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Efficiency of Some Productive and Reproductive Traits in Constructing Selection Indices for Improvement Friesian Cows in Egypt

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Abstract

THIS study aims to maximize genetic gain by inclusion some productive and reproductive traits in the selection indices. The study utilized data from 1245 first lactation Friesian cow records. The data were related to 305-day milk yield (305dMY, kg), total milk yield in each lactation (TMY, kg), lactation period (LP, d), calving interval (CI, d), days open (DO, d), and number of services per conception (NSC, service) at Sakha and El-Karada farms in Kafr El Sheikh governorate, through 1998 to 2015. Statistical analysis used animal model that included month and year of calving, farm, and age at first calving as fixed factors and animal and residuals as random effects. The month of calving and age at first calving showed non-significant effects on studied traits. The means of 305dMY kg, TMY kg, LP d, CI d, DO d, and NSC count were 3092, 3283, 287, 371, 83, and 1.8, respectively. The heritability estimates (h^2) for 305dMY kg, TMY kg, LP d, CI d, DO d, and NSC count were 0.36, 0.41, 0.20, 0.19, 0.18, and 0.21. Estimates of h^2 indicated that improvement of genetic merit could be achieved through a selective breeding program with better management practices. Genetic correlations (r_g) among the studied traits were positive and high ranging from 0.74 to 0.92. Similar trend was observed in phenotypic correlations which varied between 0.18 and 0.86. The present results suggested that it is important to include productive and fertility traits in selection indices for Friesian cows under Egyptian conditions in order to achieve higher genetic merit.

Keywords: Selection indices, genetic parameters, economic values, Friesian cows.

Introduction

Cows and buffaloes are the main sources of milk production in Egypt. As well, Friesian cows are considered the most exotic foreign breeds existing and extensive in Egypt, and they contribute a large part of the milk produced, whether on large private farms and/or smallholder farms. Therefore, the dairy sector needs to increase dairy production through genetic improvement of these cows under Egyptian conditions to increase the profitability of the sector and contribute to filling the gap in milk production in Egypt. The current study offers information about two sets of important productive and reproductive traits that are greatly associated with the profitability of dairy cattle. If dairy cows do not have appropriate reproductive efficiency, they will not have a milk production season; hence, they will not be profitable on the farm. Therefore, it is important to incorporate most reproductive and productive traits into genetic improvement programs for Friesian cows under Egyptian conditions. In turn, milk production performance, which forms the main part of the dairy scheme's revenues, is classified as a complex production trait controlled by genetic and environmental factors [1, 2, 3]. In this respect, the returns of milk production depend on the reproductive efficiency of the herd [4]. Unfavorable genetic correlations (r_g) between calving interval and milk production traits have been reported for in South African Holsteins cows, a correlated increased calving interval (decline in post-partum cow fertility) as a result from selection on milk yield traits. [5]. In the recent research by

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[6] on Friesian cows, the r_g between MY and LP with DO and CI traits were positive, high, and strong. It was also shown by [7] that a selection index is designed to maximize genetic merit or aggregate value for several traits among individuals in a population. Selection index is a method worth using in determining the appropriate weights for traits included in a selection criterion. Consequently, the objectives of the present study were to, genetic parameters to attempt to evaluate the possibility of joint improvement in milk production and fertility traits through the development of standardized selection indices, which leads to maximizing the genetic improvement in Friesian dairy cows.

Material and Methods

Data collection and management

The present study used data from 1245 first lactation Friesian dairy cows' records collected from 1998 to 2015 at Sakha and El-Karada Experimental stations. The heifers were serviced after 18 months of age or more than 350 kg of body live weight. The pregnancy was diagnosed via rectal palpation after 60 days of the last service. Animals were living together in open sheds, while being mechanically milked twice a day until drying off and kept under same system of management and feeding regime. According to the Animal Production Research Institute (APRI)'s plan, animal feeding was based on their nutritional needs. The quantity and quality of feed provided was linked to the cow's body condition two months before calving, along with the importance of focus care it. The calves were placed in special pens two to three weeks before calving. After calving, the cows were given alfalfa hay, which is high in calcium and helps reduce milk fever and stomach problems. Lactating cows were also provided with water and mineral salts throughout the day.

