Selection indices for improving the production and reproduction of Friesian cows

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ABSTRACT

The present study contained total of 670 first lactation parity complete records of Friesian cows sired by 77 bulls, raised in south of Alexandria during the period from 1985 to 2014. These records were used to estimate genetic and phenotypic parameters by using MTDFREML for total milk yield (TMY), Daily milk yield (DMY), persistency (PER), Age at first calving (AFC) and calving to first service (CFS) in addition to establishment of many combinations of selection indices. Analysis of variance showed that sire and year of calving had significant effect on all studied traits (P< 0.01), however month of calving had significant effect on DMY and CFS only. Heritability estimates were 0.37, 0.27, 0.03, 0.38 and 0.11 for the previous traits respectively, the genetic correlations ranged from -0.92 to 0.94 and phenotypic correlation ranged from -0.25 to 0.64. Comparison between twenty-two selection indices showed that the maximum return can be achieved when applying the indices, I_{10} and I_{6} which includes three or four traits. These indices are simple and easy to construct. Therefore, it is recommended to apply selection at the end of first lactation based on these indices.

Keywords: cows, reproduction, milk, selection index. economic-genetic improvement.
fertility. In addition to milk yield, reproductive and health traits are among the major traits that should be improved genetically in dairy cattle (Lucy 2001; Van Raden, 2004 and Abosaq et al., 2017). The reproductive traits measure the ability of what cows show heat in the early breeding period and the probability of the success of insemination and confirmation of pregnancy were derived. Some of these traits included the calving to first service (CFS) and age at first service (AFC). Functionality describes the ability of the cow of producing milk in an efficient way, i.e. producing the same output of products reducing input costs (Biffani et al., 2005). Selection programs represent a great opportunity to improve genetically most of these relevant traits. Fertility is economically important as it brings cows into lactation, reduces reproductive disorders, and maximizes the profitability. Hence it is argued that enhancing both productive and reproductive potential of dairy animals should be the main objective of an animal breeder.

Hazel (1943) developed the selection index theory, which allows multiple-trait selection of animals, using economically important trait information or other measurable correlated traits that were directly obtained from individuals or their relatives and weighted by their economic values (EVs). Selection indexes have been implemented in several developed countries; consequently, dairy industries have considerably improved. Initially, production traits were emphasized in these breeding programs. One of the important breeding program processes is the estimation of genetic parameters using appropriate models. Although, some investigations have been carried out in dairy cows in regard to the estimation of genetic parameters of milk yield traits, fertility traits still need further work (Shalaby et al., 2013; Hammoud et al., 2014 and Rushdi et al., 2014). Production traits are evaluated genetically with MTDFREML "animal model" proposed by (Boldman et al., 1995) which include fixed group effects and random effects represented in sire and dam within sire, animal, and residual effects.

To implement any animal breeding program, it is important to define the production circumstances of the animals of interest to determine which traits are economically interesting (breeding goals) and will be measured (selection criteria), (Prata et al., 2015). Considering the actual selection strategy, breeding values and economic values for total milk yield, daily milk yield, persistency, Age at first calving (AFC) and the period from calving to first service (CFS) are the key breeding parameters for Friesian cattle in Egypt. The aim of this study was to design a group of selection indices including combinations of the mentioned traits in Friesian heifers.

**Materials and methods**

The present study contained total of 670 first lactation parity complete records of Frisian cows sired by 77 bulls, during the period between 1985 and 2014 raised near of Alexandria. Heifers were artificially inseminated using frozen semen. Pregnancy was detected by rectal
palpation 60 days after last insemination. Animals reared under semi-open sheds. The lactating Cows were machine milked twice daily. Animals were fed ad-libitum on clover and rice straw from November to May and on Sorgum and berseem hay from June till October.

