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GENETIC VARIATION IN THE OVINE FATTY ACID BINDING PROTEIN-4 (FABP4) GENE AND ITS ASSOCIATION WITH LIVE PERFORMANCE AND CARCASS TRAITS IN EGYPTIAN OSSIMI LAMBS

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ABSTRACT: The objectives of this study were to identify the allelic and genotypic polymorphisms of fatty acid binding protein 4 (FABP4) gene and its association with growth traits (weaning weight, post-weaning daily gain and marketing weight), feed efficiency traits (feed intake and feed efficiency), body indices (body mass index, skeletal muscle index, body index and relative body index) and carcass traits [hot carcass weight, dressing (%), neck (%), for-legs (%), ribs (%), loin (%), hind-legs (%), abdominal fat (%) and tail (%)] in thirty males of the Egyptian Ossimi lambs. The polymerase chain reaction-single strand conformational polymorphism (PCR-SSCP) tool was used to identify the allelic and genotypic polymorphisms in FABP4 gene. The SSCP analysis detected two alleles (A and B with frequency of 0.73 and 0.27, respectively), and three genotypes (AA, AB and BB with frequency of 0.67, 0.13 and 0.20, respectively). The FABP4 genotype showed significant effect ($P < 0.05$) on feed efficiency and body mass index; and high significant effect ($P < 0.01$) on post-weaning daily gain, marketing weight, feed intake, skeletal muscle index, hot carcass weight and tail (%). However, the FABP4 genotype did not show significant effect ($P > 0.05$) on the values of the other studied traits [weaning weight, body index, relative body index, dressing (%), neck (%), for-legs (%), ribs (%), loin (%), hind-legs (%) and abdominal fat (%)]. The presence of A allele was significantly associated ($P < 0.05$) with body mass index and hot carcass weight; and high significantly associated ($P < 0.01$) with post-weaning daily gain, marketing weight, feed intake, feed efficiency, skeletal muscle index and neck (%), however, the presence of B allele in the genotype high significantly ($P < 0.01$) affected post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index and hot carcass weight. Obtained results showed an association between the FABP4 gene (B allele) and post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index and hot carcass weight of the Egyptian Ossimi lambs. Consequently, applying the marker assisted selection using the FABP4 gene is warranted to increase these traits and will be of considerable economic value in sheep production.

Key words: FABP4, growth, feed efficiency, body measurements, carcass, Ossimi sheep.

INTRODUCTION

Sheep is one of the most important domestic animals raised in Egypt and in other developing countries. Sheep population in Egypt increased by 66.7% from 1961 to 2005 (**Shafey *et al.*, 2014; Mahrous *et al.*, 2016**). There is almost 5.5 million head of sheep (**FAO, 2011**). Sheep are raised mainly for meat production where total populations of sheep contribute 6.4% of the total red meet produced in Egypt (**Galal *et al.*, 2002; Mahfouz *et al.*, 2008; Shafey *et al.*, 2014; Othman *et al.*, 2015**).

In sheep production, growth and feed efficiency traits are always of primary concern as they determine the economic viability of sheep farms.

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Therefore, identifying major genes affecting these traits are initial and crucial steps of establish marker assisted selection system (**Moradian *et al.,* 2013; Kumari *et al.,* 2014; Ibrahim, 2015**). It was documented that body indices traits in farm animals could be important because they are correlated with the live performance traits as, live weight (**Afolayan *et al.* 2006; Musa *et al.,* 2012; Shehata, 2013; Younas *et al.,* 2013**), feed intake (**Cam *et al.,* 2010**) and carcass weights (**Shehata, 2013; Younas *et al.,* 2013; Agamy *et al.,* 2015**).

Carcass traits of lambs are economically important for both breeders and consumers, but it is difficult to be measured until slaughtering animals which makes the genetic improvement for this kind of traits is very slow and expensive (**Agamy *et al.,* 2013**). Therefore, estimating carcass traits of selective live lambs, using a suitable technique to accomplish that goal are necessarily and enabling early selection of lambs in breeding stock (**Agamy *et al.,* 2013; Ibrahim, 2015**).

The previous traits are quantitative and the genetic improvement for them has been attained by the traditional selection methods which based on the genetic and phenotypic variations without knowledge of the number of genes that affect the trait (**Naqvi, 2007**). Throughout the last decades, the techniques of molecular genetics have been advanced, consequently, a new generation of molecular markers have been used for the genetic improvement of economic traits in farm animals (**Teneva, 2009; Cauveri *et al.,* 2016**). The use of molecular markers opens the way to select individual for a many traits at early age of life and to enhance reliability in predicting the mature phenotype of the individual (**Naqvi, 2007**).

