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SEASONAL VARIATIONS IN FURS OF GABALY AND NEW ZEALAND WHITE RABBITS AND THEIR CROSSBRED UNDER EGYPTIAN SEMI-ARID CONDITIONS

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Abstract: The effect of breed and season on rabbits' fur characteristics under Egyptian semi-arid conditions was studied in this research. Fifty-nine male rabbits aged 3-3.5 mo of Gabaly (GB, n=21) and New Zealand White (NZW, n=27) breeds and their crossbred (NZW×GB, n=11) were studied during two subsequent seasons; summer (n=31) and winter (n=28). Skin samples were taken pre-slaughtering to determine the histological parameters, skin layer thicknesses and physical traits of fur fibres. After slaughter, rabbits' furs were chrome tanned to determine physical and chemical properties. Results showed that all histological parameters of follicle dimensions were affected (P<0.01) by season, breed and their interaction. In summer, primary follicles had larger follicle dimensions and produced coarser fibres than in winter, whereas opposite results were observed for the secondary follicles. Additionally, the uniformity of fibre diameter distribution and hair length of furs were higher (P<0.01) in summer than in winter. Results indicated the role of the seasonal variations in body coat to accommodate the climatic changes. NZW rabbits were superior (P<0.01) in most histological parameters of follicle dimensions, followed by NZW×GB crossbred and finally GB rabbits, while NZW×GB crossbred produced finer (P<0.01) fur fibre than NZW and GB rabbits. Otherwise, influence of season and breed were negligible on the skin layer thickness values and the physical and chemical fur properties. Consequently, the study concluded that tanned rabbit furs are suitable for manufacturing leather garments when used alone, while reinforcing the fur with textile padding may increase their utility for other leather manufacturing purposes.

Key Words: rabbit breeds, chrome tanning, fibre, rabbit fur, season.

INTRODUCTION

Rabbit production is particularly well suited for impoverished or subsistence farmers who live on small farms in arid and tropical regions of the developing world (Rogers *et al.,* 2006). Although meat is the main goal of rabbit production, shorn hairs, furs and pelts are by-products that are usually recovered from skins with no particular production constraint (Lebas *et al.,* 1997). Egypt's topographical location makes its weather mostly warm, with temperatures ranging from 23 to 32°C in summer versus 9 to 17°C in winter (El-Nahrawy, 2011). Thus, due to the climatic changes between summer and winter, various investigations have been conducted to study season influence on rabbit adaptation and their productivity (El-Sheikh *et al.,* 2011; Fathi *et al.,* 2017; Khalil, 2018). However, previous studies on the impact of climate on body cover properties in Egyptian rabbit breeds are lacking.

Egypt's hot summers could constrain the rearing of specialised fur breeds like Angora due to their high sensitivity to heat stress (McNitt *et al.,* 2000) and the high cost of housing in air-conditioned facilities, which is neither affordable nor practical in many situations (Rogers *et al.,* 2006). Therefore, developing the capability of the well-established breeds is more logical in developing countries, in addition to understanding the role of body coat in protecting the

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animals during the different climatic conditions, as it is important to evaluate the factors that could affect their suitability for processing.

New Zealand White (NZW) and Gabaly (GB) are considered the most common meat rabbit breeds in Egypt and are well adapted to Egyptian environmental conditions (Galal and Khalil, 1994). The skins of these breeds were earlier evaluated as a by-product material and found to be suitable for garment and lining manufacture (Taha *et al.,* 2017), but the influence of season on the body cover properties of NZW and GB breeds has not been sufficiently studied. Therefore, this study was carried out to investigate the effect of breed, season and their interaction on histological constructions, skin layer thicknesses, some physical traits of fur fibres and the physical and chemical properties of tanned furs.

MATERIALS AND METHODS

Study location

This study was carried out at the Maryout Research Station, Alexandria, Egypt, which belongs to the Desert Research Centre and is located 35 km South West of Alexandria (31° 00' 22.2" N, 29° 47' 24.0" E).