**TRAITS**

Traits studied were milk traits represented in total milk yield (TMY, kg), Daily milk yield (DMY, kg) and the persistency (PER %) was determined according to (Lean et al., 1989) as follows: $=\frac{305 \text{ day milk yield (kg)}}{\text{daily peak yield (kg)}} \times 305 \text{ (days)}$, Daily milk yield (DMY), is defined by the International Committee for Animal Recording (ICAR, 2011) as (milk production over 24 hours). Milking twice a day is a common practice in many countries. In that case, DMY is the sum of the yields over 2 milkings. Reproductive traits represent the functionality involves Age at first calving, which is defined as number of months between date of birth and date at first parturition of a cow (AFC, months), and calving to first service which describe the post-partum period Anestrus (CFS, day).

**Derivation of relative economic value:**

Prior to computing the complete index, the relative economic values REV were calculated by using One phenotypic standard deviation according to (Falconer and Mackay 1996). The calculated (REV) depending on the phenotypic standard deviation where, $\text{REV} = 1/\sigma_p$, $\sigma_p$ is the phenotypic standard deviation of the trait.

**DATA ANALYSIS**


$$Y_{ijkl} = \mu + S_i + M_j + Y_k + e_{ijkl} \quad (1)$$

Where: $Y_{ijkl} =$ the individual observations, $\mu =$ the overall means, $S_i =$ the random effect of the sire $i^{th}$, $M_j =$ the fixed effect of the month of calving ($j=1-12$), $Y_k =$ the fixed effect of the year of calving ($k=1-10$), and, $e_{ijkl} =$ the residual effect with $e_{ijkl} \sim N (0, \sigma^2_e)$.

The edited data were set for the estimation of genetic parameters of milk yield and fertility traits for the establishment of selection indices. It contained 670 records from Frisian cows, sired by 77 bulls, the cows calved between 1985 and 2014. Heritability, genetic and phenotypic correlations and Co-variance components of studied traits were estimated using the MTDFREML proposed by (Boldman, et al., 1995) using multiple trait animal model (MTAM), the assumed model was:

$$y = Xb + Zu + e \quad (2)$$

where, $y =$ observations vector of records, $b =$ fixed effects vector (year of calving from 1985 to 2014 and month of calving, from January to December), $a =$ animal direct effect vector, and $e =$ residual effect vector, $X$ and $Z$ are incidence relating records to fixed and animal effects, respectively.
Establishment of many combinations of selection indices, having in focus milk production and fertility, includes traits of primary importance, such as, total milk yield (TMY), daily milk yield (DMY), persistency (PERS), age at first calving (AFC) and calving to first service (CFS). Production results for the observed traits are adjusted to a standard lactation.

Breeding value, estimated by the use of selection index method, and can be presented with the following general equation for the selection index:

\[ I = b_1(y_1 - \bar{y}) + b_2(y_2 - \bar{y}) + \ldots + b_n(y_n - \bar{y}) \]  

Where \( I \) is the value of selection index or relative breeding value evaluated by selection index determined for a certain head of cattle; \( b_i \) is multiple regression coefficients for each trait included in the selection index; \( (y_i - \bar{y}) \) is difference between phenotypic value of trait included in selection index for certain individual

Index weight:
\[ b' = p^{-1} G_a \]  

Where \( b' \) is an index coefficient, \( P \), is the phenotypic co-variance matrix, \( G \) is generic co-variance matrix and \( (a) \) is known relative economic values.

According to Van der Werf and Goddard (2003), direct expected gain \( \Delta G = (i*b' *G )/\sigma_I \), and to Falconer and Mackay (1996), correlated response selection (CRY) for one trait were calculated as:

\[ CRY = i h_x h_y r_{xy} \sigma_{py} \]  

Assuming a selection intensity 1

**Results and discussion**

The descriptive statistics of first lactation economic traits, total milk yield (TMY, kg), daily milk yield (DMY, kg), persistency (PER, %), age at first calving (AFC, month) and calving to first service (CFS, day) of Friesian heifers in Egypt are presented in table (1)

