J I T A A
Journal of the Indonesian Tropical Animal Agriculture
Accredited by Ditjen Riset, Teknologi dan Pengabdian
kepada Masyarakat No. 164/E/KPT/2021

J. Indonesian Trop. Anim. Agric.
pISSN 2087-8273 eISSN 2460-6278
http://ejournal.undip.ac.id/index.php/jitaa
49(1): 51-66, March 2024
DOI: 10.14710/jitaa.49.1. 51-66

Morphometric traits, carcass characteristics and biochemical composition of meat between local and synthetic Algerian rabbit genotypes

I. Sanah*, A. Boudjellal, and S. Becila
Biological Markers of Meat Quality (MaQuaV) team, Biotechnology and Food Quality Laboratory (BioQuAl). Institute of Nutrition, Food and Agri-Food Technologies (I.N.A.T.A.A.).
Frères Mentouri University Constantine 1, Route de Aïn El Bey, 25000 Algeria.
**Corresponding E-mail: ibtissem.sanah@umc.edu.dz*

Received August 17, 2023; Accepted November 13, 2023

ABSTRACT

The aim of this research was to study the genetic and sex effects on morphometric traits, carcass characteristics and biochemical composition of rabbit meat of two Algerian breeds, local population and synthetic line (ITELV2006). For this purpose, 60 animals (30 per group) from 90 d of age were used. The body weight and the morphometric traits recorded were determined using a digital weighing scale and flexible tape. At slaughter, carcass traits, and biochemical meat quality characteristics such us protein, fat, ash, moisture content and fatty acids composition were measured. The results obtained revealed that the synthetic line has higher values of morphometric measurements than the local breed. The sex factor and the interaction genotype X sex had a significant effect only on chest circumference ($P < 0.05$). It is also observed, that the majority of carcass characteristics were more affected by genetic than by genetics. Which body weight at slaughter of males and females derived from synthetic lines were 41% and 22% higher than local rabbits respectively. Furthermore, the new line displayed a good meat yield (60%) with a higher mean value (+ 5%) of dressing out % rather than the local one. Regarding, the proximate biochemical composition of meat, the synthetic line has shown also the highest content of protein and fat ($P < 0.05$). Concerning with fatty acids profile; the local breed exhibited the highest content of n3 and n6 polyunsaturated fatty acids (n3 and n6 PUFAs), consequently, the lower value of n-6: n-3 ratio (9.82) and the highest value of polyunsaturated fatty acids to saturated fatty acids (PUFAs/SFAs: 0.73). Finally, it should be emphasized that the relevant differences recorded in this experiment are assumed to be primarily genetic, thus, sex might be regarded as a minor factor. The synthetic showed better characteristics due to its genetic potential. Therefore, it is recommended to be used for Algerian meat production.

Keywords: Biochemical meat quality, Carcass traits, Local population, Morphometric traits, Synthetic line.

INTRODUCTION

In the Mediterranean area, rabbit meat consumption belongs to eating habits from several generations (Rotolo *et al*., 2013). This kind of meat has several advantages that make it superior to that of other species, mainly its higher protein content, its fatty acids profile, several vitamins and minerals, and low cholesterol and sodium contents (Dalle Zotte, 2002; Para *et al*., 2015). Therefore, it is considered a promising source of animal-derived protein and may have a crucial role in meeting the meat shortage in developing countries (Abdel-Azeem *et al*., 2007; Morshdy *et al*., 2022). In Algeria, an estimated production of 8474 t of rabbit meat i.e 1% of the global world production (861 739 t) was registered in 2021 (FAO, 2021). Relatedly, meat production efficiency can be enhanced by crossbreeding to acquire the advantage of diversity between rabbit breeds and lines, through complementarity and heterotic effects and to generate new breeds or lines (Balaguer, 2014). In the same context, synthetic lines have been created and adopted as a new strategy to improve rabbit production in hot climate countries, such as Egypt and Saudi Arabia (El-Raffa, 2007; Youssef *et al*., 2008). In Algeria, a new synthetic line has been developed since 2003 by crossbreeding females from the local population with males from the French INRA 2666 strain at the Technical Institute for Animal Production (ITELV) (Gacem and Bolet, 2005); to reach a compromise between the performance of the foreign commercial lines and the adaptation to the heat of the local population (El-Raffa, 2007). The strain has been developed and is now being distributed to Algerian producers through the other experimental rabbitry stations. The selection core is located in Baba Ali, Algiers, Algeria, where the genetic resources are managed. As a matter of fact, in Algeria, many studies were carried out to describe the effects of genotype and crossbreeding parameters on feed and feeding, growth and zootechnical performance of the new synthetic breed (Zerrouki *et al*., 2014; Sid *et al*., 2018; Belabbas *et al*., 2021; Belabbas *et al*., 2023).

Despite this, the new line had not been fully characterized. To the best of our knowledge, there were scarce studies estimating crossbreeding parameters on morphological traits, and meat quality. It is well known that rabbit producers are interested in the relationship that exists between body weight and physical characteristics, since this information would be reflected in their feed efficiency and growth performance and may afford important baseline data for future breed conservation (Adamu *et al*., 2022). In light of these considerations, the present study aimed to investigate the impact of rabbit genotype and sex on morphometric traits, carcass characteristics and chemical composition of the meat of two Algerian rabbit breeds.

MATERIALS AND METHODS

Animals' Raising and Slaughter

A total of 60 rabbits of the Algerian local population and a synthetic breed (30 rabbits per group,1:1 male: female ratio) were used in this experiment. The local population was obtained from the Livestock Technical Institute (ITELV Baba Ali, in northern Algeria).

In our experiment, Natural mating was performed and the animals were reared from birth to slaughter at the experimental rabbitry station of the Technical Institute of Breeding (ITELV), located in Hamma Bouziane. Constantine, Algeria. Station, which received the selection nucleus of the synthetic strain to continue the diffusion phase. Animals of both genders used in this trial were housed in collective flat deck cages (50 x 60 x 53 cm^3, 3 rabbits/cage; 10 cages/group). All cages were equipped with feeding hoppers and drinking nipples. Animals were raised and fattened under identical management conditions. The trial was performed in a ventilated room during march, april and may, temperatures ranged from 20 to 25°C, the animals were subjected to a constant photoperiod of 16L: 8D light cycle during the whole experiment period. Both breeds were fed *ad libitum* with a commercial pelleted diet containing 15% of proteins, 2.5% of fat, 10% of Ash, 12% of cellulose, calcium, phosphorus, vitamins (A, E, D3), salt (NaCl) and Telmcen, Algeria. At the end of the experiment, the groups of animals were slaughtered at the laboratory by cutting the carotid artery and jugular veins at 90 d of age. The study complied with the University of Mentouri Constantine 1 guidelines on ethical standards. The morphometric measuring, slaughtering and carcass dissection procedures followed the recommendations of the World Rabbit Science Association (WRSA), described by Blasco and Ouhayoun (1996).

