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Consequences of Selection for Post-weaning Growth Performance Traits on Fat Partition Traits in Rabbits

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ABSTRACT

Genetic and phenotypic parameters, using multi-trait animal model, for weaning weight (WW), slaughter weight (SW) and daily gain (DG) from weaning to slaughter were applied on 218 New Zealand White rabbits to improve postweaning growth traits using selection indices. The specific objective was to improve profitability of rabbit producers through increasing body weight at slaughter and daily gain from weaning to slaughter. Expected impacts of selection for post-weaning growth traits on fat partition traits were also investigated. The fat partition traits included weights of subcutaneous fat (SF) and intermuscular fat (IF) as carcass components and heart fat (HF), kidneys fat (KF), mesenteric fat (MF) and caul fat (CF) as offal components. Growth traits showed low to moderate heritability estimates (h²,0.03 to 0.37), while fat partition traits had higher h^2 estimates (0.72 to 0.93), except for SF (h^2 =0.27). Application of the reduced index considering WW and DG was as efficient as full index in terms of accuracy of selection ($r_{TI}=0.66$); it provided higher improvement in aggregate genotype represented in SW (+170.72gm) and DG (+2.41gm/day) for each round of selection. This improvement in post-weaning traits was accompanied by unfavorable expected impact in fat traits SF, HF, MF and CF (+45.32, +12.77, +56.50 and +12.25%, respectively) and favorable expected impact on IF and KF (-32.16 and -59.47gm, respectively). The single trait selection index (I₆) with SW was found to be useful for rabbit meat consumers, as it decreased the undesirable fat gain in fat depots compared to the other indices, with some reduction in accuracy. In conclusion, it is possible to improve the post-weaning growth traits through selection programs, taking into consideration the undesirable changes in fat partition traits of New Zealand White rabbits.

Key words: Rabbits, Post-weaning growth traits, Selection indices, Fat partition traits.

INTRODUCTION

The high fat diets usually have a negative effect on human health (Rohr et al. 2019; Abady 2020; Wali et al. 2020). Compared with red meats, rabbit meat is commonly considered as healthy meat due to its low-fat contents (Dalle Zotte 2002). However, the fat content of rabbit meat varies widely, ranging from 1.5% (Belabbas et al. 2019) to 7.1% (Pla et al. 2004).

Fat partitioning refers to the distribution of the animal's body fat in the various body fat depots (Shemeis and Abdallah 2000), whether in carcass components (subcutaneous and intermuscular fat depots) or in noncarcass components (heart, kidneys, mesenteric and caul fat depots). Shemeis and Abdallah (2000) reported a positive genetic correlation between marketing body weight and total body fat weight, indicating that any improvement in post-weaning growth traits would lead to increased total body fat weight. Moreover, the poor distribution of animal body fat, a consequence of selection for growth traits, would have a negative economic effect on the breeders (especially if the increased fat is concentrated in the viscera), as well as the meat consumers if the fat is concentrated in the carcass.

However, there is an apparent lack of available information regarding the negative implications of selection for post-weaning growth traits on fat partition traits in rabbits. Therefore, the current study aimed to investigate the possible effects of selection for postweaning growth traits on fat partition traits in New Zealand White (NZW) rabbits.

MATERIALS AND METHODS

Ethical Statement

All experimental practices and protocols in the present study were compatible with the research ethics guidelines in conformity with the EU Directive for protection of experimental animals (2010/63/EU).

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Experimental Rabbits

For this study, 218 New Zealand White rabbis, kept at a private rabbit farm (Qanater Farm) in Qalyobia Governorate, Cairo, Egypt, were randomly selected at the weaning age of 28 days. These rabbits were reared under naturally prevailing environmental conditions until slaughtered at 90 days of age.

Animals Management

At weaning (28-days of age), kids were separated from their dams in fattening batteries, tagged and weighed (WW). They were fed *ad libitum* a fattening commercial pelleted diet, providing 2800 kcal digestible energy/kg diet, up to the age of 90 days when they were slaughtered.