Statistical analysis

Monitoring data in the study were statistically analyzed with the general linear model (GLM) procedure **[8]** program as follows:

$Y_{ijklmn} = \mu + S_i + Mj + Y_k + F_l + AG_m + e_{ijklmn}$.

Where: Y_{ijklmn} = the observation; μ = the overall means; Si = the random effect of the i^{th} sire, M_j = the fixed effect of the j^{th} month of calving (j= 1-12); Y_k = the fixed effect of the k^{th} year of calving (k=1998 to 2015); Fl = the fixed effect of l^{th} farm (l= (Sakha) and 2=(El-Karada), AG_m = the fixed effect of the m^{th} levels of age at first calving; and e_{ijklmn} = the residual. (Co) variances genetic and phenotypic of studied traits were obtained by REML procedures using the MTDFREML program of **[9].** The multiple model was used as follows:

$$Y = Xb + Za + e$$

Where: Y = vector of observations; b = vector of fixed effects with incidence matrix X; a = vector of direct genetic effects with an incidence matrix Z, and e = vector of residual effects.

Relative economic value (REV)

According to [10] and [11] the economic values were determined via the one-unit phenotypic standard deviation method before calculating the full index. The REV for 305dMY was set as unity, and the REV's for the other traits under the study were estimated and assigned proportionally to 305dMY, as shown in Table 1.

Direct and correlated responses:

The awaited direct (ΔG_X or DR) and correlated (CR_Y) responses to selection for one trait based on first lactation records were estimated according to [11] by: ΔG_X or DR = $ih^2 \sigma_p$ and

$$CR_Y = i\, h_x\, h_y\, rA_{xy}\, \sigma_{py}$$

Where: i = intensity of selection on X, h^2 = the heritability estimate of X trait, σ_p = the standard deviation of phenotypic values, h_x = the square roots of heritability estimate of trait X, h_y = the square roots of heritability estimate of trait Y, rA_{xy} = the genetic correlation between the two traits, and σ_{py} = the standard deviation of phenotypic values of trait Y. The awaited genetic gains in one generation were estimated assuming selection based on cows, for the purpose of comparisons; intensity of selection for a trait was set to be 1.00.

The index (I) value was calculated as:

$$I = \sum_{i=1}^{n} bipi$$

Where bi is the selection index weighting factor, pi = phenotypic value, and n is the number of traits. According to **[7]**, the maximum accuracy of the index (R_{IH}) is attained when Pb = Ga. Vector b = $P^{-1}Ga$, where P^{-1} is the inverse of the phenotypic (co)variance matrix of the traits in the selection index. Values in vector b and in matrix P were used to calculate index variance $\sigma^2_I = \underline{b}' \, \underline{P} \, \underline{b}$. Variance of the total aggregate genotypic σ^2_H was a′Ga, where a´ is the transpose of the economic value column vector. Index accuracy (R_{IH}) is defined as the correlation between variance of aggregate genotypic value and variance of the index value.

Results

The phenotypic means and significance levels for independent factors of the studied traits were determined using the data described in Table 2. The results showed that the impact of sires on all studied traits was highly significant ($P \leq 0.01$), with the exception of CI was significant ($P \leq 0.05$). Contrariwise for effect the month of calving and age at first calving was a non-significant on whole studied traits. Moreover, the year of calving had a highly significant effect on 305dMY, TMY, LP, and CI, but was vice versa for DO and NSC. Additionally, farm was a significant effect on CI and LP (, while the other studied traits were not affected by the farm.