Carcass Characteristics

Immediately before slaughtering and without prior fasting, the rabbits were weighed (slaughter weight, SW). The slaughtered rabbits were bled, and the skin, genitals, urinary bladder, gastrointestinal tract and distal portions of the legs were removed before being weighted. The carcasses, with the head, thoracic cage organs (heart, lungs, thymus, trachea, and esophagus), liver, kidneys, and the perirenal and scapular fat, were weighed 30 min after slaughter (HCW) and subsequently chilled at 4°C for 24 h. After this time, the weight of the chilled carcasses (CCW) was measured, and the dressing out percentage (DP) (or slaughter yield) was calculated as the ratio between CCW and SW according to the following formula: (CCW/SW)x100. The head, liver, lungs, thymus, esophagus, heart and kidneys were removed from the carcass to obtain the reference carcass weight (RCW), which only contained meat, fat, and bone. As suggested by Honikel (1998), drip loss percentage (DLP) was measured using the whole carcass of each animal, all carcasses were suspended for 24 h at 4° C. Drip loss was the difference between a hot and chilled carcass and were expressed as a percentage of the initial weight: DLP= 100x(HCW-CCW)/HCW. To get a good prediction of the meatiness of the carcass, it is sufficient to calculate the meat to bone ratio of the hind leg (HL), the left HL was deboned to separate bone from meat, and the weight of these parts was recorded according to the following formula: M/B=MW/BW, where M/B is the meat/bone ratio, MW is the meat weight (g), and BW is the bone weight (g) (Pla, 2008). Kidney weight (KiW); liver weight (LvW); thoracic cage organs (thymus, trachea, esophagus, lung and heart weight (TVW) were also recorded. The following traits were recorded: scapular fat weight (SFW); perirenal fat weight (PFW); inguinal fat weight (IFW); the dissectible fat weight (DFW) was the sum of the weights of the perirenal, inguinal and scapular fat deposits (DFW = SFW + PFW + IFW). The carcass was cut between the last thoracic and the first lumbar vertebrae and between the 6th and 7th lumbar vertebrae, resulting in three parts: Fore part weight (FPW); intermediate part weight (IPW); hind part weight (HPW).

Linear Body Measurements (morphometric traits)

Before slaughtering and carcass dissection the following morphometric traits were measured: dorsal length (DL): interval between the atlas vertebra and the 7th lumbar vertebra; lumbar circumference (LC): carcass circumference at the level of the 7th lumbar; loin length (LL): length between the neural spines of first and last lumbar vertebra; hind leg length (HLL): length from the neural spines of last lumbar vertebra to the insertion of the calcaneus communis tendon; head length (HL); distance between the eyes (DE); fore leg round (FLR); Ear length (EL); Ear width (EW); Tail length (TL); chest circumference (ChC).

Meat Chemical Composition

The chemical composition of the meat was analyzed using the hind leg. The samples were stored in plastic bags at -20°C. Total protein (crude protein, N×6.25) content was assessed by the Kjeldahl method according to AOAC 981.10 (AOAC, 2000). Total lipids were extracted by hot treatment with hexane as solvent as described in ISO (1996) and Komprda *et al*. (2012). The ash content was determined by mineralization at 550 °C according to Marra *et al*. (1999) and Komprda *et al*. (2012). To analyze dry matter, samples were oven dried at 105°C to a constant weight (24h) (Petit *et al*., 2014).

Fatty Acids Determination

Lipid extraction was performed on the HL muscle samples by the Soxhlet method as described in ISO (1996) and Komprda *et al*. (2012). The Fatty acid (FAs) content in the HL was the average of three replicates. FAs composition was measured after methylation of samples. Fatty acid methyl esters (FAME) were prepared with boron trifluoride methanol according to Morrison and Smith (1964). The FAME were analyzed using a capillary gas chromatograph (Chrompack CP 9002, The Netherlands) equipped with silica gel capillary column (30 m × 0.32 mm (i.d.), 0.25 µm) coated with a stationary phase of (RTX 2330 90% biscyanopropyl+10% polysiloxane). Azote was the carrier gas. The oven temperature was set from 150 to 230 °C at 4 °C/min. The injector and flame ionization detector (FID) ports were set at 250 °C and 260 °C, respectively. The injected volume was 0.8 µL with a 1:100 split ratio. The individual FAME was identified by reference to the retention time of authentic FAME standards. The relative proportion of each FA in the samples was expressed as a percentage of total FA. The average amount of each FA was used to calculate the sum of the saturated Fatty acids (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs) fatty acids.

Statistical Analysis

The data were analyzed with the statistical software JMP 15 (SAS Institute Inc., Cary, NC, USA). A least square analysis was performed using the general linear model (GLM). The mathematical equation of the model was:

$$Y_{ijk} = \mu + G_i + S_j + GS_{ij} + e_{ijk}$$

where: Y_{ijk} is the dependent variable, µ=population mean, G_i=effect of i^{th} genotype (i=local, synthetic), S_j =effect of j^{th} sex (j= male, female), GS_{ij}=effect of interaction between genetic group and sex, e_{ijk}=random error effect. Residuals were assumed to be independently normally distributed. When statistical differences among groups were found (P<0.05) a Fisher comparison test was used. A Pearson correlation analysis followed by principal component analysis (PCA) was carried out to assess the relationships between morphometric traits and carcass characteristics. Comparison or correlation were considered statistically significant at a level of P<0.05.

RESULTS AND DISCUSSION

Morphological Traits

Generally, morphological traits are the structural form of organisms that are the main source of characteristics of most animal groups (De la Fuente and Rosell, 2012). Hence, data on phenotypic traits are an imperative component of comparative studies of development. Morphometrics permits the rigorous quantitative analysis of variation in organismal size and shape, and is increasingly being used for animal genetic improvement (Klingenberg, 2002). The results of the effect of genotype and sex on morphometric traits of two groups of rabbits are shown in Table 1. As expected, a genetic factor affected most of the morphometric measurements, which were higher in the synthetic line than the local population. However, sex and the interaction of genetics and sex (GxS) had a significant effect only on chest circumference.

The dorsal linear length is considered among the important meat traits, because is associated with the length of the *Longissimus lumborum* muscle, one of the main parts of the rabbit carcass (Blasco Mateu *et al*., 1993). In the present paper, the highest mean value obtained was for DL (32 cm) and CL (33 cm) for synthetic females, while the lowest was obtained in DE (4 cm) for local males. It seems that there was a tendency for the synthetic line and the female rabbits to have a longer liner body parameter (e.g. DL, DE, LC, ChC) than the local breed and the males respectively. The two breed rabbits have similarity only in tail length (P >0.05). In the same context, Adamu *et al*. (2022) in their research had argued that selection for an increase in body weight leads to an increase in body length; which may explain the current findings.

Table 1. Effect of genotype and sex on morphometric traits of two groups of rabbits

Trait (cm)	Local breed		Synthetic line		RMSE	Significance		
	Male (n=15)	Female (n=15)	Male (n=15)	Female (n=15)		Genotype	Sex	GxS
HL	10.47^{c}	10.67^{bc}	11.53^{a}	11.13^{ab}	0.80	***	Ns	Ns
DE	4.80^{b}	4.87^{b}	5.00^{ab}	5.33^{a}	0.49	*	Ns	Ns
LL	18.40^{b}	18.20^{b}	19.60^{a}	19.07^{ab}	1.57	*	Ns	Ns
LC	30.93^{b}	31.53^{b}	32.07^{ab}	33.13^{a}	2.01	*	Ns	Ns
ChC	25.00^{c}	25.40^{c}	26.73^{b}	29.33^{a}	1.71	***	**	*
FLR	5.07^{b}	4.80^{b}	5.47^{a}	5.40^{a}	0.29	***	Ns	Ns
EL	10.33^{c}	10.27^{c}	11.20^{b}	11.80^{a}	0.79	***	Ns	Ns
EW	5.60^{b}	5.60^{b}	5.93^{b}	6.93^{a}	1.34	*	Ns	Ns
HLL	10.73^{b}	10.60^{b}	11.53^{a}	11.33^{a}	0.70	***	Ns	Ns
TL	8.60^{a}	8.67^{a}	8.80^{a}	8.60^{a}	1.21	Ns	Ns	Ns

GxS: genotype x sex interaction; DL= dorsal length ; HL= head length ; DE= distance between the eyes ; LL= loin length ; LC= lumbar circumference ; ChC= chest circumference; FLR= fore leg round ; EL= Ear length ; EW= Ear width ; HLL= hind leg length ;TL= Tail length. RMSE= root mean square error. Means in the same row and effect with unlike superscripts differ at P<0.05. * P < 0.05; ** P < 0.01; *** P < 0.001; Ns= not significant.