Traits Considered

At 90 days of age, rabbits were weighted before slaughter (SW), and the daily weight gain from weaning to slaughtering age (DG) was calculated. Then they were shifted to the Meat Laboratory in the Faculty of Agriculture, Ain Shams University, Egypt, where they were slaughtered and dressed out according to the method described by Blasco et al. (1993). The non-carcass fat components, including heart (HF), mesenteric (MS), caul (CF) and kidney (KF) fats were removed and weighed. Each carcass was split into two halves and the subcutaneous fat (SF) and intermuscular fat (IF) of the right side were dissected and weighed. Weights of SF and IF were multiplied by two to get total carcass fat weight, whereas carcass and non-carcass fat weights were pooled to get total body fat weight. Percentages of each trait of carcass and non-carcass fat were also calculated.

Statistical Analysis

Multitrait-animal model was applied, using VCE-6 software package, according to Kovač et al. (2002) to analyze the recorded traits for the estimation of the genetic and phenotypic parameters. For this purpose, the following animal model was adopted:

y = Xb + Za + e

The following matrices were used for the model:

y_1	1	ΓX_1	0	0	ך 0	$[b_1]$		ΓZ_1	0	0	ך 0	$[a_1]$	1	e_{1}	ł
<i>y</i> ₂		0	X_2		0	b_2		0	Z_2		0	a_2		e_2	
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Ly_{n}	J	LX_n	0		X_n	$\lfloor b_n \rfloor$		L 0	0		$Z_n \mathbf{J}$	Lan		Le_n	ł.

where:

y = the vector of observations traits,

b = the vector of fixed effects,

a = the vector of random additive genetic direct effects,

X and Z = known incidence matrices relating observations to the respective fixed and random effects with Z augmented with columns of zeros for animals without records, and

e = the vector of random residual effects.

Definition of the True Breeding Value

The breeding objective in this study was to maximize the net income of rabbit producers through the selection for high post-weaning growth traits including slaughter weight (SW) and daily gain from weaning to slaughter (DG). The true breeding value (T) was defined as:

 $T = a_1 g_{SW} + a_2 g_{DG}$, where,

 g_{SW} = the additive genetic value for slaughter weight,

 g_{DG} = the additive genetic value for daily gain from weaning to slaughter, and

 a_1 , a_2 = the relative economic weights for SW and DG, respectively.

Economic Values

The following equation descried by Lamont (1991) was applied to calculate the economic value (a) of SW and DG:

$$a_i = \frac{\sum_{i=1}^{n} h_i^2}{h_i^2}$$
, where

 h_i^2 : The heritability estimates of the ith trait included in the true breeding value.

Selection Indices

Live performance traits, including weaning weight, slaughter weight and daily gain from weaning to slaughter were used as sources of information in different combinations of selection indices (Hazel et al. 1994) to achieve the breeding objective of this study. The various combinations were applied under the following three alternative strategies:

i) Selection based on full index including all sources of information;

ii) Selection based on the reduced indices, including combination of each source of information with the other; andiii) Selection based on single source of information.

RESULTS

Variability and Heritability

Overall means, phenotypic coefficient of variations, heritability estimates and economic values of post-weaning growth traits and fat partition traits are shown in Table 1. These results demonstrated that weaning weight exhibited higher phenotypic variability (CV, 24.4%) than that for slaughter weight (CV, 16.9%) and daily gain (CV, 20.6%). Regarding fat partition traits, it can be seen that the fat deposing subcutaneously exhibited higher variability (CV, 39.1%) than that deposing intramuscularly (CV, 17.9%). However, the heart fat depot showed the highest CV (53.3%) compared to other non-carcass components with CV varying from 28.1 to 34.6%.