Heritability (h^2) and variance components of the studied traits are summarized in (Table 3). The estimates of h^2 of 305dMY, TMY, and LP were 0.36, 0.41, and 0.20, respectively (Table 3). The genetic correlations (r_g) among productive traits (305dMY, TMY and LP) were strong positive and varied from 0.78 to 0.91, while r_g among reproductive traits (CI, DO and CI) were fluctuated between (0.81- 0.92). The same trend was also, the genetic correlations among productive and reproductive traits were high and varied between (0.74 - 0.89). Furthermore, the phenotypic correlations (r_p) estimates among productive traits were strong and ranged from 0.76 to 0.86. Similarly, the phenotypic correlations, among reproductive traits were varied between (0.50 - 0.79), and among productive and reproductive traits were fluctuated between 0.18 and 0.83 are presented in (Table 4).

Direct and correlated responses to selection for traits under current study are illustrated in (Table 5). The direct selection of 305dMY, TMY, and LP in Friesian cows led to amelioration of production performance. Which, the improvement of aforementioned productive traits per generation varied between (449.60 to 203.72 kg), (269.15 to 462.96 kg), and (19.02 to 17.03 d), respectively. Nevertheless, direct selection for productive traits led to deterioration in the reproductive performance of CI (13.86 to 20.23 d), Do (2.20 to 3.49 d), and NSC (0.13 to 0.19 services), as shown in Table 5.

The different selection indices are illustrated in table (6), indicated that the original selection index (I_1) was the best index (R_{IH}= 0.96 and RE%= 100) which includes all traits in study. Contrariwise, the minimum of R_{IH} and RE% (R_{IH} =0.78 and RE%= 81.25) was observed in indices I_4 and I_5 which included only reproductive traits. Resulted in ignoring 305dMY, TMY, and LP from the original index, led to decreased of the accuracy of the selection index about 19%. The highest predicated genetic changes of 305dMY and TMY were achieved by selection index I_9 (omission DO from full index), being 146 kg and 288 kg, respectively.

On the contrary, the lowest genetic changes for 305dMY and TMY observed in the selection index I_4 and I_5 were 84.64 and 182.05 kg, respectively. Furthermore, the best expected genetic gain of LP obtained by index I_2 (exclusion 305dMY from full index) was 8.09 d. Contrarily, decline of LP was gained by index I_{12} (omission 305dMY and LP from the full index) being -7.51 d. While the best expected genetic gains for reproductive traits were achieved by selection indices ($I_{6,}$ I_{10} and I_4). As describe as follows, these gains were obtained by selection index I_6 (-5.47d for CI when deletion TMY from full index), index I_{10} (-6.96d for DO if elimination NSPC from full index), and index I_4 (-0.98 service for NSPC when index included CI, DO, and NSC) per generation.

Discussion

The current means of TMY (3283 kg) and LP (287d) were higher than those observed by [12], which were 2425 kg and 304 d, respectively. Vice versa, the mean of CI (371 d) is shorter than they found in the first lactation. On the contrary, the mean of TMY was lower than that found for Holstein Friesian by [13], which was 3019 kg. Moreover, the current mean of LP is shorter than that estimated by [13], which is 299 d in Holstein Friesian cows, and by [14], which is 327 days in purebred Friesian cows. In addition, the present study's 305dMY was lower than (3936 kg) that was estimated by [2]. As regard by [15] in Friesian cows 305dMY and CI were a highly significant affected by year and season of calving. Likewise, in Holstein crossbreds [16] demonstrated that the year-season of calving had a highly significant effect on 305dMY and TMY.

The estimate of h^2 for 305dMY (0.30), was higher than that estimated by [17] being but was lower for LP (0.24). In addition, the present h^2 estimate for 305dMY was (0.34) closed with [3] in Friesian cows. In addition, the present study's estimates for 305dMY, LP, CI, and DO were higher than those recorded by [18]. Also, the h^2 estimates obtained by [19] for LP and DO (0.074 and 0.023, respectively) were lower than those found in this study. In the tropical highlands of Ethiopia and China, and in subtropical warm climates in Sudan, h^2 estimates for productive traits of Friesian cattle ranged (0.10 - 0.44, and 0.17 -0.39 for TMY and 305dMY, respectively [20, 21 and 22].