Since the present study is the first to analyze the morphometric traits of the Algerian local rabbit population compared with the synthetic one, it was difficult to compare the obtained results with the international literature. The few studies available have often focused on studying a phenotypic correlation between body weight and body measurement (Hassan *et al*., 2012; Adamu *et al*., 2022). A recent study carried out by Setiaji *et al*. (2022a) comprising four rabbit breeds Flemish Giant, English Spot, Angora and Rex of more than 12 months old has shown several differences and similarities in body traits among breeds. The authors have cited different factors like sex, genetic type, environmental conditions and different management conducted by the farmers. In the same context, Brahmantiyo *et al*. (2021), studied morphological characteristics of Hycole, Hyla and New Zealand white rabbits aged 20 weeks old and they found longer DL, EL, EW, head height, chest depth, Radius Ulna, and Femoris than the present paper. The same study has observed a significant effect (*P*<0.05) of GxS interaction on some body traits like: head height, length and width of the ear, chest depth, radius ulna length, and the length of the spine.

In our study, DL and EL values are similar to those recorded by Adamu *et al*. (2022) in their experiment on New Zealand White and Dutch breeds, whereas; HLL and TL values are higher than the ones obtained in our experiment. The two previous studies and the one by Šimek *et al*. (2019) have also found a significant effect of genetic type on the majority of morphometric traits. Another recent paper has noted longer DL and ChC on New Zealand breed of 12 months old, however; HL, EL and EW traits are within the range reported by Setiaji *et al*. (2022b). The differences between the results are properly due to differences in age, rabbit generation, genetic group, feed quality and environmental conditions of animals used in each experiment.

Carcass Characteristics

The results of carcass traits of two rabbit breeds are displayed in Table 2. The majority of carcass characteristics were more affected by genetics than by gender. Body weight at slaughter (SW) at 90 d of age of both groups was significantly influenced by the genotype ($P < 0.001$) and its interaction with sex ($P < 0.01$). The SW of males and females derived from the synthetic line was 41 % and 22 % higher than the local rabbits group respectively. As reported by Šimek *et al*. (2019), the SW in meat-type rabbits is an essential trait of the economy of rabbit meat production. Similar findings were produced by Belabbas *et al*. (2019) using the same breeds at the same age; they found that the synthetic line showed a higher live weight than the local popu-

Table 2. Effect of genotype and sex on carcass characteristics of two breeds of rabbit

Variable	Local breed		Synthetic line		RMSE	Significance		
	Male (n=15)	Female (n=15)	Male (n=15)	Female (n=15)		Genotype	Sex	GxS
SW, (g)	1614.12^{c}	1545.51^{c}	1974.27^{b}	2182.73^{a}	189.9	***	Ns	**
HCW, (g)	911.09^{b}	958.63^{b}	1283.08^{a}	1362.78^{a}	135.39	***	Ns	Ns
CCW, (g)	886.16^{b}	886.92^{b}	1237.04^{a}	1324.26^{a}	122.92	***	Ns	Ns
DP, %	55.12^{c}	57.62^{b}	62.59^{a}	60.65^{a}	3.26	***	Ns	*
DLP, %	2.73^{b}	6.75^{a}	3.54^{b}	2.86^{b}	4.06	Ns	Ns	*
LvW, (g)	56.82^{a}	63.96^{a}	60.31^{a}	55.80^{a}	15.91	Ns	Ns	Ns
KiW, (g)	10.06^{c}	10.24^{c}	12.36^{b}	13.79^{a}	1.44	***	*	Ns
TVW, (g)	3.43^{b}	3.58^{b}	4.36^{a}	4.71^{a}	0.57	***	Ns	Ns
RCW, (g)	704.35^{c}	715.47^{c}	963.16^{b}	1053.47^{a}	108.54	***	Ns	Ns
DFW, (g)	17.40^{b}	23.64^{b}	20.97^{b}	37.45^{a}	10.34	**	***	Ns
M/B, %	10.53^{b}	10.89^{ab}	11.38^{a}	11.15^{ab}	0.87	*	Ns	Ns
FPW, (g)	135.68^{b}	144.95^{b}	204.90^{a}	222.22^{a}	26.04	***	Ns	Ns
IPW, (g)	267.49^{c}	270.97^{c}	347.36^{b}	385.68^{a}	46.17	***	Ns	Ns
HPW, (g)	284.37^{b}	275.27^{b}	399.12^{a}	431.94^{a}	47.17	***	Ns	Ns

GxS= genotype x sex interaction; SW = slaughter weight ; HCW = hot carcass weight ; CCW = chilled carcass weight ; DP= dressing out percentage ; DLP = drip loss percentage ; LvW = liver weight ; KiW = kidney weight ; TVW = thoracic viscera weight ; RCW= reference carcass weight ; DFW= dissectible fat weight ; M/B = meat to bone ratio; Fore (FPW), intermediate (IPW) and hind (HPW) part weight of the carcass. RMSE= root mean square error. Means in the same row and effect with unlike superscripts differ at P<0.05. * P < 0.05; ** P < 0.01; *** P < 0/001; Ns= not significant.

lation (+15%, *P*<0.0001). Similarly, at 12 weeks of age, Metzger *et al*. (2006) studied four different genotypes of rabbits, they found that body weight at slaughter was significantly (*P*<0.001) influenced by the genotype. Besides; their mean values of SW for four groups (2773g; 2655g; 2923g and 2741g) are slightly higher than those recorded in this study (1614 and 1545 g for local males and females, respectively; 1974 and 2182 g for synthetic males and females, respectively). In contrast to the findings of the present study, Wang *et al*. (2016) in their study didn't find any significant difference (*P*>0.05) in SW between the two exotic breeds and the local Chinese breed. Our study shows that values obtained for carcass quality HCW, CCW and RCW were significantly affected by genotype (*P*< 0.001). Carcass weight values of the local rabbits group were lower than those reported in the synthetic rabbit line. Sex did not show any significant effect (*P* > 0.05) on the previous parameters. Our findings coincide with those obtained by Belabbas *et al*. (2019), who noticed that HCW and CCW traits from the synthetic line were heavier than those from the Algerian local population (+15%, *P*<0.0001). Likewise, recent research in Egypt made by Abou-Saleh *et al*. (2022) stated that the differences between means for carcass traits of two groups of rabbits such as: HCW, due to breed effect was not significant. In the same context, Wang *et al*. (2016) have recorded a significant effect of genotype on commercial carcass (%). Although; no effect was registered on the reference carcass (%) of rabbit breeds.

In the present study, significantly (*P* < 0.001), the synthetic line exhibited a good meat yield with higher mean values of DP (62% for male and 60% for female) than those observed for the local rabbits (55% for males and 57% for females). The DP of males and females of the synthetic line was higher by 13% and 5% than those derived from local animals respectively. In addition, a significant effect of G x S interaction was noted on DP. While, no significant effect of sex was observed on this trait in both groups. In this context, previous research made by Metzger *et al.* (2006) has shown that the genotype was found to exert a significant effect on the DP of rabbits. This can be explained by the fact that DP increased usually with weight, age at slaughtering and degree of maturity (Pla *et al*., 1996; Pla *et al*., 1998). In contrast to our findings, Belabbas *et al*. (2019) recorded higher values of DP (67% and 68%) for synthetic and local breeds respectively at similar ages of slaughter, moreover; they didn't find any significant difference between the two former groups in the DP. Likewise; Gál *et al*. (2022) found that the sex of rabbits affected the carcass dressing and a higher level was found in males compared to females (*P* < 0.05). As discussed by Daszkiewicz *et al.* (2012), DP values may vary widely, even in rabbits slaughtered at the same age, influenced by genetic factors, feeding regime, housing conditions and the specific method used for calculation.

