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## Studying The possibility of Improving Post-weaning Body Weight Traits of New Zealand White Rabbits Using Different Selection Indices

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**Abstract**

THE article aims to improve post-weaning body weight traits of New Zealand white rabbits (NZW). A total of 1,904 progenies dataset of rabbits belonging to a research rabbit farm of the Department of Animal Production, Faculty of Agriculture, Al-Azhar University, for three generations from 2019 to 2022 was used to estimate genetic parameters of body weights and to establish different selection indices with desired gains. Body weights (BW) in grams were measured at 4 (BW4), 6 (BW6), 8 (BW8), 10 (BW10) and 12 (BW12) weeks of age (referred to in the selection indices with X1, X2, X3, X4 and X5, respectively). To analyze the data, a multi-trait animal model was applied. Heritability estimates ranged from 0.12 for BW4 to 0.23 for BW12. The expected genetic gain per generation (ΔG) ranged from 5 to 50.4 g for BW4, 8.1 to 70.4 g for BW6, 13.8 to 98 g for BW8, 22.1 to 78.1 g for BW10 and from -9.47 to 130 g for BW12. To maximize the genetic response to selection, four indices were suggested based on their relative efficiency (RIH): I13: -8.31 X1 +5.14 X2+1.22 X5 (RIH = 0.64), I6: -1.47X2 +1.30 X4 (RIH = 0.59), I17: -1.894 X2 +3.976 X3-1.343 X5 (RIH = 0.58) and I10: 0.62X2 +0.078 X5 (RIH = 0.57). Regarding characteristics related to body weight in NZW rabbits it is possible to utilize selected programs aimed at genetic enhancement. However, it is important to gather additional data sources and expand to enhance indices accuracy.

**Keywords:** Body weight, genetic gain, Rabbits, Selection indices.

## Introduction

Under Egyptian conditions, the expected economic indicators for red meat until 2025 indicate an expected increase in consumption, the number of imports and the food gap, accompanied by a decrease in average per capita and an expected decrease in the self-sufficiency rate from 62% in 2020 to 57.5% in 2025 [1]. To face this shortage, attention to animal genetic resources as the basic biological capital for the development of livestock is necessary to achieve food security in the long term, which requires optimal utilization of livestock in all its forms and alternatives and the rapid adoption of a more effective process of genetic improvement to meet the large increase in demand for animal products [2].

In this regard, rabbit breeds represent an important solution in addressing the lack of meat production in developing countries [3], especially the NZW rabbit breed, which has shown wide adaptation despite the varying conditions of the Egyptian environment or different conditions of care [4,5].

One of rabbit meat production's most crucial economic traits is body weight. Understanding these traits can be a key step in creating suitable genetic selection strategies for rabbits and increasing productivity [6]. To obtain this goal, the selection index is the most efficient tool for the exploitation of available information sources for the effective genetic improvement of several traits simultaneously [7].

The main goals of this research were to: (1) evaluate the genetic and phenotypic factors that affect the body weight performance of NZW rabbits and (2) develop a set of selection indices that can be used to improve body weight traits in NZW rabbits.

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## Material and Methods

*Source of data*

In the present investigation, a total of 1,904 progenies dataset of NZW rabbits, fathered by 75 sires and mothered by 209 dams, were maintained at a rabbit research farm for rabbits belonging to the Animal Production Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt, from November 2019 until October 2022.

*Management and traits considered*

Breeding dams and sires were kept apart in hierarchical rabbit batteries with a suitable conventional dimension, arranged in two rows along the farm with a suitable service entrance. The animals were maintained under uniform housing, feeding, medical and other management practices. Three dams were randomly allocated to each sire according to a breeding plan, with the restriction that all forms of inbreeding be avoided. Weaned young rabbits were transferred to conventional progeny wire cages with feeding hoppers and drinking nipples at the age of 4 weeks. They are also ear-tagged, sexed and relocated to groups of 3-4 rabbits per cage. After that, weighing is done every two weeks.

*Traits studied*

The body weights in grams at 4 (BW4), 6 (BW6), 8 (BW8), 10 (BW10) and 12 (BW12) weeks of age were recorded for each rabbit (referred to in the selection indices with $X_1$, $X_2$, $X_3$, $X_4$ and $X_5$, respectively).