Fatty acid-binding proteins (FABPs) are a family of carrier proteins for fatty acids and other lipophilic substances between extra and intra-cellular membranes (**Chmurzyńska, 2006; Smathers and Petersen, 2011**). FABPs play a crucial role in lipid metabolism, hormone action and cellular functions in adipocytes and other cells. FABPs are a family of 14–15-kDa proteins, known as intracellular lipid chaperones, that coordinate lipid trafficking and responses in cells (**Spiegelman *et al.,* 1983; Furuhashi and Hotamisligil, 2008; Furuhashi *et al.,* 2011; Ishimura *et al.,* 2013; Furuhashi *et al.,* 2014**). These proteins are thought to facilitate the transfer of fatty acids between extra and intra-cellular membranes (**Weisiger, 2002; Ibrahim *et al.,* 2014**).

FABPs are found in all species. The family of FABPs are consists of nine subtypes exhibit unique patterns of tissues expression and are expressed most abundantly in tissues. These nine subtypes of FABPs involved in active lipid metabolism (**Damcott *et al.,* 2004; Michal *et al.,* 2006**). These subtypes are: liver (L-FABP/ FABP1), intestinal (I-FABP/FABP2), heart (H-FABP/FABP3), adipocyte (A-FABP/FABP4/ aP2), epidermal (E-FABP/FABP5/mal1), ileal (Il-FABP/FABP6), brain (B-FABP/ FABP7), myelin (M-FABP/FABP8), and testis (T-FABP/ FABP9) (**Furuhashi and Hotamisligil, 2008; Ibrahim *et al.,* 2014**).

Adipocyte-fatty acid binding protein (A-FABP), also known as FABP4 (**Yan *et al.,* 2012**). FABP4 is ranging in size from 14-15 kDa containing 128-132 amino acids (**Zimmerman and Veerkamp, 2002**), and encoded by FABP4 gene. The FABP4 is the most abundant FABP in adipocytes, controls fatty acid uptake, transport and metabolism in fat cells (**Su *et al.,* 2004; Liu *et al.,* 2015**). The FABP4 plays an important role in binding and transporting long-chain fatty acids in adipocytes of sheep (**Ishimura *et al.,* 2013**). This protein plays an important role in glucose and lipid metabolism in adipocytes (**Hotamisligil *et al.,* 1996; Cao *et al.,* 2008; Storch and Corsico, 2008**), thus, FABP4 polymorphisms might have an impact on live performance and carcass traits in sheep (**Boord *et al.,* 2002; Maeda *et al.,* 2005; Xu *et al.,* 2011; Ibrahim *et al.,* 2014; Anderson *et al.,* 2015; Yan *et al.,* 2018**).

Previous studies revealed that, FABP4 polymorphisms might have an impact on growth and carcass traits in sheep (**Xu *et al.,* 2011; Ibrahim *et al.,* 2014; Yan *et al.,* 2018**), meat tenderness, muscle marbling score and intramuscular fat content in sheep (**Xu *et al.,* 2011; Anderson *et al.,* 2015**), growth and intramuscular fat in pigs (**Gerbens *et al.,* 2001; Damon *et al.,* 2006; Ojeda *et al.,* 2006**), carcass characteristics, meat quality, fat deposition and

marbling in cattle (**Barendse *et al.*, 2009; Lee *et al.*, 2010; Sung *et al.*, 2012**), body fat content and abdominal fat in chicken (**Luo *et al.*, 2006; Wang *et al.*, 2006; Wang *et al.*, 2009**), growth and feed efficiency traits in cattle (**Zinder *et al.*, 2016**), milk production and quality in cattle (**Kulig *et al.*, 2010**), milk fat traits in buffaloes (**Dubey *et al.*, 2016**) and fleece rot resistance in sheep (**Smith *et al.*, 2010**).

The objectives of this study were to identify potential variation in FABP4 gene and to test its associations with live performance (*i.e.* growth traits, feed efficiency traits and body indices) and carcass traits of the Egyptian Ossimi lambs.

MATERIALS AND METHODS

Animal and Phenotypic data

Thirty male Ossimi lambs of nearly 3-4 months old and of 21.98 ± 1.43 kg average live body weight were used over 32 weeks period in this study. The experiment lasted from weaning (3-4 months of age) until the age of 11-12 months. During this period, all animals were kept under the same management conditions and each animal was kept in a separate shaded pen (dimensions 120 width × 150 length × 135 high cm) with the dedicated place of feeding, and adapted for the diet 10 days before beginning the experimental period. At the beginning of the experimental period, lambs were dosed against internal and external parasites using ivomec preparation.