Concerning with DLP, no significant difference (*P* > 0.05) was recorded between male and female rabbits of the synthetic and local groups. DLP was observed to be affected by G x S interaction (*P*<0.05), this parameter is essential in determining carcass quality, since it indicates the loss of moisture during the chilling period which may affect meat sensory properties (Ortiz Hernández and Lozano, 2001). Values obtained for KiW and TVW were significantly (*P* < 0.001) affected by genotype. Those two parameters were more developed in the synthetic rabbits than those local ones. Among all carcass traits, only the liver weight parameter did not differ among the two groups and both sexes. Similarly; Yalçin *et al*. (2006) found in their experiment that there were no significant differences in females and males for the weights of the liver organ of New Zealand white rabbits aged 11 weeks. According to Deltoro *et al*. (1984), the liver was defined as an organ with almost isometric growth, which may explain the obtained results. In addition to this, Gomez and Blasco (1992) recorded at a different age of slaughter (60 days) higher mean weight values of different organs from five selected rabbit strains (LvW: 87g; KiW : 14.9g ; TVW : 29g) than those obtained in our study (LvW: 59g; KiWg : 11g ; TVW : 4g). Similarly, our results are in agreement with those of Metzger *et al*. (2006), who found that the ratio of kidney weight to the carcass weight was significantly influenced by the genotype. In disagreement with our results, Pascual and Pla (2007) and Metzger *et al.* (2006) in their research didn't find any relevant differences between groups in TVW and LvW respectively.

Dissectible fat weight of local breed carcasses is observed to be significantly (*P*<0.01) lower when compared to the synthetic line. Sex factor has also highly influenced the DFW (*P* < 0.001), synthetic and local female rabbits have higher fat content than synthetic and local males Similar observations were made by Belabbas *et al*. (2019) and Metzger *et al*. (2006) who found that the weight of the perirenal fat differs significantly among rabbit genotypes. Our results are also similar to those obtained by Hernández *et al*. (2004) who found that female rabbits selected by growth rate had more fat than males.

The M/B ratio in the hind leg is considered as a good predictor of the meat content of the whole carcass (Larzul and Gondret, 2005). In our study, there was a relevant difference (*P* < 0.05) among the genotypes regarding the M/B ratio. The local breed had a lower M/B % (about 10% for males and females) compared with the synthetic line (about 11% for males and females). Distinct values of M/B % were obtained between the two sexes in both groups but differences could not be considered relevant. From this, the local rabbit probably has a lower degree of maturity since M/B % has been seen to increase as rabbits grow and according to the live weight at slaughter (Pla *et al*., 1998; Hernández *et al*., 2004). In disagreement with our results, the research conducted by Belabbas *et al*. (2019) on the same breeds showed that M/B % was similar in both lines.

Differences between genetic types (*P*< 0.001) were also found in the weight of the fore, intermediate and hind parts of the carcass, it was more developed in synthetic lines than the local one. Although, no sex effect (*P* > 0.05) on those parameters in both groups was observed. Similar observations were made by many authors in several studies where the animals' genotypes significantly influenced the different retail cuts of the carcass (Metzger *et al*., 2006; Tůmová *et al*., 2014; Belabbas *et al*., 2019). In contrast to our results, Pla *et al*. (1998) have found differences between sexes in the percentage of the HPW of three lines, and it was more developed in males than females (38.5% and 37.8%, respectively).

Biochemical Traits of Rabbit Meat

Proximate chemical composition of rabbit hind leg muscle of two breeds is presented in Table 3. Sex had no effect (P>0.05) on the major chemical component content in rabbit meat except for ash content (P < 0.05). A higher value of ash content was found in females compared to males in both groups. In the same context; there was no difference among the genotypes regarding protein, ash, and moisture content (P > 0.05). A significant effect of breed (P < 0.05) and of G x S interaction (P < 0.05) was observed on the content of fat and ash respectively. The higher value of fat content was observed in the synthetic line (+13 % and +62%) between males and females of synthetic and local breeds, respectively, which contributed to the higher energy value of meat produced by this breed. It also appears that protein percentage was 1% lower in the local population of rabbits; but differences could not be considered relevant. Our results about the approximate chemical composition of the analyzed muscle for the local and synthetic breeds were very close to those observed in many studies (Metzger *et al*., 2006; Tůmová *et al*., 2014; Molina *et al*., 2018; Belabbas *et al*., 2019; Abou-Saleh *et al*., 2022). In addition to this; several authors have tried to compare the chemical composition of HLM between males and females and among different rabbit genotypes; for instance, Gál *et al*. (2022) found that genotype influenced only the ash content; whereas a significant effect of G x S interaction was observed on the content of crude protein and ash (P < 0.001). Daszkiewicz and Gugołek (2020) in their research revealed that breed had a significant effect on protein content. Although; the sex factor did not affect the major chemical components content in rabbit meat. Similarly, Belabbas *et al*. (2019) in their trial using the same breeds and the same age as the present study reported that fat and protein content were influenced by the genotype. In agreement with our finding, fat content was higher in the synthetic line than in the local population (+35%). By contrast, the former study observed that the synthetic line had a lower value of protein content.

Fatty Acids Composition

Fatty acids composition (FAs) of HL muscle of rabbit meat is given in Table 4. As expected rabbit meat has a high concentration of unsaturated fatty acids (UFAs) with an average mean of 56 % for the two studied groups of animals. According to most data of the literature and from the nutritional viewpoint, rabbit meat has high nutritional value as a result of its lipid component, characterized by comparatively low fat and cholesterol levels, higher unsaturated fatty acids (UFAs) (60% of all FAs) and the best ratio of n-6/n-3 (Dalle Zotte, 2002; Dalle Zotte and Szendrő, 2011; Petrescu and Petrescu-Mag, 2018).

From the current study, it was observed that the UFAs were the predominant fatty acid group with average percentages of 52.08 % for males and 61.54% for females) and (55.53 % for male and 55.14 % for female, respectively for local and synthetic. Due to the significant difference in the proportion of linoleic acid and α-linolenic acid, the meat of the local population had a higher content of (n3 PUFAs) and (n6 PUFAs), re-

Table 3. Effect of genotype and sex on biochemical composition of hind leg muscle of local and synthetic breed of rabbit

Variable (%)	Local breed		Synthetic line		RMSE	Significance		
	Male (n=15)	Female (n=15)	Male (n=15)	Female (n=15)		Genotype	Sex	GxS
Protein	20.67^{a}	20.59^{a}	21.54^{a}	21.93^{a}	2.19	Ns	Ns	Ns
Fat	4.63^{ab}	2.49^{b}	5.33^{ab}	6.71^{a}	3.23	*	Ns	Ns
Moisture	77.68^{a}	76.15^{a}	76.66^{a}	76.12^{a}	3.63	Ns	Ns	Ns
Ash	1.35^{b}	2.41^{a}	1.62^{b}	1.66^{b}	0.65	Ns	*	*

GxS= genotype x sex interaction; RMSE= root mean square error. Means in the same row and effect with unlike superscripts differ at P<0.05. * P < 0.05; Ns= not significant.

Table 4. Fatty acid composition (% of total fatty acids) in hind leg meat in female and male local and synthetic rabbit breeds