*Data analysis*

*Genetic parameters*

The data was analyzed using a multi-trait animal model of body weights using the MTDFREML programs of Boldman et al. [8]. Variances computed using the REML approach of the VARCOMP procedure of SAS [9]. were used as starting values for estimating variance components. The general model was used to conduct the analyses:

**y = Xb + Za +Wpe+ e**

where: y is the vector of phenotypic observations; b is the vector of fixed effects including sex (2 levels); year (3 levels); season (4 levels), parity (5 levels) a is the vector of random additive genetic effects of the progeny; pe is the vector of random permanent environmental effects of the dam; e is the vector of residual effects and X, Z and W incidence matrices that, respectively, link phenotypic observations to fixed and random additive genetic effects.

*Selection Indices(I)*

Estimates of genetic and phenotypic (co) variances and the relative economic weight (REV) of the studied body weight traits in different combinations were used to construct twenty-two selection indices according to Hazel et al. [10].

REV was calculated as 1/σp, where σp is the phenotypic standard deviation of each trait [11]. Set the REV of the lowest age as a reference unit for other traits, since under Egyptian conditions, selling at the lowest age as breeding animals has the same profitability as selling at W12 as marketing meat, with a decrease in time and effort in favor of selling at the lowest age.

The correlation between the calculated index and the total aggregate genotype (RIH) was estimated as RIH=σi/σh. where σi is the index standard deviation and σh is the genotype standard deviation. To compare indices and decide which traits combine best into an index, relative efficiency (RE) was calculated for each index based on $R_{IH}$ compared to the best index with a high $R_{IH}$.

The expected genetic gain, gm (ΔG) for each trait after one generation of selection on the index was computed according to Hazel et al. [10]. All arithmetic operations performed on matrices were based on the Minitab 17.0 software package (State College, Pennsylv ania).

The indices consisted of the full index ($I_{22}$), which included all sources of information for the five traits, and the reduced indices, which included all possible combinations, from two to four traits (from $I_1$ to $I_{21}$).

## Results and Discussion

*Means*

Table 1 summarizes the overall means, standard deviation (SD) and coefficient of variation (CV) for BW traits. The means for BW of NZW rabbits ranged from 804.1 g at 4 weeks of age to 1564.8 g at 12 weeks of age; these means were within the range found by [12-16]. The values of CV for BW at different ages decreased with the advancement of age (Table 1). Comparable results were obtained by [14-17]. This pattern might indicate that the kits become less sensitive to non-genetic maternal effects as they age (in terms of lactation, mothering ability, litter size and weight) which decreases with age [18].

*Genetic parameter estimates*

Table 2. summarizes the estimates of heritability (h2a), phenotypic (rp) and genetic (rg) correlations for the body weight traits.

*Heritability (h2a)*

Estimates of h2a for BW in Table 2 ranged from 0.12 at BW4 of age to 0.23 at BW12 of age. Currently, available estimates of moderate h2a for BW were comparable to those found by [15-17,19]. While the estimates of h2a for BW traits were lower than those obtained by Farouk et al. [15], they were 0.23, 0.24, 0.31 and 0.34 for BW4, BW6, BW8 and

BW10, respectively. The moderate estimates of h2a for body weight traits of NZW rabbits (Table 2) showed that selection might improve BW in a short amount of time and these features could be employed as selection criteria. According to the current study, h2a estimates for the studied traits increased with age. Like those obtained by Farouk et al. [15], a study based on 625 NZW rabbits in Egypt found that h2a estimates for BW at 4, 6, 8 and 10 weeks of age were 0.23, 0.24, 0.31 and 0.34, respectively. Furthermore, Anous [20], indicated that selection for BW at younger ages may be useful for improving early rabbit body weight. Youssef et al. [12] observed increasing h2a with advancing age in BR and NZW rabbits. Furthermore, advances in age may be accompanied by a decline in non-additive genetic effects, such as common litter effects.

*Phenotypic ($r_p$) and genetic ($r_g$) correlations*

All estimates of phenotypic correlation ($r_p$) for body weight traits were high and significantly positive and ranged from 0.748 to 0.969 (Table 2). The current findings suggest that a large BW at any body weight would result in a large BW at the final marketing weight (BW12). In the same trend, current estimates concur with those found by [7, 15,16,21], which varied from 0.02 to 0.90. Given that $r_p$ includes the value of both genetic and environmental correlation, this could be the cause of the disparity between the two, since $r_p$ magnitude was higher than $r_g$. This also suggests that the environmental conditions to which the herd is exposed positively impact showing optimal productivity, particularly for traits with a negative $r_g$ (BW12 in combination with other traits).