Animals and management

This study was approved by the Animal Ethics Committee of Animal and Poultry Production Division, Desert Research Centre. A total of 59 male rabbits aged 3 to 3.5 mo of NZW (n=27), GB (n=21) and their crossbred (NZW×GB, n=11) offspring were used in this experiment. Animals were distributed as 11, 15 and 5 in summer, where the corresponding numbers were 16, 6 and 6 in winter for NZW, GB and NZW×GB, respectively. The animals were housed in a building with high clear glass windows and kept under properly controlled air ventilation. Therefore, animals were housed under natural lighting, and were protected from strong air currents. Temperatures inside the building ranged from 23 to 30°C in summer (June to August), and from 12 to 20°C in winter (December to February).

After weaning at one month of age, kits were separated from their mother does. The animals were housed together in groups of three in a metal wired cage (70×60×50 cm) and provided with feeders and automatic water nipples. After two months of age, they were individually housed in metal wire cage (70×60×50 cm).

Rabbits were fed on a balanced commercial diet (15.8% crude protein, 19.3% acid detergent fibre, 9.8 MJ digestible energy/kg as-fed bases) during the entire experiment. Feed and water were *ad libitum* without adding any antibiotics.

Determination of histological parameters

A skin biopsy sample was taken from the same right flank fur sampling region using curved scissors for histological determinations. Skin specimens were fixed on foam and flattened, then fixation was performed in calcium formol (Barker, 1958). Skin specimens were then dehydrated in an ascending series of ethanol, cleared in benzene, infiltrated in paraffin wax and then embedded in the same paraffin to prepare the blocks. These were then sliced into cross sectional and longitudinal skin sections that were stained by Haematoxylin and Eosin stain to perform the histological examinations (Drury and Wallington, 1980). The cross sectional slices were used to determine measurements of skin follicle dimensions, which included the external diameter, internal diameter, wall thickness and fibre diameter, and to estimate the ratio of secondary to primary follicles by counting the follicle groups in ten follicle groups for each skin sample taken from each animal. The longitudinal sections were used for the measurement of skin layer thicknesses (epidermis, dermis, hypodermis, papillary and reticular). Histological parameters were measured using Image analyser software (Zen, Blue edition) and a Carl-Zeiss micro-imaging device (lenses 10/0.847 and 40/0.65).

Determination of fur fibre physical traits

At slaughtering time (3 to 3.5 mo of age), rabbits' body weights (g) were recorded and, using a sharp clipper, a small snippet of the fur was taken from the right flank region of each rabbit to assess the physical traits of fur fibres, as described by Rogers *et al.* (2006). Average fibre diameter (FD) was measured using a Carl-Zeiss micro image analyser

(Zen, Blue edition). Five hundred hair fibres samples were randomly collected to determine the length and type of fibres according to Tao (1994). The standard deviation of fibre diameter (SDFD) and the standard deviation of fibre length (SDFL) were used to express the uniformity of both traits, where the higher estimates of standard deviation referred to less uniformity in the normal distribution of the values around the mean value, and vice versa (Lupton, 1995). Fine fibres were represented as percentage of fibres with diameter ≤30 μm in width as 30 μm is considered to be a reasonable cut-off between fur and hair populations (Boucher *et al.,* 1996; Rogers *et al.,* 2006).

Fur tanning and testing

After slaughtering, skin weights were determined; thereafter, skins were chrome tanned according to Taha *et al.* (2017) and then physical and chemical properties of tanned furs were recorded following standard ASTM procedures (American Society for Testing and Materials, 2014). Examined physical properties were fur thickness, fur area, tensile strength, elongation percentage at break and split tear strength, in addition to some chemical properties such as moisture, chromic oxide and acidity (pH).

Statistical analysis

Data were analysed with the SAS (2008) program using a general linear model (GLM) procedure for analysis of variance. Means were significantly separated using Duncan's multiple range tests.

The fixed effect model used was $Y_{ijk} = \mu + B_i + N_j + BN_{ij} + e_{ijk}$, where Y_{ijk} is the observation k of i^{th} breed, j^{th} season, i^{th} j^{th} breed × season interaction, μ is an overall mean, B_i is the fixed effect of breed (NZW, GB, and NZW×GB), N_j is the fixed effect of season (summer and winter), BN_{ij} is the interaction effect between breed and season, and e_{ijk} is the random error assumed to be normally distributed with mean=0 and variance=$\sigma^2 e$.