Variable (%)	Local breed		Synthetic line		RMSE	Significance		
	Male (n=15)	Female (n=15)	Male (n=15)	Female (n=15)		Genotype	Sex	GxS
C12 :0 lauric acid	0.61^{a}	0.15^{bc}	0.13^{c}	0.39^{b}	0.1	*	NS	***
C14 :0 myristic acid	3.93^{a}	2.53^{b}	2.55^{b}	2.29^{b}	0.68	NS	NS	NS
C15 :0 pentadecanoic acid	0.55^{a}	0.46^{a}	0.54^{a}	0.58^{a}	0.17	NS	NS	NS
C16 :0 palmitic acid	25.40^{b}	25.20^{b}	28.69^{a}	26.66^{b}	0.86	**	NS	NS
C17 :0 marga	0.54^{b}	0.62^{ab}	0.80^{a}	0.62^{ab}	0.11	NS	NS	NS
C18 :0 stearic acid	4.43^{b}	5.94^{a}	5.86^{a}	6.28^{a}	0.45	**	**	NS
C20 :0 arachidic acid	0.15^{c}	0.15^{c}	0.39^{a}	0.26^{b}	0.02	***	**	**
∑ SFA	35.61^{ab}	35.05^{b}	38.96^{a}	37.08^{ab}	1.96	*	NS	NS
C14 : 1ω9 tetradecenoic acid	0.44^{a}	0.34^{ab}	0.25^{b}	0.33^{ab}	0.08	NS	NS	NS
C16 : 1ω9 hypogeic acid	Traces^{d}	0.47^{b}	0.66^{a}	0.21^{c}	0.05	***	NS	***
C16 : 1ω7 palmitoleic acid	4.40^{a}	4.11^{ab}	3.99^{ab}	3.60^{b}	0.36	NS	NS	NS
C18 : 1ω9 oleic acid	20.86^{c}	27.56^{a}	27.56^{a}	22.67^{b}	0.68	NS	NS	***
C20 : 1ω9 gadoleic acid	0.33^{a}	0.51^{a}	0.51^{a}	0.42^{a}	0.12	NS	NS	NS
C24 : 1ω9 nervonic acid	0.35^{a}	0.28^{a}	0.28^{a}	0.20^{b}	0.04	*	*	NS
∑ MUFA	26.38^{b}	33.27^{a}	33.25^{a}	27.43^{b}	1.65	NS	NS	***
C18 : 2 n-6 linoleic acid	19.61^{b}	22.65^{b}	18.98^{b}	20.23^{a}	0.75	**	**	NS
C18 : 3 n-6 linolénique	0.31^{a}	0.15^{b}	0.14^{b}	Trace	0.01	***	***	NS
C20 :2 n-6 eicosadienoic acid	0.16^{bc}	0.12^{c}	0.19^{b}	0.43^{a}	0.02	***	***	***
C20 :3 n-6 eicosatrienoic acid	0.38^{a}	0.17^{b}	0.09^{c}	0.14^{bc}	0.03	***	**	***
C20 :4 n-6 arachidonic acid	1.11^{b}	1.28^{b}	0.51^{c}	3.43^{a}	0.19	***	***	***
C22 :5 n-6 eicosapentaenoic acid	1.94^{a}	1.05^{b}	0.55^{c}	1.22^{b}	0.20	**	NS	***
∑n6 PUFA	23.51^{a}	25.42^{a}	20.46^{b}	25.45^{a}	1.61	NS	**	NS
C18 :3 n-3 α-linolenic acid	1.41^{a}	1.73^{a}	1.58^{a}	0.87^{b}	0.19	*	NS	**
C20 :5 n-3 eicosapentaenoic acid (EPA)	0.42^{a}	0.45^{a}	0.12^{b}	0.14^{b}	0.06	***	NS	NS
C22 :6 n-3 docosahexaenoic acid (DHA)	0.36^{c}	0.67^{b}	0.12^{d}	1.25^{a}	0.01	***	***	***
∑n3 PUFA	2.19^{a}	2.85^{a}	1.82^{a}	2.26^{a}	0.87	NS	NS	NS
∑ PUFAs	25.7^{ab}	28.27^{a}	22.28^{b}	27.71^{a}	1.94	NS	**	NS
∑ UFAs	52.08^{c}	61.54^{a}	55.53^{b}	55.14^{b}	1.09	*	***	***
PUFAs/SFAs	0.66^{c}	0.80^{a}	0.57^{d}	0.74^{b}	0.02	**	***	NS
PUFA (n−6/n−3)	10.73^{a}	8.91^{b}	11.24^{a}	11.26^{a}	0.63	**	*	*

GxS= genotype x sex interaction; SFA= saturated fatty acids; MUFA= monounsaturated fatty acids; PUFA= polyunsaturated fatty acids; n3 PUFA= polyunsaturated fatty acids series n-3; n6 PUFA= polyunsaturated fatty acids series n-6.
RMSE= root mean square error. Means in the same row and effect with unlike superscripts differ at P<0.05. * $P < 0{,}05$; ** $P < 0{,}01$; *** $P < 0{,}001$; Ns= not significant.

spectively. In the same context, the synthetic line was richer in both SFAs and MUFAs and poorer in PUFAs in comprising the local rabbits. The saturated fatty acids (SFAs) pattern was characterizby three dominant SFAs: palmitic acid (PA, C16:0); stearic acid (ST, C18:0); and Myristic acid (MA, C14 :0). PA, ST and MA acids ranged from (25 to 28)%; (4 to 6)%; and (2 to 3)%; of total FAs, respectively. The most representative monounsaturated fatty acids (MUFAs) were oleic acid (OA, C18 : 1ω9) and palmitoleic acid (PA, C16 :1) with average concentrations of (20 to 27)% and (3 to 4)% of total FAs, for both groups and sexes respectively. According to Combes (2004), rabbit meat is rich in oleic (C18:1n-9) and palmitoleic (C16:1) FA and their sum is higher than 20% of all FA. Moreover, the pattern of (n6 PUFA) was characterized by one dominant PUFA: linoleic acid (LA, C18:2n-6), percentages of this FA oscillated around 18-22% of total FAs for both groups and sexes. Concerning the (n3 PUFA), it was found that α-linolenic acid (LnA ,C18 :3 n-3) was the most representative n3 PUFA with an average mean of 1.39 % of total FAs. It should be noted that the n-6:n-3 ratio was higher in the synthetic group and varied from (8.91 and 10.73) and (11.24 and 11.26) for local and synthetic lines, respectively ($p < 0.01$). Additionally, a significant difference ($P < 0.01$) was also recorded between the two studied groups in terms of PUFAs/SFAs ratio in which, the meat of local rabbit has a high level of PUFAs/SFAs in comprising with a synthetic one. As reported by D.H.S.S (1994), the optimal value of the n-6:n-3 ratio varies from 1 to 4, and a ratio of 0.45 or higher for PUFA/SFA. However, in our case both genotypes and sexes exhibited a higher content than the recommended value of n-6:n-3 ratio. It is properly due to the diet content of FAs which may have much higher n6 PUFAs than n3 PUFAs as explained by Mínguez *et al*. (2017) in their study. While; the PUFA/SFA ratio obtained in the current study was both higher than 0.45, hence; the meat analyzed has a good quality. These indexes can be used to evaluate the nutritional quality of the meat and perirenal fat of rabbits and to describe the dietetic value for human consumption (Peiretti *et al*., 2011). It should be noted that the FAs profile of rabbit meat is largely influenced by various factors including diet, genotype, sex, breeding and/or physical activity and anatomical location (Gasperlin *et al*., 2006; Peiretti, 2012; Yonkova *et al*., 2017). Accordingly, our findings are different in terms of SFAs and UFAs total content than those obtained by Daszkiewicz and Gugołek (2020) on *Longissimus thoracis* and *lumborum* muscle; in which they recorded SFAs ranged from 45.85% to 49.39%, and UFAs ranged from 54.15% to 50.61% in Californian and Flemish Giant Gray Rabbits. Whereas; our results concerning MUFAs, PUFAs and UFAs are higher than those registered by Daszkiewicz *et al*. (2021) using the same muscle in New Zealand White rabbit.

On the whole, the genotype and GxS interaction has affected the most representative FAs especially (n3 PUFAs) and (n6 PUFAs), ($P < 0.05$). Similarly; Daszkiewicz and Gugołek (2020) in their study noted that breed affected the concentration of lauric acid, pentadecanoic acid, margaric acid, stearic acid, and arachidic acid. Regarding the effect of gender, the SFAs and MUFAs profiles of rabbit meat were similar in males and females of both breeds, a significant difference was observed only in the concentrations of stearic acid ($P < 0{,}01$) ; arachidic acid ($P < 0{,}01$); and nervonic acid ($P < 0{,}05$), whereas the majority of n6 PUFAs and n3 PUFAs proportions were affected by sex of animals except for eicosapentaenoic acid (C22 :5 n-6), α-linolenic acid and eicosapentaenoic acid (C20 :5 n-3). By contrast; Gasperlin *et al*. (2006) in their study, demonstrated that neither genotype nor sex exerted significant effects on the fatty acid composition of rabbit meat expect for palmitoleic FA content.