<table>
<thead>
<tr>
<th>Trait</th>
<th>No.</th>
<th>Mean</th>
<th>SD</th>
<th>C,V%</th>
<th>Min</th>
<th>Max</th>
<th>REV(1/(\sigma_p))</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMY</td>
<td>670</td>
<td>4709</td>
<td>1701.4</td>
<td>36.13</td>
<td>564</td>
<td>11310</td>
<td>1</td>
</tr>
<tr>
<td>DMY</td>
<td>670</td>
<td>13.94</td>
<td>3.94</td>
<td>28.3</td>
<td>3.7</td>
<td>28.6</td>
<td>431.83</td>
</tr>
<tr>
<td>PERS</td>
<td>669</td>
<td>64.7</td>
<td>9.96</td>
<td>15.39</td>
<td>28</td>
<td>100</td>
<td>170.82</td>
</tr>
<tr>
<td>AFC</td>
<td>670</td>
<td>30.9</td>
<td>6.3</td>
<td>20.51</td>
<td>21</td>
<td>36</td>
<td>-270.06</td>
</tr>
<tr>
<td>CFS</td>
<td>654</td>
<td>88.82</td>
<td>53.83</td>
<td>60.61</td>
<td>12</td>
<td>394</td>
<td>-31.61</td>
</tr>
</tbody>
</table>

The present overall mean of TMY was 4709 kg, similar results were 4736 kg found by Tawfiq et al., (2000) working on Friesian cows, and higher than the published values on Friesian cattle in Egypt 3530 kg by El-Awady (2009), and 3950 kg by Hammoud et al.(2014) and lower than those published by Shalaby et al., (2013) Being 5387 kg; the overall mean of DMY 13.94 kg and the average milk yield varied from 3.7 to 28.6 kg, the present mean was higher than that reported by Abdel-Gader et al., (2007) and Hammoud et al. (2014) being 12.29 kg and 13 kg respectively.
in Friesian cows; the overall mean of PERS 64.7%, it’s varied from 28 to 100%; many authors estimated persistency by other methods.

The present overall mean of AFC was 30.9 months, Hammoud et al., (2010) and Abdel-Gader et al., (2007) recorded almost similar results 30.7 and 30 months respectively in Friesian cows.

The C.V % ranged from 15.39 % for PER and 60.61% for CFS (Table 1), such large coefficients of variation are indicative leaders for opportunities for improvement in these traits. The difference between the present results and other publications may be related to genetic factors, climatic condition, managerial practices and/or feeding system and differences in statistical models. The economic values of the traits studied were relative to TMY.

All studied traits were significantly influenced (P<0.01) by the sire and year of calving; daily milk yield and calving to 1st service period were significantly affected by month of calving while TMY, PERS. and AFC were not influenced (P>0.05) by month of calving as mentioned in table (2). Having in mind the heritability of observed milk traits in standard lactation and reproductive traits in available literature sources can be considered values that have a wide interval of variation. Table (3) shows estimates of heritability ($h^2$) as well as phenotypic and genetic correlations and variance components among different milk production and reproductive traits, values of the heritability estimates ranged from 0.03 (having in focus the PERS), to 0.38 for the AFC. These estimates are in agreement with most of the previous references. These estimates indicated considerably low to moderate genetic to environmental variance ratio for these traits and reflected differences in the cows' response to the existing environmental conditions.

The heritability estimate for TMY (0.37) was in consonance with (0.35) and (0.22-0.46 which obtained by El-Awady (2009) and Hammoud et al. (2014), respectively in the same breed in Egypt and (0.35) by Al-Smarai (2015) in Holstein breed in Iraq.

Table 2: Analysis of variance for genetic and non-genetic factors affecting on TMY, DMY, PER, AFC and CFS in Friesian cows.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>df</th>
<th>F-Value</th>
<th>TMY</th>
<th>DMY</th>
<th>PER</th>
<th>AFC</th>
<th>CFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sire</td>
<td>76</td>
<td>2.05 **</td>
<td>3.17**</td>
<td>1.67**</td>
<td>1.78 **</td>
<td>1.61 **</td>
<td></td>
</tr>
<tr>
<td>Month of calving</td>
<td>11</td>
<td>1.72 ns</td>
<td>2.68**</td>
<td>1.75 ns</td>
<td>1.21 ns</td>
<td>2.63 **</td>
<td></td>
</tr>
<tr>
<td>Year of calving</td>
<td>9</td>
<td>5.36 **</td>
<td>6.44**</td>
<td>3.75 **</td>
<td>6.32 **</td>
<td>3.39 **</td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>573</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
increased if the index was constructed with three or four of these facts which agree with those found by (El-Arian, 2005).