RESULTS AND DISCUSSION

Histological parameters

Follicle dimensions of the primary and secondary follicles were significantly affected by season, breed and their interaction (Table 1). The only exception was the insignificant effect of breed on the wall thickness of the primary follicles.

Regarding the season effect on primary follicles which produced coarser fibres, follicle dimensions were larger in summer than in winter, whereas the opposite was found in secondary follicles. These results coincided with those

Table 1: Least square means±standard error of histological parameters for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbits.

	Season (N)			Breed (B)				N×B
Histological Parameters	Summer	Winter	Sig.	NZW	GB	NZW×GB	Sig.	Sig.
Primary follicle (P)								
External diameter	131.72±3.50	100.66±2.93	**	124.22±4.06^{b}	104.74±3.79^{a}	112.64±4.24^{a}	**	**
Internal diameter	61.63±2.14	49.00±1.80	**	64.20±2.39^{c}	45.50±2.23^{a}	54.22±2.50^{b}	**	**
Wall thickness	70.09±2.24	51.66±1.88	**	60.03±2.61	59.24±2.44	58.41±2.73	ns	**
Fibre diameter	47.37±1.97	36.47±1.65	**	49.91±2.19^{c}	32.73±2.04^{a}	41.52±2.28^{b}	**	**
Secondary follicle (S)								
External diameter	35.80±1.65	42.21±1.33	**	39.10±1.76^{b}	34.04±1.71^{a}	46.68±1.82^{c}	**	**
Internal diameter	14.33±0.85	17.68±0.68	**	14.80±0.90^{a}	13.50±0.87^{a}	21.26±0.93^{b}	**	**
Wall thickness	21.46±1.08	24.53±0.87	*	24.29±1.17^{b}	20.54±1.13^{a}	25.43±1.20^{b}	**	**
Fibre diameter	8.60±0.67	11.57±0.54	**	8.59±0.71^{a}	8.98±0.69^{a}	13.95±0.74^{b}	**	**
S/P ratio	14.69±1.94	13.02±2.15	ns	18.70±2.07^{b}	11.55±2.18^{a}	10.40±2.43^{a}	*	ns

Sig.: Significance, ns: Non-significance, *$P<0.05$, **$P<0.01$

Means in the same row and trait having different superscripts are significantly different ($P<0.05$).

found by Thébault and Vrillon (1994) and Rafat *et al.* (2007). Moreover, season is a determinant factor in controlling the growth cycle of skin follicles in rabbits (Oznurlu *et al.,* 2009). The seasonal fluctuations in skin follicle dimensions are highly related to the changes in follicle activity and to the rate of cell proliferation during the fibre development process (Thorburn *et al.,* 1966). These seasonal variations change the growth rate of the follicular cell layers and the activity of the germinal matrix to proliferate and elongate coat fibres (Stenn and Paus, 2001).

In genetically different breeds of rabbits, two types of coat fibres could be distinguished: the coarse guard fibres that are produced by the primary follicles and the finer fibres produced by the secondary ones (Rogers *et al.,* 2006). The presence of thick guard fibres during the incidence of the hot summer climate increases the openness of the body coat to facilitate heat dissipation from the skin surface (Govindiah and Nagarcenker, 1983).

Additionally, Guirgis and El-Ganaieny (1998) stated a correlation coefficient (0.48) between body temperature and the coarse fibre percentages, whereas El-Ganaieny *et al.* (1992) reported that the absence of coarse fibres and the increased diameters of fine fibres in cold climate conditions keep the animal body warm by maintaining a still air layer throughout the coat fibres to reduce the thermal exchange between the animal body and the surrounding environment. Therefore, these seasonal variations in both follicle types may indicate an adaptive mechanism of the body coat to accommodate the seasonal climatic variations.

With respect to the breed effect, the primary follicles had higher (P<0.01) values of external diameter, internal diameter and fibre diameter in NZW than in GB and NZW×GB rabbits. In the secondary follicles, NZW×GB crossbred had higher (P<0.01) values of external diameter, internal diameter and fibre diameter than the other breeds studied. The higher values of primary and secondary follicle dimensions of NZW compared with GB rabbits are in agreement with the results of Taha *et al.* (2017). This may indicate that crossbreeding increases the dimensions of the secondary follicles in NZW×GB rabbits more than in NZW and GB rabbits, while this trend was different in the dimensions of the primary follicles, where those of NZW×GB rabbits were higher than in GB rabbits and less than those of NZW rabbits.

