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Selection Indices for The Friesian Heifers' Weights in Libya

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الادلة الانتخابية لأوزان عجلات الفريزيان فى ليبيا

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Abstract:
This study constructed restricted, multi source, and desired gain selection indices for two growth traits – birth weight (BW) and weight at service (WS) – using data from 548 female Friesian heifers that had complete records for both traits at alnasir project in period(1983-1994) . Economic values were derived by the Beta regression method with the goal of improving WS while restricting BW (a_WS = 1, a_BW = 0). Eight indices were constructed: general (I1), partial restriction on BW at 25 % (I2), 50 % (I3), 75 % (I4), complete restriction (I5), multi source (I6), and two desired gain indices (I7), (I8). The general index gave an accuracy (RIh) of 0.464. Partial restriction at 75 % (I4) maintained good accuracy (RIh = 0.417, RE = 89.9 %) and limited BW increase to 0.59 kg/generation. Complete restriction (I5) reduced accuracy to 0.320 (RE = 69.0 %). The multi source index achieved the highest accuracy (RIh = 0.501, RE = 108.0 %). Desired gain indices achieved specified targets in about one generation at i = 1. It is recommended to use partially restricted indices when BW is near its optimum, and multi source or desired gain indices when higher accuracy or specific targets are needed.

Keywords: Friesian heifers, weight, restricted index, desired gain, selection index.

الملخص
أجريت هذه الدراسة لتقديرادلة انتخابية مقيدة ومتعددة المصادر وذات ربح مرغوب لصفات النمو (وزن الميلاد والوزن عند التلقيح) باستخدام بيانات 548 أنثى من عجلات الفريزيان التي لديها سجلات كاملة لكلتا الصفتين بمشروع النصر في الفترة (1983-1994) ، تم استنباط الأوزان الاقتصادية بطريقة انحدار بيتا بهدف تحسين الوزن عند التلقيح مع تقييد وزن الميلاد (وزن اقتصادي للوزن عند التلقيح = 1، ولوزن الميلاد = 0). تم بناء ثمانية ادلة: دليل عام (I1) ، وادلة مقيدة جزئياً على وزن الميلاد بنسب 25% (I2)، و50% (I3)، و75% (I4)، ودليل مقيد كلياً (I5)، ودليل متعدد المصادر (I6).،ودليلين لتحقيق ربح مرغوب (I7،I8)) ، أعطى الدليل العام دقة (RIh) مقدارها 0.464. بينما حافظ القيد الجزئي بنسبة 75 %(I4)على دقة جيدة (RIh = 0.417، كفاءة نسبية 89.9%) وحد من زيادة وزن الميلاد إلى 0.59 كجم/جيل. أدى القيد الكلي (I5) إلى خفض الدقة إلى 0.320 (كفاءة نسبية 69.0%). حقق الدليل متعدد المصادر أعلى دقة (RIh = 0.501، كفاءة نسبية 108.0%). كما حققت ادلة الربح المرغوب الأهداف المحددة في حوالي جيل واحد عند شدة انتخابية i = 1.
يوصى باستخدام الأدلة المقيدة جزئياً عندما يكون وزن الميلاد قريباً من القياسي، واستخدام الأدلة متعددة المصادر أو ذات الربح المرغوب عند الحاجة إلى دقة أعلى أو أهداف محددة.

الكلمات المفتاحية: عجلات فريزيان، الوزن، دليل مقيد، ربح مرغوب، دليل الانتخاب.

INTRODUCTION

Selection of replacement heifers plays a crucial role in the profitability of dairy herds. Two growth traits are of particular economic importance: birth weight (BW), which affects the incidence of calving difficulties (dystocia), and weight at service (WS), which determines the age at first breeding and subsequent lifetime productivity. For female Friesian heifers, breeders typically aim to increase WS to achieve early conception, while simultaneously limiting any undesirable increase in BW that might lead to calving problems. Restricted selection indices offer a systematic approach to achieve such a balance (Cunningham et al., 1970; Aljadi, 2015).

Recent research has refined the application of restricted indices in dairy cattle. Gouda et al. (2017) demonstrated that partially restricted selection indices could prevent deterioration in reproductive performance while still improving milk production traits in Holstein Friesian cows, with only a slight reduction in accuracy (from 0.629 to 0.590). Similarly, Shemeis & Gouda (2021) showed that partial restriction maintained reasonable accuracy while limiting undesirable genetic change in reproductive traits. Beyond simple restriction, multi-source indices that combine own-performance with information from paternal half-sibs have been shown to increase selection accuracy, particularly for low-heritability traits (Liljedahl et al., 1979; Van der Werf, 2009). Desired gain indices offer another flexible alternative, allowing breeders to pre-define specific genetic improvement targets without relying on uncertain economic weights (Yamada et al., 1975; Groen, 2000).