Correlations and PCA

The relationship between morphometric measurements and carcass characteristics of rabbit meat from local and synthetic breeds is presented in Table 5. The correlation between the different measurements in this study was observed to be positive and highly significant ($P<0.05$). The DL has a considerable influence on many carcass traits, for example; DL was positively correlated with SW (r= 0.97); HCW, CCW, RCW, TVW (r= 0.99), KiW (r= 0.98).etc. It also appears that SW has many correlated relationship with several variables such us: HCW(r= 0.97) ; CCW(r= 0.98) ; RCW(r= 0.99) ; KiW(r= 0.99) ; TVW(r= 0.98) ; FPW(r= 0.97); IPW and HPW (r= 0.99). Similar to the current results, Dalle Zotte (2002) reported a direct relationship between body weight at slaughter and carcass weights (HCW, CCW, RCW). In the present study a high positive value of correlation was observed between LD and SW (r= 0.97), this value is higher than those obtained by Adamu *et al*. (2022) (r= 0.70) and Akinsola *et al*. (2014) (r= 0.94). Our results indicate also that as LL and body weight increase, traits also increase. In the same context, Adamu *et al*. (2022) concluded that selection for an increase in body weight leads to an increase in body length. Correlations observed in this study were in line with those recorded by several papers. A study carried out by Yalçin *et al*. (2006) revealed that carcass length was correlated ($P<0.01$) positively with

Table 5. Pearson's correlation coefficients between morphological traits and carcass characteristics of rabbit meat from local and synthetic breed

Variable	DL	HL	DE	LL	LC	ChC	FLR	EL	EW	HLL	SW	HCW	CCW	DP%	DLP	KiW	TVW	RCW	DFW	Mb%	FPW	IPW	HPW
DL	1																						
HL		1																					
DE			1																				
LL		0.95		1																			
LC			0.98		1																		
ChC			0.99		0.98	1																	
FLR							1																
EL	0.97					0.96		1															
EW			0.98			0.98			1														
HLL				0.98			0.96			1													
SW	0.97							0.99			1												
HCW	0.99							0.97			0.97	1											
CCW	0.99							0.98			0.98	0.99	1										
DP%		0.98												1									
DLP															1								
KiW	0.98		0.95		0.96	0.96		0.99			0.99	0.98	0.98			1							
TVW	0.99				0.95			0.98			0.98	0.99	0.99			0.99	1						
RCW	0.99							0.99			0.99	0.99	0.99			0.99	0.99	1					
DFW																			1				
Mb%		0.96												0.99						1			
FPW	0.99							0.97			0.97	0.99	0.99			0.98	0.99	0.99			1		
IPW	0.99					0,95		0.99			0.99	0.99	0.99			0.99	0.99	0.99				1	
HPW	0.98							0.98			0.99	0.99	0.99			0.98	0.98	0.99				0.99	1

DL= dorsal length ; HL= head length ; DE= distance between the eyes ; LL= loin length ; LC= lumbar circumference ; ChC= chest circumference; FLR= fore leg round ; EL= Ear length ; EW= Ear width ; HLL: hind leg length; SW = slaughter weight ; HCW = hot carcass weight ; CCW = chilled carcass weight ; DP= dressing out percentage ; DLP = drip loss percentage ; KiW = kidney weight ; TVW = thoracic viscera weight ; RCW= reference carcass weight ; DFW = dissectible fat weight ; M/B = meat to bone ratio; Fore (FPW), intermediate (IPW) and hind (HPW) part weight of the carcass.

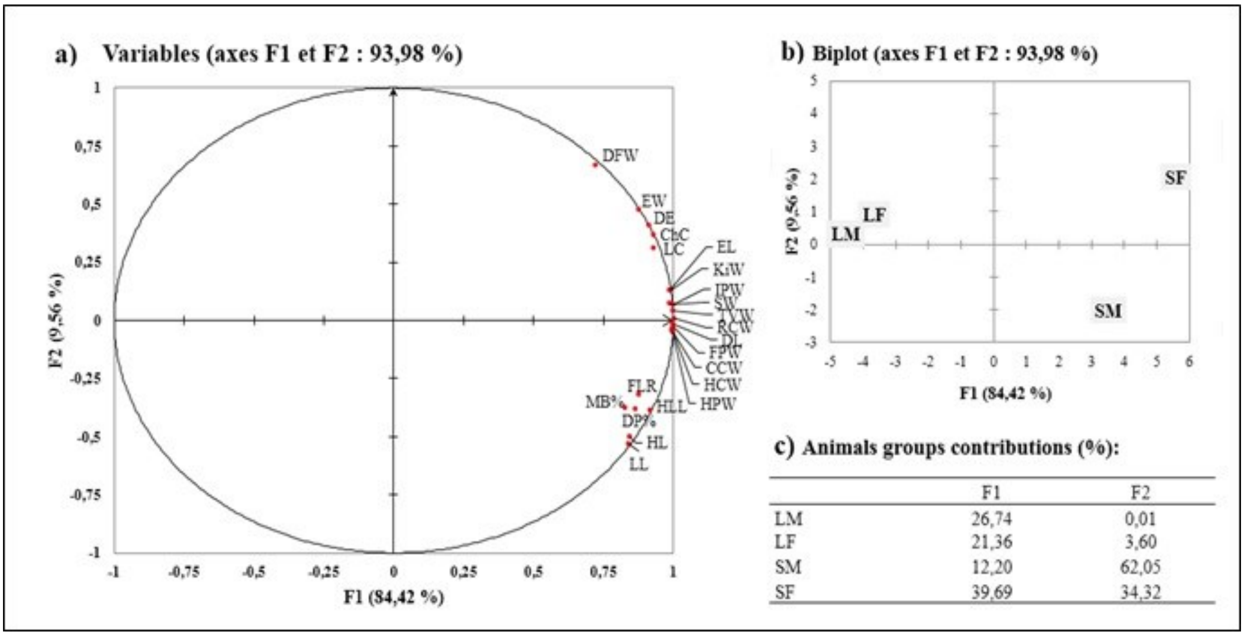

Figure 1. Principal component (PC) analysis of morphological traits and carcass characteristics of rabbit. a) Projection of the studied variables in the two first components. b) Bi-plot of the animal groups observations on the two first principal components. c) Animals groups contributions (%).

SM= Synthetic male; SF= Synthetic female; LM= local male ; LF= local female; DL= dorsal length ; HL= head length ; DE= distance between the eyes ; LL= loin length ; LC= lumbar circumference ; ChC= chest circumference; FLR= fore leg round ; EL= Ear length ; EW= Ear width ; HLL= hind leg length; SW = slaughter weight ; HCW = hot carcass weight ; CCW = chilled carcass weight ; DP= dressing out percentage ; KiW = kidney weight ; TVW = thoracic viscera weight ; RCW= reference carcass weight ; DFW = dissectible fat weight ; M/B = meat to bone ratio; Fore (FPW), intermediate (IPW) and hind (HPW) part weight of the carcass.

carcass weight and dressing percentages and negatively with lumbar circumference. Zepeda-Bastida *et al*. (2019) recorded higher positive correlations between hot carcass and live weight (0.917), skin (0.79), foot (0.58) and lumbar circumference of the carcass (0.707). Moreover, Adamu *et al*. (2022) reported a positive and highly significant (P<0.01) correlation between leg length, tail length, nose to shoulder length and leg length. As the present study has found, several findings reported in the literature review showed that animal morphometric measures are highly correlated to carcass characteristics (Okoro *et al*., 2010; Afolabi *et al*., 2012). Hence, rabbit linear measurement should be used for predicting carcass quality and for choosing animals for meat production in selected markets (Zepeda-Bastida *et al*., 2019).