The magnitude for h^2 estimates of post-weaning growth traits varied from low to moderate, the values being 0.03±0.01 for WW, 0.35±0.08 for SW and 0.37±0.10 for DG. On the other hand, estimates of heritability for SF, KF, IF, MF, HF and CF were moderate to very high with estimated values of 0.27±0.009, 0.72±0.008, 0.82±0.008, 0.84±0.009, 0.85±0.005 and 0.93±0.003, respectively.

Economic Values

According to Lamont (1991), the economic values for aggregate genotype traits were calculated to be 2.06 for slaughter weight and 1.94 for daily gain (Table 1).

Table 1: Phenotypic coefficient of variations ($CV_p\%$), heritability estimates with standard errors ($h^2\pm SE$) and economic values (a) of post-weaning growth traits and fat partitioning traits in rabbits

Traits	Mean <u>+</u> SE	CV _p %	h ² ±SE	a
i. Post-weaning growth traits				
• Weaning weight (gm)	406.10±6.72	24.4	0.03 ± 0.01	-
• Slaughter weight (gm)	1746.80±20.10	16.9	0.35 ± 0.08	2.06
• Daily gain (gm/day)	21.30±0.29	20.6	0.37±0.10	1.94
ii. Fat partition traits $(\%)^{\text{t}}$				
1. Carcass component depots				
Subcutaneous fat	12.55±0.33	39.1	0.27 ± 0.009	-
Intermuscular fat	23.52±0.28	17.9	0.82 ± 0.008	-
2. Non-carcass component depots				
Heart fat	8.61±0.34	53.3	0.85 ± 0.005	-
Kidneys fat	24.70±0.53	32.3	0.72 ± 0.008	-
Mesenteric fat	23.60±0.44	28.1	0.84 ± 0.009	-
Caul fat	7.02±0.16	34.6	0.93±0.003	-

1: Fat depot weight as percentage of total body fat depots weight.

Correlations

Genetic (r_G) and phenotypic (r_P) correlations for fat partition and post-weaning growth traits are presented in Table 2. Moderate to high genetic correlation were found among post-weaning growth traits (r_G =0.53 to 0.98). Rabbits with higher percentage of intermuscular fat in their carcasses tended to have lower fat in mesenteric and kidney depots (r_G =-0.96 and -0.62, respectively), with accelerating fat in caul and heart depots (r_G =0.91 and 0.67, respectively).

In general, except with SF, negligible to low genetic correlations between post-weaning growth traits and fat partition traits were recorded in the present study, in positive direction with HF, MF and CF (r_G =0.04 to 0.18) and in negative direction with IF and KF (r_G =-0.10 to -0.27). However, low to high genetic positive correlations were seen between SF and WW, SW and DG (r_G 0.25, 0.79 and 0.85, respectively).

There was an antagonism between SF and IF, HF and CF (r_G =-0.46, -0.44 and -0.31, respectively). Heart fat was negatively and highly correlated with each of KF and MF (r_G =-0.90 and -0.74, respectively), but showed high positive genetic correlation with CF (r_G =0.79).

Indices

In the present study, seven selection indices were constructed using genetic and phenotypic (co) variances estimates and their relative economic values were also calculated. The weighing factors, indices standard deviation and accuracy of selection for each index with the relative efficiency to the full index are given in Table 3. The full index including all sources of information exhibited the highest accuracy of selection (r_{TI} =0.66), followed by reduced indices including two sources of information (r_{TI} =0.65 to 0.66) and finally single trait indices (r_{TI} =0.13 to 0.60).

Expected Genetic Gain

Table 4 and Fig. 1 show the expected genetic change to selection per generation for post-weaning growth traits and fat partition traits.

Post-weaning Growth Traits

Application of the considered seven selection indices improved the aggregate genotype traits by 33.48gm to 170.72gm for SW and by 0.35gm/day to 2.41gm/day for

DG, with expected positive impact on WW by 11.87gm to 25.68gm for each round of selection.

Fat Partition Traits

Undesirable change in SF, HF, MF and CF (3.94 to 45.32, 8.52 to 13.88, 9.46 to 56.5 and 3.02 to 12.25gm, respectively) occurred following the application of seven selection indices. Moreover, IF and KF decreased by -10.65 to -33.20 and -6.64 to -61.63gm, respectively.