On the other hand, the secondary to primary follicles ratio (S/P) was higher in summer than in winter, but the difference between the two seasons was insignificant. Considering the breed effect, NZW rabbits had a higher (P<0.05) S/P ratio than both GB and NZW×GB rabbits. This result did not concur with Taha *et al.* (2017), who found that S/P ratio was insignificantly higher in GB than NZW rabbits.

Fur fibre physical traits

Although rabbit breeds used in this study are reared mainly for meat production and are not considered as fur breeds (Galal and Khalil, 1994), evaluating their fur fibre physical traits may help in further approaches for marketing of pelts and developing their use in rabbit fur manufacture (Lebas *et al.,* 1997). In this regard, Table 2 and Figure 1 show the fur fibre physical traits for the studied breeds. Data in Figure 1 indicated that during summer NZW produced

Table 2: Least square means±standard error of fur fibre physical traits for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbits.

Fur fibre physical traits		FD (µm)	SDFD (µm)	Fine fibres[1] (%)	FL (cm)	SDFL (cm)
Season (N)	Summer	17.12±0.37	9.70±0.57	94.73±0.52	3.71±0.06	0.46±0.01
	Winter	17.79±0.39	6.93±0.61	96.70±0.56	3.38±0.06	0.42±0.02
	Significance	ns	**	*	**	ns
Breed (B)	NZW	18.27±0.37[b]	9.08±0.67	94.67±0.58[a]	3.54±0.07	0.47 ±0.02
	GB	17.07±0.41[ab]	8.31±0.75	96.06±0.64[ab]	3.62±0.08	0.43 ±0.02
	NZW×GB	16.15±0.57[a]	7.01±1.03	97.15 ±0.89[b]	3.47±0.11	0.42 ±0.02
	Significance	**	ns	*	ns	ns
N×B	Significance	**	**	**	*	*

[1]Fine fibres mean hairs with diameters ≤30 µm.

FD: fibre diameter, SDFD: standard deviation of fibre diameter, FL: fibre length, SDFL: standard deviation of fibre length, ns: Non-significance, *P<0.05, **P<0.01

Means in the same column and trait having different superscripts are significantly different (P<0.05).

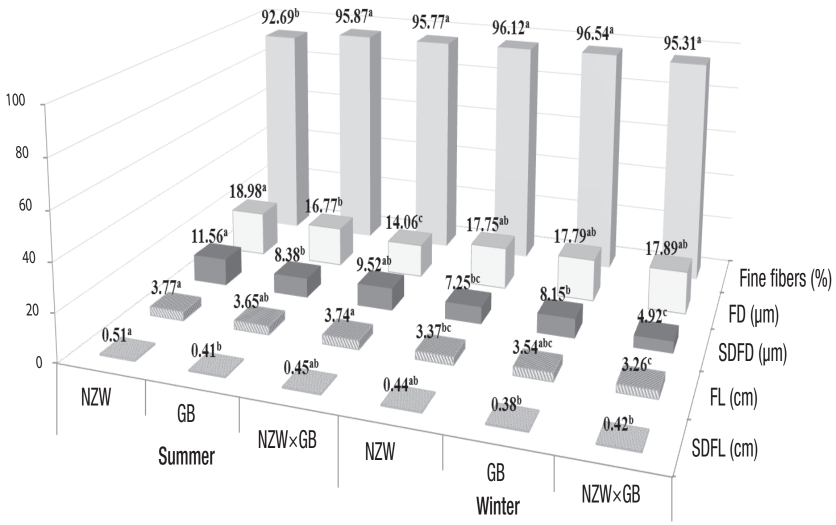

Figure 1: Means of fur fibre physical traits for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbit offspring, showing interaction effect of season× breed. Means with different superscripts for the same trait are significantly different ($P<0.05$). FD: fibre diameter, SDFD: standard deviation of fibre diameter, FL: fibre length, SDFL: standard deviation of fibre length.

the coarsest fibres ($P<0.01$), with the lowest fibre diameter homogeneity ($P<0.01$) and lowest fine fibres content ($P<0.01$). Additionally, no significant differences in fibre length were detected among the studied breeds in summer, as GB and NZW×GB rabbits produced furs of more homogenous fibre length than NZW rabbits. On the other hand, during winter, the furs of the studied breeds were similar in terms of fibre physical traits.

