalski and Piweznski, (2012); Eaglen *et al*., (2012 and 2013); Mokhtari *et al*. (2015) and Babaei *et al*. (2015).

Results in Table (2) demonstrate that t estimate of M305 was 0.39 meaning that cows can be selected for M305 on the basis of relatively small number of records in the present study. This result was nearly matched by the finding of 0.36 reported by Mustafa *et al*. (2002).

Concerning the t estimates for FT as shown in Table (2), it was 0.53 for RP, which is higher than 0.24 reported by Amin *et al*. (2000), while around unity (0.99) for SB. However, Mukherjee *et al*. (1993) reported very low t estimates (0.02 and 0.07) for SB and RP, respectively. Moderate t estimates of RP, could be due to the effects of the temporary environmental conditions such as management, nutrition and other physiological factors on the trait. It appears that RP and SB are considered as high repeated observations that may play important role in direct and indirect culling of dairy cattle cows.

The low t estimate (0.08,Table 2) for GL matches with the 0.12 reported by Toghiani (2012) but much less than 0.17 and 0.20 reported by Ihlam *et al*. (2012) and Babaei *et al*. (2015), respectively. For DO, very low t estimate, (0.01, Table 2) was less than 0.10 by Toghiani (2012) .Generally, the low t estimates for the reproductive traits (GL and DO) indicate that the additive variability of those traits are low which shows a strong influence of temporary environmental effects on those traits and justify accumulation of further records for better selection and performance.

Genetic and phenotypic correlations:

Table 3 shows the correlation coefficients between M305 and FT. Concerning the r_G estimate between M305 and RP trait, it was generally very small, -0.04 (Table 3), and confirming with the results of Martin *et al*. (1986) that M305 was not considerably affected in cows with difficulty at the time of calving. As RP showed moderate r_{Pe} estimate (0.32) with M305. This indicates that cows that had retained placenta probably would be repeated with the advancing of lactations.

As evidenced in Table (3) in terms of different associations of M305 with the studied FT; SB showed negative and moderate r_G estimate with M305 (-0.20) and go in parallel with the results of Bicalho *et al*. (2008); Atashi, (2011) and Atashi *et al*., (2012).

Table 3. Estimates of correlation coefficients between M305 and FT

	Correlations with M305			
Trait	r_G	r_{Pe}	r_{Te}	r_P
RP	-0.04	0.32	0.05	0.08
SB	-0.20	0.11	0.04	-0.02
GL	0.01	-0.63	0.05	0.00
DO	0.60	0.38	0.11	0.12

r_G: genetic correlations; r_{Pe}**:** permanent environmental correlation; r_{Te}: temporary environmental correlation and r_P: phenotypic correlations.

Very weak r_G estimate (0.01) between M305 and GL that is presented in Table (3) was smaller than the finding of 0.09 reported by Eaglen *et al*. (2013). This could mean that GL of a cow before giving birth was not genetically related to M305. On the other hand, the negative and high r_{Pe} estimate between them was in agreement with Norman *et al*. (2011) and Jenkins *et al*. (2016).

Moderate positive r_G estimate was shown in Table (3) between M305 and DO (0.60) was supported by the findings 0.36 and 0.65 of Toghiani, 2012 and Zavadilova and Zink, 2013, respectively. The genetic correlation of milk production with DO was in agreement with Kadarmideen *et al*. (2000); Pryce and Veerkamp (2001) and Scheid Filho *et al*. (2012) beside the moderate r_{Pe} estimate between them indicates that increasing M305 is associated with longer days to successful conception, prolonging the distance between two calving intervals and this can lead to reducing the number of calves born during the economic period of cows in the herds.