DISCUSSION

Variability and Heritability

In the present study, the variability in body weight at older age (12-weeks) was found to be lower than that at earlier age (4-weeks). Similar results were observed by by Ezzeroug et al. (2020), Peiró et al. (2019) and Sakthivel et al. (2017) in rabbits. This variation may be due to the genetic and environmental effect of dams on kids at weaning. Among all fat depots, the percentage of intermuscular fat depot showed the lowest CV (17.9%) compared to other fat depots (CV, 28.1 to 53.3%). A similar pattern of variability in New Zealand White rabbits has previously been reported by Shemeis and Abdallah (2000).

In the present and various previous studies, weaning weight has been found to be less heritable (0.03, Table 1; 0.03, Ezzeroug et al. 2020; 0.09, Sakthivel et al. 2017; 0.04, Drouilhet et al. 2013; 0.04, Lukefahr et al. 1996) than slaughter weight (0.35, Table 1; 0.27, Sakthivel et al. 2017; 0.34, Dige et al. 2012; 0.39, Garreau et al. 2008; 0.36, Moura et al. 2001; 0.82, Shemeis and Abdallah 2000) or daily gain (0.37, Table 1; 0.19, Peiró et al. 2019; .42, Sakthivel et al. 2017). Moderate heritability estimates of SW and DG indicate the possibility of improving these traits through selection. The h² estimates for fat partition traits were found to be quite high (0.72±0.008 to 0.93 ± 0.003), with the exception of the moderate estimate of subcutaneous fat (0.27±0.009). The high heritability estimates of fat partition traits are the indicative of the fact that rabbits can attain the optimal slaughter weight with the minimal effects of environmental and physiological factors; this leads to the increase of the genetic variance in these traits.

Table 2: Genetic (above diagonal) and	phenotypic	(below diag	onal) corre	lations for p	ost-weanin	g growth tr	aits and fat	partition tra	uts in rabbits
Trait	WW	SW	DG	SF	IF	HF	KF	MF	CF
i. Post-weaning growth traits									
Weaning weight (gm)	-	0.69	0.53	0.25	-0.27	0.18	-0.10	0.09	0.04
Slaughter weight (gm)	0.59	-	0.98	0.79	-0.25	0.10	-0.25	0.16	0.05
Daily gain (gm/day)	-0.21	0.66	-	0.85	-0.22	0.04	-0.27	0.16	0.05
ii. Fat partition traits									
1. Carcass component depots									
Subcutaneous fat (%)	0.10	0.45	0.45	-	-0.46	-0.44	0.15	0.47	-0.31
Intermuscular fat (%)	-0.11	-0.34	-0.31	-0.10	-	0.67	-0.62	-0.96	0.91
2. Non-carcass component depots									
Heart fat (%)	0.21	0.09	08	-0.32	0.48	-	-0.90	-0.74	0.79
Kidneys fat (%)	0.08	-0.05	-0.16	0.26	-0.34	-0.82	-	0.61	-0.75
Mesenteric fat (%)	-0.03	0.10	0.16	-0.04	-0.93	-0.56	0.31	-	-0.94
Caul fat (%)	0.003	0.09	0.11	-0.18	0.76	0.67	-0.63	079	-

Table 3: Weighing factors, indices standard deviation (σ_1), accuracy of selection (r_{TI}) estimated from each index (*I*) and relative efficiency (RE) to the full index ($I_1 = 100$)

Selection alternative Strategy	Index	Index trait	Weighing factors ^a		σ_{I}	\mathbf{r}_{TI}	RE%	
	Ι		WW	SW	DG			
i. Full index	I_1	WW, SW, DG	-1.33	1.75	-49.03	349.64	0.66	100
ii. Reduced index	I_2	WW, SW	-0.54	0.97	-	350.97	0.65	98.5
	13	WW, DG	0.43	-	62.29	356.38	0.66	100.0
	I_4	SW, DG	-	0.41	35.78	353.53	0.65	98.5
iii. Single index	I_5	WW	0.20	-	-	69.66	0.13	19.7
	I_6	SW	-	0.72	-	318.47	0.58	87.8
	I_7	DG	-	-	56.82	326.41	0.60	90.9

a: WW=Weaning weight; SW=Slaughter weight, DG=Daily gain.