Therefore, except for the mean of fibre diameter and fine fibre percentage, the effect of breed on the other fur fibre physical traits was insignificant (Table 2). The information available on studied breeds is scanty.

Considering the season effect in Table 2, winter fur fibres tended to have coarser fibres with more homogeneous lengths, though the differences between the two seasons were insignificant. Thus, winter furs were better than summer furs in fibre physical traits due to the higher percentage of fine fibres ($P<0.05$), the greater homogeneity of fibre diameter ($P<0.01$) and the more uniformity of fibre length during winter. These results were in accordance with Lebas *et al.* (1997), Rogers *et al.* (2006) and Rafat *et al.* (2007).

Skin layer thicknesses

Figure 2 shows the vertical sections of NZW, GB and NZW×GB rabbits' skins in summer and winter seasons, while the mean values of their skin layer thicknesses (μm) are shown in Figure 3. Neither season nor breed affected skin layer thicknesses. Total skin layer thickness was relatively thicker in winter than in summer. Except for the papillary layer, all other skin layers were thinner in summer than in winter. As a non-sweating animal, rabbits may acclimate to the ambient temperature via other mechanisms, such as vasoconstriction in cold climate or panting and vasodilation in hot climate (Rafel *et al.,* 2012; Milling *et al.,* 2018). Vasodilation during the hot season helps offset heat loss via the skin surface. Meanwhile, it acts to increase follicle activity and may explain the seasonal variations in follicle dimensions besides the higher thickness of papillary layer during summer. On the other hand, higher thicknesses of epidermis, dermis and hypodermis layers in winter may improve thermal insulation adaptation by increasing total skin thickness (Thorburn *et al.,* 1966; El-Ganaieny *et al.,* 2001). NZW rabbits had the thickest skin layers and NZW×GB crossbreed ranked at mid-values, while GB rabbits had the thinnest thicknesses. The obtained trend between NZW and GB rabbits agreed with the results of Taha *et al.* (2017).