To facilitate the interpretation of the correlations, a principal component analysis (PCA) of morphometric measurement and carcass characteristics was performed and displayed in among Figure 1a, which shows the projection of the variables on the plane defined by the two principal components, which explained more than 93% of the total variation. The first principal component accounted for 84 % of the total variability. The predominant variables defining this axis are : DL, SW, HCW, CCW, EL, KiW, TVW, DFW, FPW, IPW, etc. The former traits were highly and positively correlated amongthemselves. Additionally; they were far from the origin and close to the axis, but negatively correlated with DLP located on the negative part of the figure. Whereas, the second dimension explained 9% of the variability and was mostly by HLL, LL, LC, FLR, DFW, EW, etc. It seems that carcass characteristics of rabbits contributed mostly describing the first PC *i.e.* they explained a large part of the observed variation, while the morphological measurements defined typically the second factor. By plotting the parameters scores for PC1 and PC2, it can be noted two distinctive groups according to genetic type and sex (Figure 1b).

The first two axes were able to discriminate between the two genetic groups and between males and females for the selected variables. The synthetic breed animals are grouped on the right side and the local ones are on the left side in the upper part of the figure. According to Figure 1 (b and c) we find that animals of both breeds are located near the 1st PC and contributed roughly to its definition. While, the 2nd PC (2nd factor) was strongly represented by the Synthetic breed (96% of the total contribution). The results from PCA emphasize the differences previously obtained between the two groups of animals studied and reveal the most effective variables and the relationships between them.

CONCLUSION

Based upon the results of this experiment, it could be concluded that the significant differences observed between the two studied groups are assumed to be the consequence of the genetic factor and heterotic effects. Although, the sex factor does not have a pronounced effect on the evaluated variables, probably because there was not a complete sexual dimorphism at this age. Differences in the degree of maturity between the breeds were important in affecting the majority of morphometric characteristics, carcass trait weights and meat quality. It should also be noted, that synthetic line has a high genetic potential compared to the local ones. Consequently, it had the best carcass traits with the highest slaughter weight which is important from a production point of view and also interesting biochemical meat content. However, the local population was characterizing by a more desirable fatty acid composition. Our findings have contributed to characterize the synthetic line as well as it would be recommended that rabbit breeders should consider the achieved results to gain these advantages.

ACKNOWLEDGEMENTS

We are very grateful to the ITELV and especially to Ghania Zitouni, (ITLEV, Algiers) and Khalfaoui Zakaria (ITLEV, Constantine) for their valuable contribution to this study. Special thanks to Mrs Fiarouz DJEGHIM (Teacher Researcher, Laboratoire de Nutrition et Technologie Alimentaire, INATAA, Université des Frères Mentouri, Constantine 1) for her contribution in statistical analysis. This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Abdel-Azeem, A., A. M. Abdel-Azim, A. A. Darwish and E. M. Omar. 2007. Litter traits in four pure breeds of rabbits and their crosses under prevailing environmental conditions of Egypt. The 5th inter. Con. on Rabbit Prod. in Hot Clim., Hurghada, Egypt. 39-51.

Abou-Saleh, R., A. Soliman, M. El-Mahdy and T. Hassan. 2022. Influence of Weaning Age and Housing System on Carcass Traits and Meat Quality of V-Line and Moshtohor Rabbits. Annals Agric. Sci. Moshtohor. 60 (4).

Adamu, J., A. Adam, A. Yahaya, A. Raji, H. Abbaya and I. Ogu. 2022. Phenotypic correlation of body weight and morphometric measurements of two breeds of rabbit. J. Anim. Sci. Vet. Med. 7(1):1-5.

Afolabi, K., P.O. Orimoloye, A.A. Awah, B.C. Lalabe and F.O. Odekina. 2012. Estimation of inter-relationship between body weight and morphometric structural measurements of domestic rabbits reared under matured rubber plantation. World J. Young Researchers. 2:83-87.

Akinsola, O., B. Nwagu, M. Orunmuyi, G. Iyeghe-Erakpotobor, E. Eze, A. Shoyombo, E. Okuda and U. Louis. 2014. Prediction of bodyweight from body measurements in rabbits using principal component analysis. Sci. J. Anim. Sci. 3:15-21.

AOAC. 2000. Association of Official Analytical Chemists, Official methods of analysis of AOAC international (17th edition). USA.

Balaguer, C. M. 2014. Genetic Analyses of Growth, Carcass and Meat Quality Traits in Maternal Lines of Rabbits and Their Diallel Cross/Análisis Genético de Caracteres de Crecimiento, Matadero y Calidad de Carne en Lineas Maternales de Conejo y en su Cruzamiento Dialélico, Universitat Politècnica de València.

Belabbas, R., M. de la Luz García, H. AinBaziz, A. Berbar and M. J. Argente. 2021. Litter size component traits in two Algerian rabbit lines. *World Rabbit Sci.* 29(1):51-58.

Belabbas, R., M. de la Luz García, H. Ainbaziz, N. Benali, A. Berbar, Z. Boumahdi and M.J Argente. 2019. Growth performances, carcass traits, meat quality, and blood metabolic parameters in rabbits of local Algerian population and synthetic line. Vet. World 12. 55.

Belabbas, R., R. Ezzeroug, M. L. García, A. Berbar, G. Zitouni, D. Talaziza, Z. Boudjella, N. Boudahdir, S. Dis and M. J. Argente. 2023. Prenatal factors affecting the probability of survival between birth and weaning in rabbits. World Rabbit Sci. 31: 11-20.

Blasco, A. and J. Ouhayoun. 1996. Harmonization of criteria and terminology in rabbit meat research. Revised proposal. World rabbit Sci. 4.

Blasco Mateu, A., J. Ouhayoun and G. Masoero. 1993. Harmonization of criteria and terminology in rabbit meat research. World Rabbit Sci. 1.

Brahmantiyo, B., H. Nuraini, A. W. Putri, M. Mel and C. Hidayat. 2021. Phenotypic and morphometric characterization of Hycole, Hyla and New Zealand White rabbits for KUAT hybrid (tropical adaptive and superior rabbit). Sarhad J. Agric. 37:09-15.

Combes, S. 2004. Valeur nutritionnelle de la viande de lapin. INRAE Productions Animales 17:373-383..

Dalle Zotte, A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. Livest. Prod. Sci. 75:11-32.

Dalle Zotte, A. and Z. Szendrő. 2011. The role of rabbit meat as functional food. Meat Sci. 88:319-331.

Daszkiewicz, T. and A. Gugołek. 2020. A comparison of the quality of meat from female and male Californian and Flemish Giant Grey rabbits. Animals. 10: 2216.

Daszkiewicz, T., A. Gugołek, P. Janiszewski, D. Kubiak and M. Czoik. 2012. The effect of intensive and extensive production systems on carcass quality in New Zealand White rabbits. World Rabbit Sci. 20:25-33.

Daszkiewicz, T., A. Gugołek, D. Kubiak, K. Kerbaum and E. Burczyk. 2021. The fatty acid profile of meat from New Zealand White rabbits raised under intensive and extensive production systems. Animals. 11:3126.

De la Fuente, L. and J. Rosell. 2012. Body weight and body condition of breeding rabbits in commercial units. J. Anim. Sci. 90:3252-3258.

Deltoro, J., A.M. Lopez and A. Blasco. 1984. Alometrías de los principales componentes corporales, tejidos y medidas de la canal en conejo. I, Proceedings of the 3rd World Congress of Cuniculture, Rome, pp. 570-577.

El-Raffa, A. 2007. Formation of a rabbit synthetic line (Alexandria line) and primary analysis of its productive and reproductive performance. Egypt. Poult. Sci., 27(2):321 334.

FAO, 2021. Données statistiques de la FAO, domaine de la production agricole: Division de la statistique.

Gacem, M. and G. Bolet. 2005. Création d'une lignée issue du croisement entre une population locale et une souche européenne pour améliorer la production cunicole en Algérie. Proc.: 11èmes Journées de la Recherche

Cunicole, 29-30 November, 2005. Paris, France. 15-18.

Gál, R., D. Zapletal, P. Jakešová and E. Straková. 2022. Proximate chemical composition, amino acids profile and minerals content of meat depending on carcass part, sire genotype and sex of meat rabbits. Animals. 12: 1537.

Gasperlin, L., T. Polak, A. Rajar, M. Skvarèa and B. Zlender. 2006. Effect of genotype, age at slaughter and sex on chemical composition and sensory profile of rabbit meat. World rabbit sci. 14.