Comparison between twenty-two selection indices showed the original selection $I_1$ which included TMY, DMY, PER, AFC and CFS, was suggested to be used for improving milk production and keep the fertility at appropriate levels. The original index which included all five traits ranked the 14th (RE=100%), and its accuracy (R= 0.581). The equation original selection index was:

$$I_1 = 0.624 \text{TMY} + 8.834 \text{DMY} + 67.178 \text{PER} - 102.566 \text{AFC} - 4.693 \text{CFS}.$$  (6)

Comparison of selection indices indicates that if index was constructed with three or four traits, when TMY or CFS were omitted from original index resulted in considerable increase in RE values. The most effective indices were $I_2$ which incorporate TMY, DMY, PER and AFC (RE=113.77), the second index in rank $I_{10}$ incorporated DMY, PER and AFC (RE=113.25) and the third index $I_6$ which incorporate DMY, PER, AFC and CFS (RE=112.39), therefore the rank increases to the top, 1st, 2nd and 3rd respectively. Severe decline in RE values occurred in $I_{21}$, which when TMY, DMY and CFS were dropped from original index and therefore, the ranking decreased to be 20th ($R_{11}=0.340$) and (RE=58.52%).

A noticeable decrease in (RE) value occurred when AFC was dropped from the original index, since the ranking were decline to later order this result agree with El-Arian (2005) which found that the drop AFC from original index lead to decrease of its efficiency (RE=58.7 and $R_{11}=0.405$). The breeders are interested in any desirable decrease in AFC and CFS because this will increase directly the income of milk and calves sale, as well as reduce the generation interval and then increase the annual genetic gain. It would be desirable to reduce AFC and CFS in an index incorporating DMY and/or PER with one of the previous reproductive traits at the least yielded comparable improvement in $I_6$, $I_{10}$, $I_{18}$, $I_{19}$.

The expected genetic change in one generation through original index $+468.9$ kg for TMY, $+0.784$ kg for DMY, $+0.58$ % for PER, $-1.07$ month and undesirable gain $+0.54$ day for CFS. It appears that the difference in the expected genetic change for all indices can be accounted for largely by the differences in the genetic correlation between the traits. When criteria were dropped from the index, the genetic gain $\Delta G$ of the remaining criteria changed, for instance when TMY was dropped, the direct and indirect predicted genetic change from positive to negative value and from negative to high negative value. Omitting TMY caused high accuracy in $I_2$ and $I_{10}$ associated with desired gain in the traits, however the index $I_{10}$ seem appropriate and simple with only three candidates DMY, PER and AFC as follows:

$$I_{10} = 231.056 \text{DMY} - 48.156 \text{PER} - 97.284 \text{AFC} \quad (R_{11}=0.653 \text{ and RE}=113.25\%)$$  (7)

$I_{10}$ lead to desired gain milk production and fertility traits, on the other hand selection based on $I_{10}$ would lead to deterioration in persistency the equation of $I_6$ was:

$$I_6 = 0.624 \text{TMY} + 8.834 \text{DMY} + 67.178 \text{PER} - 102.566 \text{AFC} - 4.693 \text{CFS}.$$
Table 4. Selection criteria, weighting factors (b’s), expected genetic change (ΔG), accuracy (R_{bi}) and relative efficiency (RE) in general index I₁ and reduced indices I₂ – I₁₂ to improve TMY, DMY, PER, AFC and CFS in Friesian cows.