From a genetic standpoint, strong positive correlations ($r_g$) and high (ranging from 0.692 to 0.963) between sequential body weight stages from BW4 to BW12 weeks of age were detected in the current study (Table 2). These results might be explained by the selection for higher BW at weaning (BW4) would be an associated with increase in marketing body weight. The magnitude of $r_g$ between pairs of BW4, BW6, BW8, BW10 and BW12 traits generally reported a wide variation ranging from medium positive to high for the NZW breed [16, 21-24].

*Construction of selection indices*

Table 3 lists the selection index weighting factors (b), index accuracy (RIH) and efficiency (RE%) of various indices in comparison to the reference index ($I_{13}$) and the estimated genetic gain (G) for each trait.

In terms of RIH, the triple index ($I_{13}$: RIH = 0.64) with BW4, BW6 and BW12 included produced the best results, followed by the binary index ($I_6$: RIH = 0.59) with both BW6 and BW10. They were followed in the descending order of preference by a binary ($I_{17}$: RIH = 0.58) and a triple ($I_7$: RIH = 57) index, the similarity of both being that they had both BW6 and BW12. From another point of view, indices not including BW4 and BW6 ($I_{12}$, $I_{18}$, $I_{11}$ and $I_{12}$) showed reduced accuracy of 0.19, 0.27, 0.30 and 0.37, respectively (Table 3). While including BW4 and/or BW6 caused a rise in the accuracy of the index (accuracy ranged from 0.57–0.64), this seems to be due to the higher $r_g$ between them (rg = 0.818, Table 2). In this regard, it would therefore be preferable to include BW4 and BW6 in an index that incorporates body weight traits in NZW rabbits.

Consistent with the current results, Khalil et al. [23], El-Fiky et al. [25] and El-Deghadi and Ibrahim [18] reported that selection indices at the early age stage after weaning are promising compared to the late stages. In contrast, Moustafa et al. [26] found that selection based on marketing body weight is preferable to that based on BW4 and daily gain for improving body weight performance.

The expected genetic change per generation ($\Delta G$) ranged from 5 to 50.4 g for BW4, from 8.1 to 70.4 g for BW6, from 13.8 to 98 g for BW8, from 22.1 to 78.1 g for BW10 and from -9.47 to 130 kg for BW12. In this respect, Anous [20] found comparable results using an index that included BW4 and BW6 of age, with $\Delta G$ of 57.5 and 1.3 g, respectively.

From an applied point of view, among the top four indices, $\mathbf{I_{13}}$ combining both BW4 and BW6 can be proposed for NWZ rabbit commercial farms to improve body weight traits at an early age. Whereas, to improve the final marketing weight, it is recommended to use $\mathbf{I_7}$.

## Conclusion

Considering the findings of the current study, it is possible to use the four selection indices that have been identified as the best ones, which are: $I_{13}$, $I_6$, $I_{17}$ and $I_7$. These indices can be used as an effective tool for breeders to achieve rapid genetic improvement of body weight traits to reach the highest possible economic return for such traits. There is a need for more data sources and to broaden the scope of research in both genetic and non-genetic components to increase the accuracy of the indices.

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*Ethical Considerations*

The present study has been conducted by the guidelines of the Ethics Committee of the International Animal Care and use Committee (ARC-IACUC) Agricultural Research Center Approval number ARC ABRI 67- 2024.

*Conflicts of interest*

The authors declare that there is no conflict of interest.

*Funding statement*

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*Author`s contributions*

All Authors collaborate equally.

**TABLE 1. Actual means, standard deviations (SD) and coefficients of variation (CV%) for body weight traits in NZW rabbits.**

| Body weight(g) | Number | Mean | SD | CV (%) |
|---|---|---|---|---|
| BW4 | 1904 | 408.10 | 92.26 | 22.60 |
| BW6 | 1737 | 670.77 | 107.43 | 16.01 |
| BW8 | 1627 | 962.80 | 128.51 | 13.34 |
| BW10 | 1571 | 1260.44 | 133.73 | 10.61 |
| BW12 | 1564 | 1554.80 | 145.73 | 9.37 |

BW4, BW6, BW8, BW10 and BW12= body weights at 4, 6, 8, 10 and 12 weeks of age.