At the beginning of growth trial, all lambs were individually weighted, then weekly in the morning before drinking and feeding and after fasting period about 12 hours. The lambs were individually fed according to body weight measured every week. Lambs requirements were adjusted every week according to changes of lamb live body weights. The routine used in the experimental consisted of concentrate feed mixture contained 65% total digestible nutrients (TDN) and 14% crude protein.

Lambs were fed their nutritional requirements according to **NRC (1985)**. The amounts of concentrates were offered twice daily at 6:00 am and 4:00 pm. In addition, lambs were fed on hay according to their availability (*Ad libitum*). Drinking water and mineral blocks were made available all the daytime.

At the time of slaughtering, six body measurements were taken for each lamb, the live body measurements were taken by a centimeteric tape to the nearest centimeter. These measurements included: body length (the distance between the highest point of shoulder and pinbone), height at withers (the height from the floor level to the highest point of the withers), height at hips (the perpendicular distance from the floor level to the dorsal point on the median point lying between the left and right tuber coxae), heart girth (the circumference of the chest of animal just behind the fore legs) and thigh circumference (the circumference of the hind leg as close as the abdominal of animal). From these measurements, four body conformational indices were calculated according to **Salako (2006)**.

- Body mass index = (slaughtering weight × 100)/ height at withers.
- Skeletal muscle index = (thigh circumference × 100)/ height at withers.
- Body index = (body length × 100)/ heart girth.
- Relative body index = (body length × 100)/ height at withers.

At the end of experiment, all lambs were fasted for 16 hours and slaughtered according to the Islamic rituals by severing the carotid artery and jugular veins. After slaughtering and complete bleeding, lambs were skinned and eviscerated. The external offal's (non-carcass components) (head, skin, and legs) were removed. All internal offal's (heart, trachea and lungs, liver, kidneys, spleen and tests) were separated from the dressed carcass and weighed at the nearest 0.1 kg (**Ibrahim *et al.*, 2014**).

Carcasses were weighted hot (about 1 hr., after slaughtering). Neck and fat tail were removed from carcasses and weighted. The rest of each dressed carcass was longitudinally spilt into approximately two equal halves and the left side was divided into 4 cuts (for-leg, ribs, loin and hind-leg) according to **Atti and Ben Hamouda (2004)**. These cuts were weighted at the nearest 0.1 kg. Then, carcass traits were calculated as percentages [hot carcass weight, dressing (%), neck (%), for-legs (%), ribs (%), loin (%), hind-legs (%), abdominal fat (%) and tail (%)].

Genotyping

Blood samples were collected onto FTA cards (Whatman Bio Science, Middlesex, UK) and genomic DNA was purified using a two-step washing procedure as described in **Zhou *et al.* (2007)**.

Polymerase chain reaction (PCR)

According to the reference of **Burrows (2013)**, a pair of specific primers (F: 5`-CAGGAATTTGATGAAGTCACT-3` and R:5`-GTAACATGGTTCAGAGCTAG-3`) were synthesized to amplify a variable fragment (350bp) within the exon2-intron 2 region of the ovine FABP4 gene.

PCR carried out in a total reaction volume of 20 ul containing the genomic DNA on one 1.2-mm punch of FTA card, 2.5 ul of 10x PCR buffer, 1.5 mM of MgCl2, 150 uM of dNTP (Eppendorf, Hamburg, Germany), 0.25 uM of each primer and 0.5 U of Taq DNA polymerase (Qiagen, Hilden, Germany). The thermal profile consisted of 2 min at 94^{o}C, followed by 35 cycles of 30 sec. at 94^{o}C, 30 sec. at 60^{o}C and 30 sec. at 72^{o}C, with a final extension of 5 min at 72^{o}C. Amplification was carried out in S1000 thermal cyclers (Bio-Rad, Hercules, CA, USA).

Single strand conformational polymorphism analysis

According to **Ibrahim *et al.* (2014)**, a 3 µl of each PCR product was mixed with 7 µl of loading dye (98% formamide, 0.025% xylene cyanol, 0.025% bromophenol blue and 10 mM EDTA-Eppendorf, Hamburg, Germany), denatured at 105° C for 5 min, rapidly chilled on wet ice and loaded on 16 × 18 cm; 14% acrylamide: bisacrylamide (37.5: 1; Bio- Rad, USA) gels. The electrophoresis was run in 0.5 x TBE buffer for 18 hr. at 320 V and 12ºC. Gels were silver stained using the method of **Byun *et al.* (2009).**

Statistical Analysis

Allelic and genotypic frequencies of FABP4 gene were calculated using simple gene counting method (**Falconer and Mackay, 1996**). Hardey-Weinberg equilibrium was tested by comparing expected and observed genotypic frequencies using $\chi 2$ test. The population would be considered to be in Hardy-Weinberg equilibrium if it failed the $\chi 2$ test at the level of 0.05.