Correlations

Rabbits which are weaned at higher weight are expected to reach the slaughter age at higher weight (r_G , 0.69, Table 2; 0.61 (Ezzeroug et al. 2020) and 0.73 (Moustafa et al. 2014). Moreover, slaughter weight was found to be positively and highly correlated with daily gain, the r_G value being 0.98. This is in agreement with r_G values of 0.95, 0.98 and 0.96 reported by Drouilhet et al. (2013), Lukefahr et al. (1996) and Polastre et al. (1992), respectively. This indicates that rabbits with faster daily gain would be heavier at fixed slaughter age.

Selection of rabbits for faster daily gain and heavier slaughter weight would expect to produce rabbit carcasses with higher percentages of subcutaneous fat (r_G =+0.85 and +0.79, respectively), lower intermuscular fat (r_G =-0.22 and -0.25, respectively) and kidney fat (r_G =-0.27 and -0.25, respectively). This indicates that the expected genetic impact for improvement of post-weaning growth traits on the basis of subcutaneous fat would also influence other fat depots in the body of rabbits with different degrees.

The genetic antagonism between caul fat and both of kidney fat and mesenteric fat depots (r_G =-0.94 and -0.75, respectively), noticed in the present study, is in agreement with the findings of Shemeis and Abdallah (2000), who observed high negative genetic association of kidneys knob and channel fat with mesenteric and heart fat depots (r_G =-0.91 and -0.92, respectively).

Indices

Regarding the accuracy of selection, the best results were achieved by the first strategy, called the full index (I_1 : $r_{TI}=0.66$), in which all sources of information were included. This seems to be due to the higher inter-genetic correlation between them. On the other hand, the best reduced index (second strategy), including WW and DG,

was as efficient as the full index in terms of accuracy of selection (I_3 : $r_{TI}=0.66$). However, application of the reduced index, including SW with either WW or DG, decreased the selection accuracy by only 1.5%. The single trait index, including either SW (I_6) or DG alone (I_7) was as efficient as the full index (I_1) by 90.9 and 87.8%, respectively and as efficient as WW alone (I_5) by 68.1 and 71.2%, respectively. This is most probably due to high positive genetic relationship between SW and DG $(r_G=0.98, Table 2)$. In agreement with these results, Khalil et al. (1986) and El-Deghadi and Ibrahim (2018) concluded that selection indexes based on earlier growth weight would be more effective than those based on older growth weight to select for 12-week weight. On the other hand, Anous (2001) stated that use of single selection index, including slaughter weight or daily gain from 4-6 week alone, was more efficient than the index including WW alone (by 10.34 and 14.79%, respectively). According to Moustafa et al. (2014), selection based on marketing body weight is better than that based on weaning weight and daily gain for growth improvement.

Expected Genetic Gain

Post-weaning Growth Traits

The use of full index including all sources of information in the present study increased the true breeding value by 170.7gm in slaughter weight and 2.41gm/day in daily gain, with increase of weaning weight by 25.0gm per generation. However, selection based on the best reduced index (I_3), including weaning weight and daily gain, showed better results in terms of improving the aggregate genotype traits either in SW (+170.7gm) or in DG (+2.41gm/day) than those of the full index. This seems to be due to higher correlation between SW and DG. On the other hand, the single trait selection index with SW (I_6) appeared to be the best single index to improve slaughter



Fig. 1: Expected genetic change in post-weaning growth traits and fat partition traits depending on selection for full index (I1), with the best reduced index (I3) and single trait index (I6).