Genetic correlations among production traits were strong positive. [23] obtained a similarly high genetic correlation (0.83) between 305dMY and LP but estimated a moderate genetic correlation (0.50) between 305dMY and DO. The present results are in a recommendable direction, signalizing that high-yielding cows are having longer LP and DO. Agree with indicated by [24] and [18] on Friesian cows. Direct and correlated responses to selection for traits under current study are agreed with those found in Holstein Friesian cows by [25]. Also, the current results are consistent with [26 and 27] realized the direct selection and correlated responses to milk traits and udder health in buffalo. [12] reflected that the best expected genetic gains in Friesian cows for TMY, LP, and CI were 150.84 kg, 11.38 d, and -13.54 d, respectively. In addition, they clarified that omitting TMY from the original index resulted in a decrease in accuracy about 17%. Also, in this regard, [26] stated that the expected genetic gain for TMY varied between 110 to 304 kg in Friesian cows.

[28] found that limited maternal genetic effects and selection indices was practically exclusively based on the direct genetic effects. She added that exclude the TMY and/or 305dMY from the original selection index lead to a decrease in relative efficiency by about 37%. [29] demonstrated that the best selection indices achieved genetic gain in milk production and reproduction traits in Egyptian native cows using the selection indices included (TMY, LP, CI and DO, RIH=0.623), (TMY, GI, DO, RIH=0.610), (LP, CI and DO, RIH=0.581) and (TMY, LP and CI, RIH=0.561). [30] on German Holstein dairy cattle, recommended that the integration of a resilience [can be measured by parameters based on variance and the correlation of daily milk yields in dairy cows] selection index in milk production breeding value estimation would be more effective than using only resilience indicator.

Conclusion

The current heritability estimates for productive traits affirm the possibility of realizing a considerable rate of genetic improvement in them. Heritability estimates for reproductive studied traits indicated the ability to achieve a plausible rate of improvement for these traits through genetic improvement and managerial and environmental manipulations at the same time. The selection index includes all studied traits except DO, showed the highest genetic gains was expected for 305dMY and TMY, with to the highest accuracy. The accuracy decreased by almost 17% when omitting the TMY trait from the original selection index. Therefore, the present results recommend the use the full selection index after dropping DO trait, when using selection indices to improve the genetic merit of productive and productive traits in Friesian cows under Egyptian conditions.

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Declaration of Conflict of Interest

The authors declare that none of the authors have any competing interests.

Ethical of approval

This study received ethical approval from the Research Ethics Committee of the Faculty of Agriculture and veterinary medicine at Kafrelsheikh University (reference KFS-IACUC 142/2023)

TABLE 1. The relative economic values of the investigated traits for 305dMY according to the one-unit phenotypic standard deviation method

Trait	305dMY, kg	TMY, Kg	LP, d	CI, d	DO, d	NSC, count
1/ σ_p	1/912	1/1286	1/85.2	1/89	1/15.5	1/0.8
Relative economic value	1	0.7092	10.704	10.247	58.839	1140

305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

TABLE 2. Phenotypic means, standard deviations (SD), coefficient variability (C.V%), and significance levels of independent variables studied traits in Friesian cow.

Trait Items	305dMY, Kg	TMY, kg	LP, d	CI, d	DO, d	NSC, count
Mean ± SD	3092±912	3283±1286	287±85.2	371±89	83±15.5	1.8±0.8
C.V (%)	29.50	39.17	29.68	23.99	18.78	44.44
Independent Variable	**Significance levels**					
	F	**F**	**F**	**F**	**F**	**F**
Sires	1.69^{**}	1.47^{**}	1.42^{**}	1.41^{*}	1.94**	1.66^{**}
Month of calving	0.99^{ns}	0.99^{ns}	0.57^{ns}	0.81^{ns}	1.08^{ns}	1.04^{ns}
Year of calving	4.83^{**}	3.08^{**}	3.55^{**}	3.20^{**}	0.74^{ns}	0.64^{ns}
Farm	2.87^{ns}	2.97^{ns}	13.6^{**}	4.59^{*}	0.002^{ns}	0.0.0002
AFC	2.41^{n}	0.24^{ns}	1.4^{ns}	0.50^{ns}	0.28^{ns}	0.11^{ns}
Residual	1442935	726607	6645.93	7511.5	224.96	0.5987