<table>
<thead>
<tr>
<th>Index</th>
<th>Rank</th>
<th>TMY kg</th>
<th>DMY kg</th>
<th>PER %</th>
<th>AFC month</th>
<th>CFS day</th>
<th>R_{bi}</th>
<th>RE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁</td>
<td>14</td>
<td>0.624</td>
<td>468.9</td>
<td>8.834</td>
<td>0.784</td>
<td>-</td>
<td>-</td>
<td>67.178</td>
</tr>
<tr>
<td>I₁</td>
<td>1</td>
<td>0.575</td>
<td>477.8</td>
<td>172.632</td>
<td>0.893</td>
<td>-</td>
<td>-</td>
<td>-59.997</td>
</tr>
<tr>
<td>I₁</td>
<td>12</td>
<td>0.441</td>
<td>473.5</td>
<td>227.808</td>
<td>1.050</td>
<td>-</td>
<td>-</td>
<td>-39.027</td>
</tr>
<tr>
<td>I₁</td>
<td>6</td>
<td>0.405</td>
<td>416.1</td>
<td>160.838</td>
<td>0.848</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>I₁</td>
<td>13</td>
<td>0.4877</td>
<td>395.0</td>
<td>-</td>
<td>0.845</td>
<td>-</td>
<td>-</td>
<td>-8.0762</td>
</tr>
<tr>
<td>I₁</td>
<td>8</td>
<td>0.577</td>
<td>523.2</td>
<td>116.48</td>
<td>0.933</td>
<td>-</td>
<td>-</td>
<td>-16.069</td>
</tr>
<tr>
<td>I₁</td>
<td>13</td>
<td>0.36</td>
<td>471.5</td>
<td>155.409</td>
<td>0.974</td>
<td>-</td>
<td>-</td>
<td>-0.88</td>
</tr>
<tr>
<td>I₁</td>
<td>7</td>
<td>0.358</td>
<td>339.5</td>
<td>-</td>
<td>0.845</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>I₁</td>
<td>2</td>
<td>0.376</td>
<td>376.5</td>
<td>231.056</td>
<td>0.753</td>
<td>-</td>
<td>-</td>
<td>-48.156</td>
</tr>
<tr>
<td>I₁</td>
<td>19</td>
<td>-</td>
<td>376.5</td>
<td>231.056</td>
<td>0.753</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>I₁</td>
<td>5</td>
<td>0.537</td>
<td>475.7</td>
<td>97.662</td>
<td>0.804</td>
<td>-</td>
<td>-</td>
<td>-121.67</td>
</tr>
<tr>
<td>I₁</td>
<td>10</td>
<td>0.4948</td>
<td>552.0</td>
<td>92.1892</td>
<td>0.915</td>
<td>-</td>
<td>-</td>
<td>-0.88</td>
</tr>
<tr>
<td>I₁</td>
<td>10</td>
<td>0.46306</td>
<td>526.3</td>
<td>-</td>
<td>0.845</td>
<td>-</td>
<td>-</td>
<td>-4.2074</td>
</tr>
<tr>
<td>I₁</td>
<td>4</td>
<td>0.42</td>
<td>391.3</td>
<td>-</td>
<td>0.845</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>I₁</td>
<td>17</td>
<td>0.30536</td>
<td>493.6</td>
<td>-</td>
<td>0.845</td>
<td>-</td>
<td>-</td>
<td>-0.88</td>
</tr>
<tr>
<td>I₁</td>
<td>16</td>
<td>0.36</td>
<td>476.45</td>
<td>176.817</td>
<td>0.943</td>
<td>-</td>
<td>-</td>
<td>-24.74</td>
</tr>
<tr>
<td>I₁</td>
<td>9</td>
<td>0.36</td>
<td>376.45</td>
<td>132.186</td>
<td>0.540</td>
<td>-</td>
<td>-</td>
<td>-0.45</td>
</tr>
<tr>
<td>I₁</td>
<td>18</td>
<td>0.36</td>
<td>376.45</td>
<td>132.186</td>
<td>0.540</td>
<td>-</td>
<td>-</td>
<td>-0.45</td>
</tr>
<tr>
<td>I₁</td>
<td>11</td>
<td>0.36</td>
<td>476.45</td>
<td>176.817</td>
<td>0.943</td>
<td>-</td>
<td>-</td>
<td>-24.74</td>
</tr>
<tr>
<td>I₁</td>
<td>20</td>
<td>0.36</td>
<td>476.45</td>
<td>176.817</td>
<td>0.943</td>
<td>-</td>
<td>-</td>
<td>-24.74</td>
</tr>
</tbody>
</table>
\[ l_0 = 305.25 \text{DMY} - 69.929 \text{PER} - 99.532 \text{AFC} - 11.677 \text{CFS} \]  
\[ (R = 0.658 \text{ and } RE = 112.39\%) \]