Gomez, E. and A. Blasco. 1992. Growth curves of lines selected on growth rate or litter size. J. Appl. Rabbit Res. 15:872-872.

Hassan, H., K. Elamin, I. Yousif, A. Musa and M. Elkhairey. 2012. Evaluation of body weight and some morphometric traits at various ages in local rabbits of Sudan. J. Anim. Sci. Adv. 2:407-415.

Hernández, P., S. Aliaga, M. Pla and A. Blasco. 2004. The effect of selection for growth rate and slaughter age on carcass composition and meat quality traits in rabbits. J. Anim. Sci. 82:3138-3143.

Honikel, K. O. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49(4):447-457.

ISO, 1996. Meat and meat products - Determination of free fatty acids. ISO, 1444: 1996 (F).

Klingenberg, C. P. 2002. Morphometrics and the role of the phenotype in studies of the evolution of developmental mechanisms. Gene. 287(1-2), 3-10.

Komprda, T., J. Kuchtík, A. Jarošová, E. Dračková, L. Zemánek and B. Filipčík. 2012. Meat quality characteristics of lambs of three organically raised breeds. Meat Sci. 91:499-505.

Larzul, C. and F. Gondret. 2005. Aspects génétiques de la croissance et de la qualité de la viande chez le lapin. Productions animales. 18:119-129.

Marra, A.I., A. Salgado, B. Prieto and J. Carballo. 1999. Biochemical characteristics of dry-cured lacón. Food Chem. 67:33-37.

Metzger, S., M. Odermatt, Z. Szendrő, M. Mohaupt, R. Romvari, A. Makai, E. Biro-Nemeth, I. Radnai and L. Sipos. 2006. Comparison of carcass traits and meat quality of Hyplus hybrid, purebred Pannon White rabbits and their crossbreds. Arch. Anim. Breed. 49:389-399.

Mínguez, C., J. Sánchez, P. Hernández, M. Ragab, A.E. Nagar and M. Baselga. 2017. Genetic analysis of meat quality traits in maternal lines of rabbit and their diallel cross. Meat sci. 131: 1-8.

Molina, E., P. González-Redondo, R. Moreno-Rojas, K. Montero-Quintero and A. Sánchez -Urdaneta. 2018. Effect of the inclusion of Amaranthus dubius in diets on carcass characteristics and meat quality of fattening rabbits. J. Appl. Anim. Res. 46:218-223.

Morrison, W. R. and L. M. Smith. 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride–methanol. J. Lipid Res. 5(4):600-608.

Morshdy, A. E., W. S. Darwish, E. S. El Sebay, and E. Ali. 2022. Amino acid profile of rabbit meat: dietary intake and the effect of freezing on the amino acid composition. Thai J. Vet. Med. 52:251-258.

Okoro, V., C. Ezeokeke, U. Ogundu and C. Chukwudum. 2010. Phenotypic correlation of bodyweight and linear body measurement in Chinchilla rabbits (*Orycotolagus cuniculus*). J. Agric. Biotech. Sustain. Dev. 2:27.

Ortiz Hernández, J. and R. Lozano. 2001. Effect of breed and sex on rabbit carcass yield and meat quality. World Rabbit Sci. 9.

Para, P.A., S. Ganguly, R. Wakchaure, R. Sharma, T. Mahajan and P.K. Praveen. 2015. Rabbit meat has the potential of being a possible alternative to other meats as a protein source: A brief review. Int J Phar Biomedi Res. 2:17-19.

Pascual, M. and M. Pla. 2007. Changes in carcass composition and meat quality when selecting rabbits for growth rate. Meat Sci. 77:474-481.

Peiretti, P., L. Gasco, A. Brugiapaglia and F. Gai. 2011. Effects of perilla (*Perilla frutescens*

L.) seeds supplementation on performance, carcass characteristics, meat quality and fatty acid composition of rabbits. Livestock Sci. 138:118-124.

Peiretti, P. G. 2012. Effects of dietary fatty acids on lipid traits in the muscle and perirenal fat of growing rabbits fed mixed diets. Animals. 2:55-67.

Petit, T., Y. Caro, A.-S. Petit, S. J. Santchurn and A. Collignan. 2014. Physicochemical and microbiological characteristics of biltong, a traditional salted dried meat of South Africa. Meat sci. 96:1313-1317.

Petrescu, D. C. and R. M. Petrescu-Mag. 2018. Consumer behavior related to rabbit meat as functional food. World Rabbit Sci. 26: 321-333.

Pla, M. 2008. A comparison of the carcass traits and meat quality of conventionally and organically produced rabbits. Livest. Sci. 115:1-12.

Pla, M., L. Guerrero, D. Guardia, M. Oliver and A. Blasco. 1998. Carcass characteristics and meat quality of rabbit lines selected for different objectives: I. Between lines comparison. Livest. Prod. Sci. 54:115-123.

Pla, M., P. Hernández and A. Blasco. 1996. Carcass composition and meat characteristics of two rabbit breeds of different degrees of maturity. Meat Sci. 44:85-92.

Rotolo, L., F. Gai, S. Nicola, I. Zoccarato, A. Brugiapaglia and L. Gasco. 2013. Dietary supplementation of oregano and sage dried leaves on performances and meat quality of rabbits. J. Integr. Agric. 12:1937-1945.

Setiaji, A., S. Sutopo, D. Lestari, E. Kurnianto and M. Novianti. 2022[a]. Morphometric characterization of New Zealand white rabbit raised at different areas. Online J. Anim. Feed Res. 12:350-355.

Setiaji, A., Lestari, D. A., Kurnianto, E., and Sutopo, S. 2022[b]. Morphometric traits of imported rabbits and their progenies. J. Advanced Vet. Res. 12(3):217-220.

Sid, S., M. Benyoucef, H. Mefti-Korteby and H. Boudjenah. 2018. Performances de reproduction des lapines de souche synthétique et de population blanche en Algérie. Livest. Res. Rural Dev. 30.

Šimek, V., M. Sedláková, A. Softić and D. Zapletal. 2019. The comparison of the selected morphometric traits in three medium-sized rabbit breeds. Acta fytotech zootech. 22:138-143.

Tůmová, E., Z. Bízková, V. Skřivanová, D. Chodová, M. Martinec and Z. Volek. 2014. Comparisons of carcass and meat quality among rabbit breeds of different sizes, and hybrid rabbits. Livest. Sci. 165:8-14.

Wang, J., Y. Su, M.A. Elzo, X. Jia, S. Chen and S. Lai. 2016. Comparison of carcass and meat quality traits among three rabbit breeds. Korean J. Food Sci. Anim. Resour. 36:84.

Yalçin, S., E. Onbasilar and I. Onbasilar. 2006. Effect of sex on carcass and meat characteristics of New Zealand White rabbits aged 11 weeks. Asian-Australas. J. Anim. Sci. 19:1212-1216.

Yonkova, P., G. Mihaylova, S. Ribarski, V. Doichev, R. Dimitrov and M. Stefanov. 2017. Fatty acid composition of subcutaneous and visceral fat depots in New Zealand White rabbits. Bulg. J. Vet. Med. 20.

Youssef, Y., M. Iraqi, A. El-Raffa, E. Afifi, M. Khalil, M. García and M. Baselga. 2008. A joint project to synthesize new lines of rabbits in Egypt and Saudi Arabia: emphasis for results and prospects, Proc. 9th World Rabbit Congress, Citeseer. 1637-1642.

Zepeda-Bastida, A., M.A. Martínez and S.S. Simental. 2019. Carcass and meat quality of rabbits fed Tithonia tubaeformis weed. Rev. Bras. de Zootec. 48.

Zerrouki, N., F. Lebas, M. Gacem, I. Meftah and G. Bolet. 2014. Reproduction performances of a synthetic rabbit line and rabbits of local populations in Algeria, in 2 breeding locations. World Rabbit. Sci. 22:269-278.