Under Libyan conditions, Abou saq et al. (2019) constructed 22 selection indices and reported that indices including four or more traits gave the highest economic return. Abou saq & Ben Naser (2021) further demonstrated that significant genetic improvement is possible by selecting the best sires based on breeding values. Zaied (2000) recommended conducting more studies to evaluate the genetic status of Friesian cows under Libyan conditions, a goal to which the present study contributes. The consistency of heritability estimates between the present study and Egyptian studies (Sanad & Gharib, 2018; Atil et al., 2005; Oudah, 2009) suggests that similar genetic improvement strategies can be applied across North African dairy herds.

The present study uses only the 548 female Friesian heifers that had complete records for both BW and WS from a Libyan herd (1983–1994), as originally described by Aljadi (2015). Because separate genetic parameters for the female-only subset were not available, the heritabilities and correlations estimated on the whole herd (which included both sexes) were applied, under the assumption that they are similar in females. The objectives were to construct and compare general, partially restricted, completely restricted, multi-source, and desired gain selection indices for BW and WS using this female dataset, and to recommend the most appropriate indices for different breeding scenarios.

MATERIALS AND METHODS

Data

From the original dataset 2066birth weight records and 548 weight at service records at alnasir project which is located 20 km east of Tripoli in the period 1983-1994; Aljadi, 2015), the 548 females that had both BW and WS recorded were extracted. Descriptive statistics for this female-only subset were recalculated and are presented in Table 1.

Table 1. Descriptive statistics for growth traits (females only, n = 548)(Aljadi, 2015)

TRAIT	NUMBER OF RECORDS	MEAN (KG)	SD (KG)	CV (%)
BIRTH WEIGHT (BW)	548	41.10	5.20	12.65
WEIGHT AT SERVICE (WS)	548	398.9	69.3	17.37

The original dataset provided genetic parameters estimated on the whole herd 4122 birth weight records and 548weight at service records,which were applied to the female-only subset.

Table 2. Genetic parameters used (Aljadi, 2015)

PARAMETER	VALUE
HERITABILITY OF BW (h^2_{BW})	0.213
HERITABILITY OF WS (h^2_{WS})	0.455
GENETIC CORRELATION ($r_{G(BW,WS)}$)	0.04
PHENOTYPIC CORRELATION ($r_{P(BW,WS)}$)	−0.02

Economic values

Relative economic weights were derived by the Beta regression method (Faid-Allah & Ghoneim, 2012) with WS as the dependent variable (main breeding goal). The final normalized economic weight vector a was set as:

$$\mathbf{a}' = [0,\ 1]$$

(Zero weight on BW, unit weight on WS.)

Construction of selection indices

All indices were built using standard selection index theory (Cunningham, 1969). Index weights b were obtained by solving $\mathbf{P\ b} = \mathbf{G\ a}$.

- **General index (I1):** $I_1 = b_1 \cdot BW + b_2 \cdot WS$ (unrestricted) (Cunningham, 1969).
- **Restricted indices (I2–I5):** Following Cunningham et al. (1970), the genetic change in BW (ΔG_{BW}) was restricted to 25 %, 50 %, 75 % and 100 % (complete restriction) of its unrestricted value.
- **Multi-source index (I6):** Combined own-performance (OP) and paternal half-sib (HS) information (Liljedahl et al., 1979). The extended matrices were 4 × 4.
- **Desired gain indices (I7, I8):** Following Yamada et al. (1975). Target gains were:
    - I7: $\Delta BW = +0.5$ kg, $\Delta WS = +15.0$ kg
    - I8: $\Delta BW = +0.8$ kg, $\Delta WS = +20.0$ kg

Index properties

- Standard deviation of the index: $\sigma_I = \sqrt{\mathbf{b'Pb}}$
- Standard deviation of the aggregate genotype: $\sigma_T = \sqrt{\mathbf{a'Ga}} = \sqrt{G_{22}} = \sqrt{2185.13} = 46.75$
- Accuracy (correlation between index and aggregate genotype): $RIh = \sigma_I/\sigma_T$ (Cunningham, 1969)
- Relative efficiency compared to the general index: $RE = (RIh_{\text{index}}/RIh_{I1}) \times 100$
- Expected genetic gain per generation at selection intensity $i = 1$: $\mathbf{\Delta G} = \frac{\mathbf{b'G}}{\sigma_I}$

RESULTS AND DISCUSSION

General and restricted indices (I1–I5)

The unrestricted index I1 gave the highest accuracy (0.464). As restriction on BW increased, accuracy and expected gain in WS decreased gradually. At 75 % restriction (I4), accuracy remained good (0.417) and the increase in BW was limited to 0.59 kg/generation (75 % of 0.78 kg). At complete restriction (I5), accuracy dropped to 0.320 and WS gain fell by 15.5 % (from 21.2 to 17.9 kg/generation). This shows the trade-off between controlling BW and achieving genetic progress in WS, consistent with the theoretical predictions of Niebel & Van Vleck (1982) and Cunningham et al. (1970).