No. of records =1245 * P<0.05 ** P<0.01 n.s =non-significant; df for (sires = 96, month of calving = 11, year of calving = 17, farm =1, Age at first calving (AFC)=2 and residual = 1117; 305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

TABLE 3. Variance components and heritability of different studied traits under investigation.

Item	Traits					
	305dMY	**TMY**	**LP**	**CI**	**DO**	**NSC**
$\sigma^2 a$	1070.33	1184.22	84.18	204.15	93.49	136.08
$\sigma^2 e$	1893.85	1684.12	334.75	853.75	420.71	510.70
$\sigma^2 p$	2964.18	2868.34	418.93	1057.90	514.20	646.77
h^2	0.36	0.41	0.20	0.19	0.18	0.21
C^2	0.64	0.59	0.80	0.81	0.82	0.79

σ^2_a = additive genetic variance; σ^2_e = residual (temporary environmental variance σ^2_p = phenotypic variance; h^2 = heritability; c^2 = fraction phenotypic variance to permanent environmental e^2 = fraction phenotypic variance due to residual effects; 305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

TABLE 4. Estimates of genetic correlation (r_g) under the diagonal and phenotypic correlation (r_p) above the diagonal for traits studied.

Item	305dMY	TMY	LP	CI	DO	NSC
305dMY		0.86	0.81	0.64	0.68	0.18
TMY	0.91		0.76	0.63	0.83	0.26
LP	0.78	0.78		0.77	0.80	0.30
CI	0.89	0.87	0.80		0.79	0.50
DO	0.83	0.84	0.75	0.85		0.61
NSC	0.74	0.88	0.79	0.81	0.92	

305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

TABLE 5. Expected direct and correlated responses to selection per generation for studied traits of Friesian in Egypt.

Response to selection Direct response	305dMY	TMY, kg	LP, d
305dMY, kg	373.96		
TMY, kg		462.96	
LP, d			17.03
Correlated response			
305dMY, kg		318.88	203.72
TMY, kg	449.60		269.15
LP, d	19.02	17.83	
CI, d	22.08	20.23	13.86
DO, d	3.49	3.31	2.20
NSC, count	0.17	0.19	0.13

305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

TABLE 6. The expected genetic change (ΔG) partial regression coefficients (b, s), the accuracy (R_{IH}), and relative efficiency (RE%) of studied traits in selection indices (I,s) for the generation.