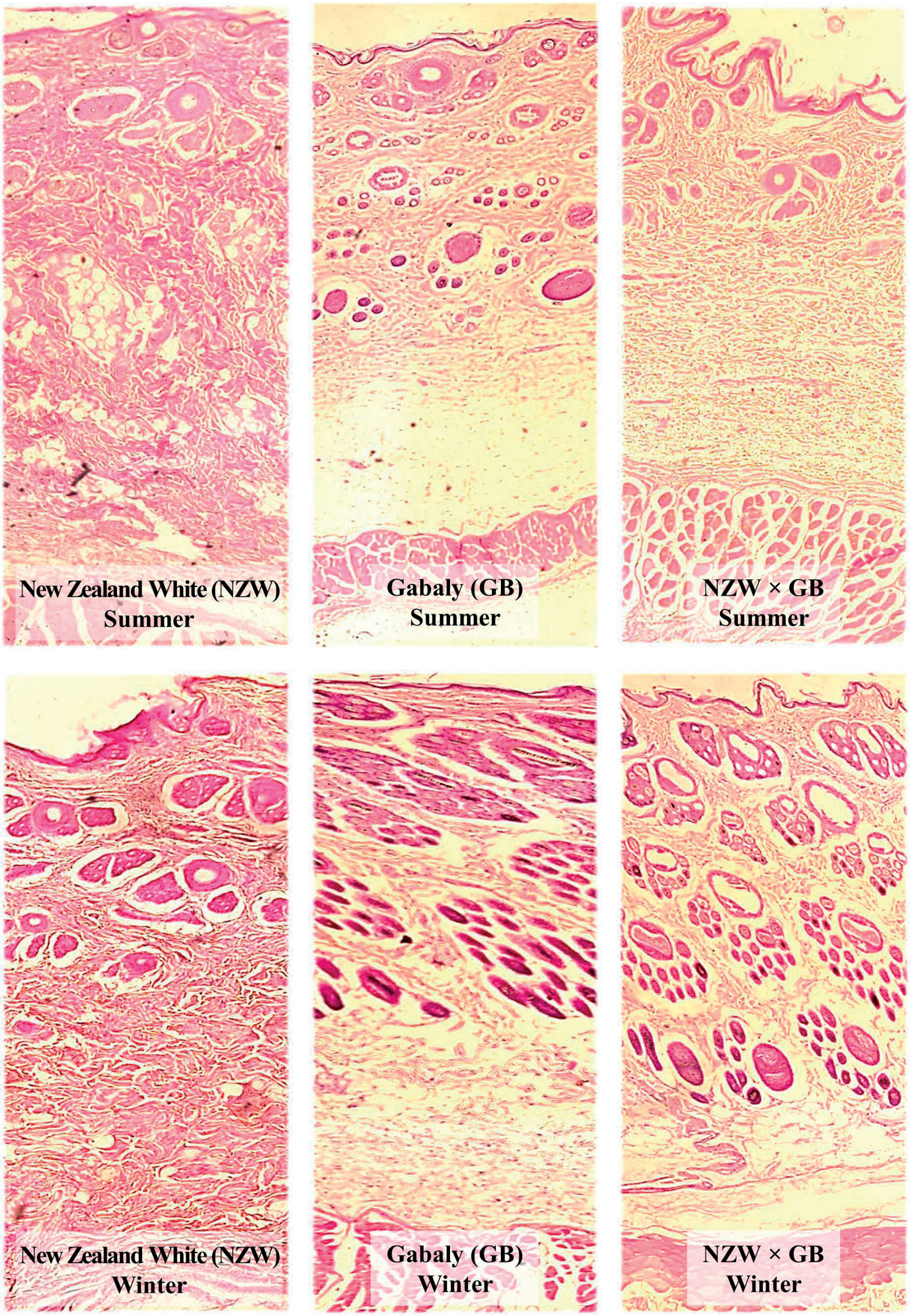

Figure 2: Vertical sections of New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbit skins show different skin layers in summer and winter seasons (H&E., ×100).

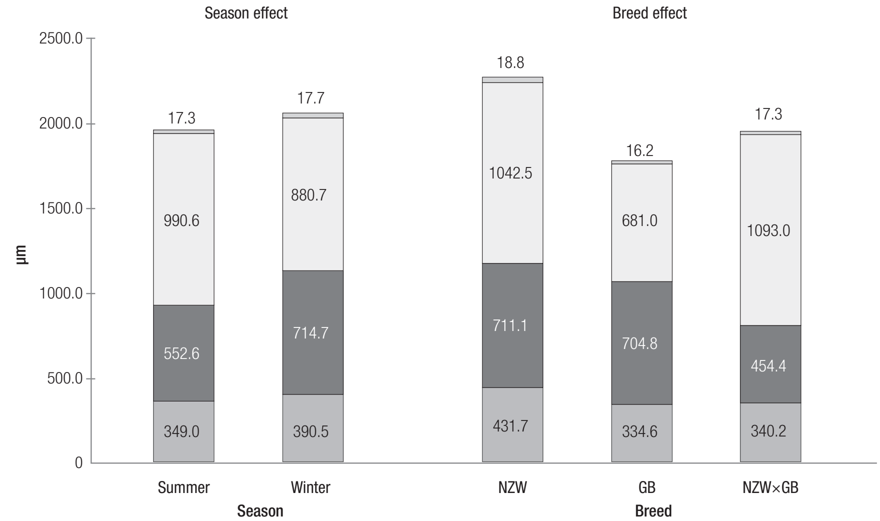

Figure 3: Means of skin layer thicknesses (µm) for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbits, showing non-significant effects of season and breed. Hypodermis, Reticular, Papillary, Epidermis.