 Table 4: Expected genetic change to selection per generation for post-weaning growth traits and fat partition traits (selection intensity = 1)

 Trait
 Visit

 Selection strategy

Irait	Unit	Selection strategy							
		Full index Reduced in			x	Single inde	ex		
		I ₁	I_2	I ₃	I_4	I ₅	I_6	I7	
		WW, SW, DG	WW, SW	WW, DG	SW, DG	WW	SW	DG	
i. Post-weaning growth traits									
- Weaning weight	gm	24.72	25.04	25.67	25.20	11.87	25.68	20.71	
- Slaughter weight	gm	167.62	168.20	170.72	169.40	33.48	152.65	156.32	
- Daily gain	gm/day	2.23	2.30	2.41	2.37	0.35	2.04	2.26	
ii. Fat partitioning traits									
1. Carcass component depots	5								
- Subcutaneous fat	%	45.03	44.94	45.32	45.17	3.94	38.64	43.52	
- Intermuscular fat	%	-32.16	-32.48	-33.20	-32.78	-10.65	-31.28	-28.72	
2. Non-carcass component d	epots								
- Heart fat	%	10.60	11.53	12.77	12.09	10.25	13.88	8.52	
- Kidneys fat	%	-59.47	-60.14	-61.63	-61.00	-6.64	-52.29	-58.66	
- Mesenteric fat	%	55.50	55.68	56.50	56.09	9.46	49.83	52.39	
- Caul fat	%	11.77	11.93	12.25	12.08	3.02	11.11	10.96	

weight and daily gain (+152.6gm and +2.04gm/day, respectively). Similar results were observed by Anous (2001) using an index including body weight at weaning and six weeks of age, with daily gain on weaning weight (+57.5gm) and daily gain (+1.3gm/day). However, El-Deghadi and Ibrahim (2018) recommended an index including body weight at 6 and 8-weeks of age to improve genetic performance in Gabali rabbits.

Fat partition Traits

Application of selection by full index (I_1) developed rabbits with unfavorable fat partition subcutaneously (+45.03unit), mesenteric (+55.5unit), caul (+11.7unit) and heart (+10.6unit) depots, accompanied by decrease in intermuscular fat and kidney fat depots (-32.1 and -59.47 unit, respectively). However, compared to the full index, use of reduced index, including WW and DG, resulted in comparable genetic change in carcass component fat depots (+45.32unit for SF and -33.20unit for IF) and higher change in offal component fat depots (+12.77unit in HF, -1.63unit in KF, +56.50unit in MF and +12.25unit in CF). On the other hand, use of single trait index with SW alone (I_6) decreased the undesirable fat gain in subcutaneous (by 6.39unit), mesenteric (by 5.67unit) and caul (0.66unit) depots, with reduction of expected acute deterioration in kidneys fat by 7.18unit. Application of this index would be beneficial for the rabbit meat consumers' health, as they would consume rabbit meat with lower fat depots in carcass and offal. However, Shemeis and Abdallah (2000) reported an expected increase in intermuscular fat (+1.91unit) through using the single trait selection index based on slaughter weight.

Conclusion

Based on the results of the present study, the following reduced selection index could be recommended for commercial rabbit farmers to improve post-weaning growth traits, including slaughter weight and daily gain from weaning to slaughter:

*I*₃=0.43WW+62.29DG (r_{TI}=0.66)

This index would result in higher profitability for the rabbit breeders with the risk of expected unfavorable impact on fat partition depots depositing in carcass (subcutaneous depot) and offal components (mesenteric, caul and heart depots) and higher reduction in intermuscular fat and kidney fat depots, which also play an important role in the kidney functions. However, if the breeders are ready to accept the reduction in weight gain of rabbits for consumers' satisfaction, then the following index could be advised:

I₆=0.72SW (r_{TI}=0.58)

This index would reduce the expected increase in undesirable fat depots, with relatively low reduction in selection accuracy.

Author's Contribution

The author was actively involved from the start of the research planning and executing, analyzing the data and writing of manuscript.

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