Selection indices	Traits												R_{IH}	RE%
	305dMY		TMY		LP		CI		DO		NSC			
	B	ΔG	B	ΔG	b	ΔG	B	ΔG	B	ΔG	b	ΔG		
I_1	11.46	140.10	2.72	251.14	1.04	6.04	-3.32	-5.31	-0.12	-6.34	-8.66	0.88	0.96	100.00
I_2	-	87.29	2.51	240.42	1.32	8.09	-0.81	-4.95	-4.51	-5.38	-11.31	-0.44	0.80	83.33
I_3	-	85.69	-	208.54	1.46	7.95	-2.14	-4.67	-4.48	-5.47	-10.62	-0.34	0.79	82.29
I_4	-	84.64	-	206.47	-	7.29	-2.17	-4.66	-4.60	-5.37	-11.34	-0.98	0.78	81.25
I_5	-	85.22	-	182.05	-	7.58	-	-4.58	-4.81	-5.39	-12.42	-0.10	0.78	81.25
I_6	10.08	114.17	-	193.43	0.87	6.38	-1.91	-5.47	-0.67	-6.23	-9.55	-0.86	0.94	97.92
I_7	11.17	133.14	2.64	241.74	-	5.46	-3.26	-5.31	-0.16	-6.27	-8.23	-0.01	0.95	98.96
I_8	-10.88	143.74	1.48	277.39	0.93	6.48	-	-5.31	-0.61	-6.21	-10.36	-0.95	0.94	97.92
I_9	11.54	146.25	2.76	287.95	1.04	6.05	-3.35	-5.31	-	-6.30	-8.65	-0.85	0.95	98.96
I_{10}	12.97	106.28	4.64	220.86	0.88	4.24	-7.48	-4.68	0.04	-6.96	-	-0.39	0.89	92.71
I_{11}	9.87	113.27	-	192.71	-	6.72	-1.89	-5.46	-0.69	-6.17	-9.17	-0.01	0.94	97.92
I_{12}	9.91	112.99	-	175.49	-	6.91	-	-5.41	-0.86	-6.11	-10.10	-0.08	0.93	96.88
I_{13}	-	88.31	-2.58	277.90	-	-7.51	-0.80	-4.95	-4.62	-5.46	-11.98	-0.14	0.80	83.33
I_{14}	-	88.41	2.82	277.32	-	7.62	-	-4.95	-4.69	-5.43	-12.38	-0.18	0.80	83.33

305-day milk yield (305dMY); total milk yield (TMY); lactation period (LP); calving interval (CI); days open (DO); and number of services per conception (NSC).

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كفاءة بعض الصفات الإنتاجية والتناسلية فى تكوين أدلة انتخابية لتحسين أبقار الفريزيان فى مصر

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الملخص

البيانات المستخدمة في التحليل تحتوى على 1245 سجلًا لأول موسم حليب لصفات إنتاج اللبن فى 305 يوم وكمية اللبن الكلية لطول موسم الحليب والفترة بين ولادتين وعدد الأيام المفتوحة وعدد مرات التلقيح اللازمة لحدث الحمل فى أبقار الفريزيان الموجودة في مزرعتي سخا والقرضا في الفترة من 1998 إلي 2015م. استخدام نموذج الحيوان في التحليل الاحصائي متضمنًا شهر وسنة الولادة والعمر عند الولادة كعوامل ثابتة والحيوان والمتبقي كأتثير عشوائي. علاوة علي ذلك، اظهرت النتائج أن تأثير شهر الولادة والعمر عن أول ولادة غير معنوى علي الصفات المدروسة. وكانت المتوسطات لكمية اللبن فى 305 يوم وكمية اللبن الكلية و طول موسم الحليب والفترة بين ولادتين وفترة الأيام المفتوحة وعدد التلقيحات اللازمة لحدوث الحمل 3092كجم و 3283كجم، 287 يوم، 371يوم، 83 يوم و 1.8 تلقيحة على التوالي. كانت تقديرات المكافئ الوراثي للصفات السابقة 0.36، 0.41، ، 0.20 ، 0.19، 0.18 و 0.21 علي التوالي. أظهرت تقديرات المكافئ الوراثي إمكانية تحقيق التحسين من خلال اختيار برنامج التربية مع تحسين ممارسات الرعاية. كانت الارتباطات الوراثية بين الصفات المدروسة موجبة وعالية وتتروح بين 0.74 الي 0.92 .أخذت الارتباطات المظهرية نفس الاتجاه ولكن كانت قيمتها أقل وتراوحت بين 0.18 إلي 0.86. اظهرت النتائج الحالية أهمية ادخال الصفات الإنتاجية والتناسلية في الانتحاب الممارس في أبقار الفريزيان تحت الظروف المصرية للحصول على أعلى جدارة وراثية.

الكلمات الدالة: الأدلة الانتخابية، المعالم الوراثية، القيمة الاقتصادية، أبقار الفريزيان.