Tanned furs properties

Table 3 shows results of animal weight (g), skin weight (g), skin area (cm^2) and tanned fur thickness (mm) of rabbits as affected by season, breed and their interaction. Although no significant effect of season was detected on animal weight, season affected (P<0.01) the skin weight, skin area and tanned fur thickness. The values were higher in winter than in summer and coincided with the aforementioned changes in skin layer thicknesses. These results may be due to the low heat stress and the high feed intake in winter, as stated by Khalil (2018).

The effect of breed on animal weight, skin weight, skin area and tanned fur thickness was insignificant, although NZW rabbits tended to present higher values than the corresponding values in GB and NZW×GB crossbred rabbits. This obtained trend of breed effect was in disagreement with Taha *et al.* (2017).

Figure 4 shows insignificant effects of season and breed on the physical and chemical properties of tanned fur, which shows the similarity in the tanning process of all furs, as well as the similarity among all furs in quality and the purposes of use. All fur properties accounted for close values and coincided with the previous research on

Table 3: Least square means±standard error of animal weight, skin weight, fur area and fur thickness for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbits.

Parameters		Animal weight (g)	Skin weight (g)	Fur area (cm^2)	Fur thickness (mm)
Season (N)	Summer	1862.50±55.53	167.38±7.83	1018.34±31.74	0.87±0.01
	Winter	1921.43±59.36	194.39±8.37	1131.97±33.93	0.91±0.01
	Significance	ns	**	**	**
Breed (B)	NZW	1982.14±57.78	191.75±8.57	1121.27±34.77	0.90 ±0.01
	GB	1809.52±66.72	168.86±9.90	1020.98±40.15	0.87±0.01
	NZW×GB	1809.09±92.18	171.27±13.67	1040.52±55.47	0.88±0.02
	Significance	ns	ns	ns	ns
N×B	Significance	ns	ns	ns	ns

ns: Non-significance; ***P*<0.01

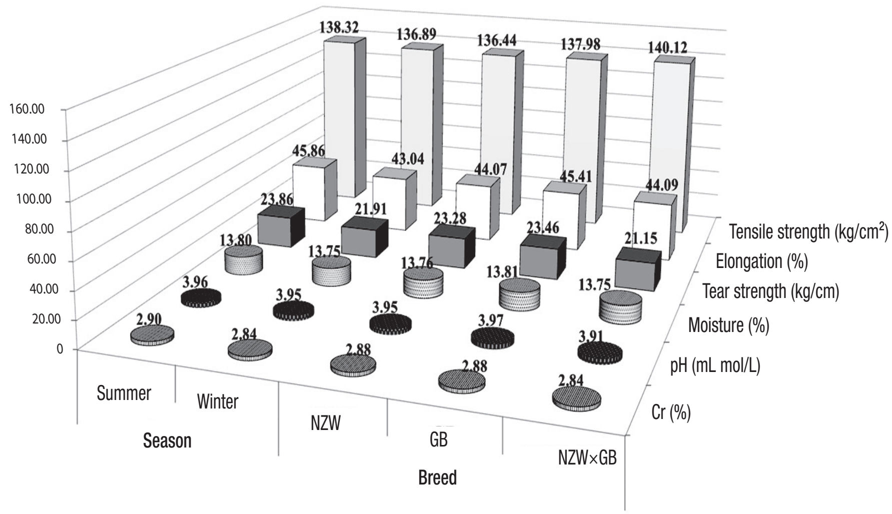

Figure 4: Means of fur physical and chemical properties for New Zealand White (NZW), Gabaly (GB) and their crossbred (NZW×GB) rabbit offspring, showing non-significant effects of season and breed.

rabbits' furs and leathers (Souza *et al.,* 2016 and Taha *et al.,* 2017). Although tensile strengths were lower than the acceptable range for most manufacturing purposes, the values of elongation rate and tearing strengths coincided with the reference recommended by BASF (2007). Thus, the suitability of the tanned furs obtained from this study were limited to leather garment manufacturing when used alone, while they may be widely used in manufacturing bags and other leather products when reinforced with textile padding.

CONCLUSIONS

Although NZW, GB and their crossbred rabbits are not from fur rabbits, their furs were similar in quality. On the other hand, no seasonal variations in the physical and chemical properties of the furs were detected in the current study. Therefore, all tanned furs in this study were suitable for use by different leather manufactures.

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