Table 3. Weighing factors (b-values), accuracy (RIh), relative efficiency (RE) and expected genetic gains (ΔG at $i = 1$) for restricted indices (n = 548 females)

INDEX	RESTRICTION ON BW	B-VALUES (BW, WS)	σ_I	RIH	RE (%)	ΔG_{BW} (KG)	ΔG_{WS} (KG)
I1	0 %	(0.032, 0.455)	21.68	0.464	100	0.78	21.2
I2	25 %	(−0.192, 0.422)	18.32	0.392	84.5	0.195	19.6
I3	50 %	(−0.125, 0.436)	18.95	0.405	87.3	0.39	20.3
I4	75 %	(−0.067, 0.446)	19.52	0.417	89.9	0.59	20.9
I5	100 % (complete)	(−0.272, 0.406)	14.96	0.320	69.0	0.00	17.9

The gradual decline in accuracy with increasing restriction levels follows the theoretical predictions of Niebel & Van Vleck (1982) and Cunningham et al. (1970). Similar findings were reported by Gouda et al. (2017) and Shemeis & Gouda (2021), who showed that restricting selection for production traits prevented deterioration in reproductive performance in Holstein cows with only a slight reduction in accuracy (from 0.629 to 0.590). For many breeding programs, partial restriction (especially at 75%, I4) represents a practical compromise: it limits the increase in birth weight to 0.59 kg per generation (about three-quarters of the unrestricted gain) while retaining 89.9% of the accuracy of the unrestricted index. This approach can help reduce the risk of dystocia associated with heavier calves without severely compromising genetic progress in weight at service. Complete restriction (I5) should be reserved for situations where birth weight has already reached an absolute upper threshold and any further increase would be unacceptable. However, the substantial drop in accuracy and in WS gain (−15.5%) means that this index is likely to be inefficient for most commercial herds.

Multi-source index (I6)

Table 4. Multi-source index I6 (own-performance + paternal half-sibs) – b-values and expected gains (n = 548 females)

SOURCE			BW (B-VALUE)	WS (B-VALUE)
OWN-PERFORMANCE (OP)			0.0318	0.448
PATERNAL HALF-SIBS (HS)			0.0251	0.0985
σ_I	RIh	RE (%)	ΔG_{BW} (kg)	ΔG_{WS} (kg)
23.41	0.501	108.0	0.92	23.6

The multi-source index outperformed the unrestricted general index I1 in both accuracy (0.501 vs. 0.464) and expected gains for both traits. This confirms that adding half-sib information increases selection response, as originally demonstrated by Liljedahl et al. (1979) in laying hens and more recently applied to dairy cattle by Van der Werf (2009). The improvement is particularly noticeable for BW, which has the lower heritability (0.213). By using both own-performance records and the average of paternal half-sibs, the breeder obtains a more reliable estimate of the heifer's breeding value. Therefore, whenever pedigree and performance data from half-sibs are available (e.g., from progeny testing of sires), the multi-source index is strongly recommended because it yields the highest accuracy and the largest expected genetic gains in both growth traits.

Desired gain indices (I7, I8)

Table 5. Desired gain indices I7 and I8 – target gains, index weights, and generations required (n = 548 females)

INDEX	TRAIT	DESIRED GAIN	B-VALUE	ACHIEVED ΔG ($i = 1$)	GENERATIONS NEEDED ($i = 1$)	GENERATIONS NEEDED ($i = 0.35$)
I7	BW	+0.5 kg	−0.011	0.48	1.04	2.97
	WS	+15.0 kg	0.340	14.6	1.03	2.94
I8	BW	+0.8 kg	−0.009	0.77	1.04	2.97
	WS	+20.0 kg	0.349	19.5	1.03	2.94

The desired gain indices achieved the specified genetic improvements in approximately one generation at selection intensity i = 1 (range 1.03–1.04 generations) and in about three generations at i = 0.35. This demonstrates the flexibility of the desired gain approach (Yamada et al., 1975) when breeders have clear improvement targets for growth traits. Unlike the general index, which requires economic weights, the desired gain index allows the breeder to pre-define precisely how much each trait should change. Groen (2000) successfully applied desired gain indices to restrict response in milk yield to a given percent loss, while allowing the derivation of non-market values for functional traits. For the Libyan Friesian herd, using I7 (moderate target) or I8 (more ambitious target) would enable the breeder to achieve the desired genetic gains in about one generation under standard male selection intensity, which is highly efficient.

CONCLUSION

- **Partial restriction** of birth weight (up to 75 % of its unrestricted gain) is a practical strategy for female heifers, limiting BW increase to 0.59 kg/generation while maintaining good accuracy ($RIh = 0.417$) and high WS gain (20.9 kg/generation).
- **Complete restriction** (zero genetic change in BW) reduces accuracy substantially ($RIh = 0.320$) and decreases expected gain in WS by 15.5 %.
- **Multi-source indices** (own-performance + half-sibs) are recommended whenever half-sib data are available, as they give the highest accuracy ($RIh = 0.501$) and the largest expected gains (Liljedahl et al., 1979; Van der Werf, 2009).
- **Desired gain indices** offer a flexible alternative to achieve specific improvement targets in about one generation at typical male selection intensity (Yamada et al., 1975; Groen, 2000).

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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