Genetic parameters for FT:

Tables (4, 5 and 6) present estimates of heritability and genetic parameters among FT. Results in Table (4) evidenced positive r_G between

RP and GL (0.29) that were higher than 0.15 that obtained by Nogalski and Piweznski (2012) while, Koeck *et al*. (2014) showed antagonistic r_G estimates (-0.01 to -0.18) between GL and RP. Binabaj *et al*. (2014) revealed that few days shorter GL than the average are associated with a higher incidence of RP. Moderate r_G estimates between RP and GL may indicate that cows that had RP probably suffer from prolonged GL.

Referring to the weak r_G estimate 0.10 between DO and RP in this study, Table (4), it was supported by the results of Coleman *et al*. (1985) and Kaneko *et al*. (1997) where they emphasized that the intervals from calving to conception were not related to the occurrence of RP. Scheid Filho *et al*. (2012) reported that DO for cows with RP was shorter (P=0.03) than those without it. Morrow (1986) explained that veterinary treatments for cows had RP stimulates uterine contractions with expulsion of the placenta and uterine involution that may favor subsequent conception.

Moderate r_G estimate, Table (5), between GL and SB (0.25) was higher than 0.18 and lower than 0.56 by using different models by Nogalski and Piweznski (2012). This result agrees with the conclusion of Jamrozik *et al*. (2005) and Eaglen *et al*. (2012), that GL were genetically associated with SB and suggest that the calf that gestates longer before birth to a multiparous dam, is disposed to a complicated birth and vice versa.

Table (5) clarified that SB presented that favorable moderate r_G estimates with DO 0.34 and that is in line with the finding of El Tarabany (2015) with pure Holstein cows experiencing SB had significantly longer DO compared with normal births. Moreover, Meyer *et al*. (2000) and Bicalho *et al*. (2007) proved that the SB prolonged days to conception (DO) compared with healthy cows.

Our negative and strong r_G correlations between GL and DO (-0.79) in Table (6) do coincide with some studies as those of Veerkamp *et al*. (2001) and Kadarmideen *et al*. (2003) that strong (positive and negative) relationships ranging from ±0.70 to ±0.98 for fertility traits were observed. While, Toghiani (2012) evidenced low r_G estimates between GL and DO (0.008).

Table 4. Estimates of correlation coefficients between RP and both of GL and DO, and their heritability and repeatability estimates

Traits	Correlations				h^2	t
	r_G	r_{Pe}	r_{Te}	r_p		
GL	0.29	-0.00	-0.08	-0.02	0.07	0.11
RP					0.25	0.45
DO	0.10	0.03	0.03	0.03	0.01	0.26
RP					0.26	0.48

r_G:genetic correlations; r_{Pe}**:** permanent environmental correlation; r_{Te} : temporary environmental correlation; r_P: phenotypic correlations; h^2: heritability and t: repeatability.

Table 5. Estimates of correlation coefficients between SB and both of GL and DO and their heritability and repeatability estimates

Traits	Correlations				h^2	t
	r_G	r_{Pe}	r_{Te}	r_P		
GL	0.25	0.34	0.26	0.10	0.07	0.11
SB					0.18	0.99
DO	0.34	0.05	0.01	0.03	0.02	0.05
SB					0.27	0.99

r_G:genetic correlations; r_{Pe}**:** permanent environmental correlation; r_{Te} : temporary environmental correlation; r_P: phenotypic correlations; h^2: heritability and t: repeatability.

Table 6. Correlation coefficients between GL and DO

Correlation	Correlations between GL and DO
Genetic	-0.79
Permanent Environmental	-0.96
Temporary Environmental	-0.01
Phenotypic	-0.04

CONCLUSION

Breeding for increased production in dairy cattle is known to have side effects on fertility traits and reproductive disorders. Results of the current study highlight the genetic parameters and different relationships among milk production and some functional traits. Reflecting that moderate h^2 and t estimates of RP and SB, and their genetic correlations with milk production and other functional traits, it can be concluded that, inclusion of functional traits in genetic improvement programs should be considered to achieve genetic progress in M305 and minimize the incidence and the risks of RP and SB without prolonging DO.