**TABLE 2. Estimates of heritability ± standard error (SE) (bold on diagonal), genetic ±SE (below diagonal) and phenotypic correlations (above diagonal) among post-weaning growth traits in NZW rabbits.**

| | BW4 | BW6 | BW8 | BW10 | BW12 |
|---|---|---|---|---|---|
| BW4 | 0.12±0.02 | 0.868 | 0.798 | 0.804 | 0.748 |
| BW6 | 0.818±0.07 | 0.14±0.05 | 0.879 | 0.863 | 0.808 |
| BW8 | 0.731±0.06 | 0.799±0.05 | 0.18±0.06 | 0.935 | 0.893 |
| BW10 | 0.727±0.05 | 0.768±0.06 | 0.884±0.04 | 0.21±0.03 | 0.969 |
| BW12 | 0.692±0.06 | 0.712±0.07 | 0.828±0.06 | 0.963±0.03 | 0.23±0.06 |

BW4, BW6, BW8, BW10 and BW12= body weights at 4, 6, 8, 10 and12 weeks

**TABLE 3. Weighing factors (*b values*), the efficiency of the index (RIH), the relative efficiency (RE) of different indices and the expected genetic gain per generation (ΔG) for body weight traits in NZW rabbits.**

| Index no. | *b* values | $R_{IH}$ | $R_E$% | Expected genetic gain, gm (ΔG) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | BW4 | BW6 | BW8 | BW10 | BW12 |
| | Binary indices | | | | | | | |
| $I_1$ | $0.126\ X_1 + 0.139\ X_2$ | 0.38 | 59.2 | 5 | 8.1 | - | - | - |
| $I_2$ | $1.047\ X_1 - 0.514\ X_3$ | 0.19 | 30.3 | 18 | - | 13.8 | - | - |
| $I_3$ | $0.013\ X_1 + 0.282\ X_4$ | 0.49 | 76.1 | 30 | - | - | 53.8 | - |
| $I_4$ | $0.488\ X_1 + 0.006\ X_5$ | 0.42 | 65.2 | 43.5 | - | - | - | 84.2 |
| $I_5$ | $0.112\ X_2 + 0.121\ X_3$ | 0.36 | 57.1 | - | 16.3 | 40 | - | - |
| $I_6$ | $-1.47\ X_2 +1.300\ X_4$ | 0.59 | 91.6 | - | 37.6 | - | 70.2 | - |
| $I_7$ | $0.620\ X_2 + 0.078\ X_5$ | 0.57 | 88.5 | - | 34 | - | - | 130 |
| $I_8$ | $2.26\ X_3 - 1.570\ X_4$ | 0.27 | 41.9 | - | - | 98 | 48 | - |
| $I_9$ | $0.11\ X_3 - 0.22\ X_5$ | 0.46 | 70.8 | - | - | 19.7 | 63.7 | - |
| $I_{10}$ | $1.69\ X_4 -1.08\ X_5$ | 0.38 | 59.8 | - | - | - | 46.7 | 70.8 |
| | Triple indices | | | | | | | |
| $I_{11}$ | $-0.019\ X_1 +1.49\ X_2 -0.880\ X_3$ | 0.30 | 46.6 | 8 | 19.4 | 39 | - | - |
| $I_{12}$ | $1.35\ X_1 - 0.892\ X_2 +0.135\ X_4$ | 0.37 | 57.5 | 16 | 24.2 | - | 63.3 | - |
| $I_{13}^*$ | $-8.31\ X_1 + 5.14\ X_2 +1.22\ X_5$ | 0.64 | 100.0 | 83 | 70.4 | - | - | -9.47 |
| $I_{14}$ | $-0.639\ X_1 +0.598\ X_3 +0.234\ X_5$ | 0.45 | 69.9 | 50.4 | - | 69.4 | - | 116.5 |
| $I_{15}$ | $0.761\ X_1 - 0.0.544\ X_4 +0.463\ X_5$ | 0.46 | 71.4 | 13.5 | - | - | 22.1 | 32.9 |
| $I_{16}$ | $1.75\ X_2 - 0.952\ X_3 -0.0224\ X_4$ | 0.37 | 58.7 | - | 16.8 | 31.4 | 56.9 | - |
| $I_{17}$ | $-1.894\ X_2 +3.976\ X_3 -1.343\ X_5$ | 0.58 | 90.2 | - | 53.1 | 17 | - | 114.2 |
| $I_{18}$ | $-0.530 X_3 +3.321\ X_4 -1.900\ X_5$ | 0.43 | 66.8 | - | - | 21.1 | 78.1 | 125 |
| | Quad indices | | | | | | | |
| $I_{19}$ | $-0.262\ X_1 +1.30\ X_2 -0.277\ X_3 -0.0901\ X_4$ | 0.36 | 56.4 | 15.1 | 21.9 | 32.9 | 52.4 | - |
| $I_{20}$ | $1.198\ X_1 - 0.164\ X_2 -0.0695\ X_3 -0.017\ X_5$ | 0.40 | 62.6 | 14 | 16.8 | 21.5 | - | 40.3 |
| $I_{21}$ | $1.76\ X_2 + 3.16\ X_3 - 6.82\ X_4 +2.95\ X_5$ | 0.38 | 59.0 | - | 23.3 | 25.3 | 35.5 | 45.7 |
| | Full index | | | | | | | |
| $I_{22}$ | $1.584 X_1 +0.0735\ X_2 - 0.749\ X_3 - 0.232\ X_4 +0.435 X_5$ | 0.18 | 29.3 | 19.5 | 24.6 | 36.1 | 54.8 | 83.5 |