Noticeable in order to minimize CFS duration, adequate index has to ignore those indices containing TMY, \( l_{10} \) and \( l_6 \) when omitting TMY or CFS, the \( \Delta G \) were +376.5 and +376.5 kg for TMY as correlated response, +0.753 and +0.859 kg for DMY, -0.13 and +0.24 % for PER, -1.86 and -1.71 month for AFC and -1.22 and -2.7 days for CFS when using \( l_{10} \) and \( l_6 \) respectively.

The present estimates for AFC are higher than those reported by Atil (2006) working on 2133 normal first lactation of Holstein-Friesian cows constructed four selection indices involving all combinations of two or three traits (TMY, LP and age at first calving, reported that the expected genetic gain per generation for AFC ranged from 0.62 to -1.75. and using another set of that herd by (Atil et al. 2006) reported that \( \Delta G \) ranged from -0.35 to -0.65 month for AFC. (Kaushik and khanna 2003) when including LP, DP and CFS they found that the maximum genetic improvement for CFS was -20.74 days.

The results illustrate the importance of including DMY with either AFC and/or CFS in any selection index to improve the total merit of dairy cows in that herd. It’s recommended to apply selection at the end of first lactation based on these indices.

**CONCLUSION**

The study has demonstrated that selection to reduce age at first calving and calving to first service periods is justified. From the economic point of view, the profitability depends on introducing one or two traits of fertility with traits of milk production, the maximum return can be achieved by applying the indices \( l_{10} \) and \( l_6 \) which include three or four traits, because these indices are simple and easy to construct. The results illustrate the importance of including DMY with either AFC and/or CFS in any selection index to improve the total merit of dairy cows in that herd. It’s recommended to apply selection at the end of first lactation based on these indices.

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الأدلة الإنتخابية لتحسين إنتاجية وتناسل أبقار الفريزيان

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المستخلص

استخدمت الدراسة المقدمة 670 سجل إدار لعجلاث في الموسم الأول ثم تلقيحها بـ 77 طن简约ة خلال الفترة 1985 – 2014 وذلك لتقدير المعايير الوراثية وموظفيه باستخدام MTDFREM ومتها لم تمت مجموعة من الأدلة الانتخابية تتضمن عدة توافق من صفات إنتاج الحليب الكلي (TMY) والانتاج الجلبي اليومي (DMY) والقVAR (PER) والمثابسة (PER) والفترة بين الوضع وأول تلقيح (CFS). وقد أظهرت النتائج أن عامل الأم وسنة الوضع لهما تأثير عالي المعنوي على كل الصفات المدروسة أما شهر الوضع فكان له تأثير عالي المعنوي على صفات إنتاج الحليب الكلي والفترة بين الوضع وأول تلقيح فقط. كما أن تقديرات المكافأ الوراثي كانت 0.37, 0.27, 0.38, 0.03, 0.11 للصفات المدروسة على التوالي. وترامحت قيمة الارتباط الوراثي من 0.91 إلى 0.94 أما في الارتباط المظيري فتراوح من 0.25 إلى 0.64. وعند مقارنة 22 دليل انتخابي بين أنه عند تطبيق الدليل (I1) والدليل (I2) سيعود ذلك بخصوص مردود من حيث القيمة الوراثية الكلية للحيوان. ولذلك توصى هذه الدراسة بتطبيق أحد هذين الدلائل عند إجراء الانتخاب في العجلات في نهاية الموسم الأول.

الكلمات الدالة: أبقار، تناسل، حليب، دليل انتخاب، اقتصاد، تحسين وراثي.