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العلاقات بين الصفات الوظيفية و إنتاج اللبن في ماشية الفريزيان باستخدام نماذج سلمية و خطية.

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في الآونة الأخيرة، أصبحت الصفات الوظيفية موضع اهتمام مربي ماشية اللبن حيث تشمل أهداف التربية الصفات الوظيفية بالإضافة إلى صفات إنتاج اللبن. لذا ، كانت أهداف هذه الدراسة هى تقدير مكونات التباين والارتباطات الوراثية و المظهرية للصفات الوظيفية وإنتاج اللبن. تم تجميع ٣٦٧٤ سجلا لعدد ١٢٣٠ بقرة بنات ١٦٠ طلوقة و٨٥٧ أم لقطيع فريزيان مربى في محطة بحوث الانتاج الحيواني بسخا – معهد بحوث الانتاج الحيواني – مصر.

تم تحليل صفة إنتاج اللبن في ٣٠٥ يوم مع الصفات الوظيفية باستخدام نموذجين. فقد تم التحليل مع الصفات الثنائية (٠,١) وهي احتباس المشيمة و الولادة النافقة باستخدام نموذج الحيوان السلمي لتقدير مكونات التباين والتغايروالمعالم الوراثية . وقد استخدم نموذج الحيوان الثنائي المتعدد للتحليل مع الصفات المستمرة كمحصول انتاج اللبن في ٣٠٥ يوم – طول فترة الحمل –والايام المفتوحة.

كانت تقديرات المكافئ الوراثي تراوحت بين ٠.١٩ – ٠.٢٤ لصفة محصول اللبن في ٣٠٥ يوم ،ومن ٠.٢٣ – ٠.٢٦ لصفة احتباس المشيمة ومن ٠.١٨ – ٠.٣٢ لصفة الولادة النافقة و ٠.٠٧ لصفة طول فترة الحمل وحول ٠.٠١ لصفة طول الايام المفتوحة على الترتيب. وبلغت قيم المعامل التكراري ٠.٣٩ لصفة محصول اللبن في ٣٠٥ يوم ومن ٠.٤٥ – ٠.٥٣لصفة احتباس المشيمة و ٠.٩٩ لصفة الولادة النافقة ومن ٠.٠٨ – ٠.١١ لصفة طول فترة الحمل ومن ٠.٠١ – ٠.٢٦ لصفة طول الايام المفتوحة علي الترتيب. تشير قيم المكافئ الوراثي المتوسطة والمعامل التكراري المرتفعة لصفة الولادة النافقة بالإضافة لعلاقتها الارتباطية الوراثية السلبية (المرغوبة) مع محصول انتاج اللبن في ٣٠٥ يوم (- ٠.٢٠) وكذلك قيم ارتباطاتها الوراثية المعتدلة علي التوالي مع صفتي طول فترة الحمل وطول الايام المفتوحة لإمكانية تحقيق التحسين الوراثي المباشرلمحصول اللبن ضد تكرار حدوث الولادة النافقة عن الانتخاب الغير مباشر. كانت قيم المكافئ الوراثي لصفة احتباس المشيمة متوسطة وذات علاقة ارتباط وراثي موجب مع صفتي طول فترة الحمل والايام المفتوحة علي الترتيب تشير لإمكانية استخدام الانتخاب المباشر ضد حدوث حالات احتباس المشيمة بالتوازي مع الاستجابة المتوقعة للانتخاب ضد زيادة طول فترة الحمل والايام المفتوحة في المواسم اللاحقة. الانتخاب للأبقار عالية الادرار قد ينتج عنة انخفاض محتمل في حالات الولادات النافقة مع الاخذ في الاعتبار العلاقات الوراثية الغير مرغوبة لصفة محصول اللبن مع طول فترة الايام المفتوحة وكذلك الارتباطات الوراثية الموجبة والمعتدلة بين صفة طول فترة الحمل وكلا من الصفات الوظيفية (الولادة النافقة واحتباس المشيمة) .