$X_1$=BW4; $X_2$=BW6; $X_3$=BW8; $X_4$=BW10 and $X_5$ = BW12; Reference index for calculating relative efficiency (RE)

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## دراسة إمكانية تحسين صفات وزن الجسم بعد الفطام في الأرانب النيوزلندي الابيض باستخدام ادلة انتخابية مختلفة

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[3]قسم الانتاج الحيواني- معهد البحوث الزراعية والبيولوجية - المركز القومى للبحوث - الجيزة – مصر.

**الملخص**

يهدف البحث إلى تحسين صفات وزن الجسم بعد الفطام للأرانب من سلالة النيوزلندي الابيض. تم استخدام إجمالي بيانات وزنية 1904 مجموعة من السجلات الانتاجية لمزرعة الارانب البحثية التابعة لقسم الإنتاج الحيواني بكلية الزراعة جامعة الأزهر بالقاهرة، في الفترة من 2019 إلى 2022 لتقدير المقاييس الوراثية لأوزان الجسم وإنشاء مجموعة مختلفة من الأدلة الإنتخابية لتقدير العوائد الوراثية المتوقعة لكل دليل. تم قياس أوزان الجسم بالجرام عند 4، 6، 8، 10 و 12 أسبوع من العمر ولتحليل البيانات، تم تطبيق النموذج الحيواني متعدد الصفات بطريقة معظمة الاحتمال غير المقيدة وغير المعتمدة على حساب المشتقات التفاضلية وقد أشتمل النموذج الإحصائي على تأثيرسنة و موسم الولادة وترتيب البطن وجنس الارنب كعوامل ثابتة كما شمل تأثير الحيوان والتأثير البيئي الدائم كعوامل عشوائية. وتم تكوين أدلة الانتخاب لوزن الجسم عند 4، 6، 8، 10 و 12 أسبوع. وتراوح وزن الجسم بين 408.1 جم لوزن الجسم عند 4 أسبوع الى 1554.8جم لوزن الجسم عند 12 أسبوع .تراوحت قيم المكافئ الوراثي من 0.12 لـوزن الجسم عند 4 أسابيع إلى 0.23 لـ وزن الجسم عند الأسبوع 12. تراوح العائد الوراثي المتوقع لكل جيل ($\Delta G$) من 5 إلى 50.4 جم لـوزن الجسم عند 4 اسابيع، ومن 8.1 إلى 70.4 جم لـوزن الجسم عند 6 اسابيع، ومن 13.8 إلى 98 جم لوزن الجسم عند 8 اسابيع، ومن 22.1 إلى 78.1 جم لـوزن الجسم عند 10 اسابيع، ومن - 9.47 إلى 130 كجم لـوزن الجسم عند 12 أسبوع، لتعظيم الاستجابة الوراثية للانتخاب، تم اختيار أربعة ادلة انتخابية بناءً على كفاءتها النسبية (RIH) وهى $I_{13}$ ، و$I_6$، و $I_{17}$، و $I_{10}$ وتراوحت كفاءتهم النسبية بين 64% وحتى 0.57 %. ولذا و فيما يتعلق بصفات وزن الجسم بعد الفطام للأرانب من سلالة النيوزلندي الابيض، يمكن استخدام الانتخاب كأداة للتحسين الوراثي مع الأخذ في الاعتبار الحاجة إلى المزيد من مصادر البيانات وتوسيع نطاقها لزيادة دقة الأدلة الانتخابية.

**كلمات مفتاحية:** وزن الجسم، العائد الوراثى، الأرانب، الأدلة الإنتخابية.