Associations of variation at FABP4 gene with growth and carcass traits were determined by analysis of variance of quantitative traits. General Linear Model (GLM) procedure in SPSS software (version 19) was used to perform the analysis. Fixed effect of variation at FABP4 gene (FABP4 genotype or the absence/presence of each allele in animal genotype) included as independent variable in the linear model. Where significant, there were further explored using pairwise comparison (Duncan test; $P \leq 0.05$).

The general linear model was:

$$Yij = \mu + Gi + eij$$

Where Yij = observed value; µ = overall mean for each trait; Gi = fixed effect of the variation at FABP4 gene and eij = random error.

RESULTS AND DISCUSSION

Allelic and Genotypic Frequencies

PCR-SSCP analysis of FABP4 is shown in Table 1 and Fig. 1. Results of examined lambs showed only two alleles (A and B with frequencies of 0.73 and 0.27, respectively) and three genotypes (AA, AB and BB with frequencies of 0.67, 0.13 and 0.20, respectively).

Results presented in Table 1 show that the frequency of allele A was higher (73%) than that of allele B (27%). **Shin *et al.* (2012) and Ardicli *et al.* (2017)** reported that the frequency of allele B was higher (67%) than that of allele A. In this concept, the allele and genotype frequencies are known to vary between breeds and even between the different populations within the same breed (**Ardicli *et al.,* 2017**). Furthermore, evaluating the existence of epistasis, genetic linkage and pleiotropy is important to consider different combinations of the polymorphisms (**Carvalho *et al.,* 2012**).

Sequence Variation in the FABP4 Gene

Sequencing the amplicons representative of detected SSCP banding patterns, confirmed two different DNA sequences (Fig. 2). The result revealed only one substitution (g. 211 T > A) in the studied region of FABP4 gene. This substitution resulted in a change for the amino acid chain, from tryptophan to arginine (**Ibrahim *et al.,* 2014**). This may affect the expression and/or the function of FABP4 gene and hence affect sheep growth, feed efficiency, body indices and carcass traits.

Table 1. Genotypic and allelic frequencies of FABP4 gene in Egyptian Ossimi lambs

Genotype frequency (%)			Allele frequency (%)	
AA	AB	BB	A	B
0.67	0.13	0.20	0.73	0.27

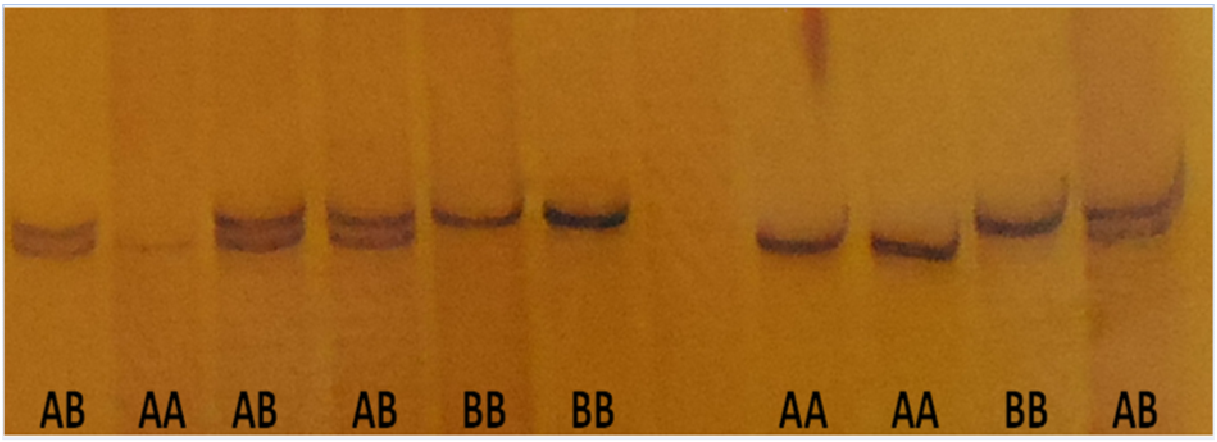

Fig. 1. PCR-SSCP analysis for exon 1 of FABP4 gene in Egyptian Ossimi lambs

```
Allele A     1  ggaaggaaaactgcagaggctggcaatgaaggaaatgatcttatatcattcccaattggt   60
Allele B     1  ------------------------------------------------------------

Allele A    61  tatgcccaagatcacatgttctgggcacctttaaaaggaagttatctggactcagaggat  120
Allele B    61  ------------------------------------------------------------  120

Allele A   121  aacagcatcttgctgaaagctgcacttctttctcatcttgaagaataattctagaaagct  180
Allele B   121  ------------------------------------------------------------  180

Allele A   181  cacaaaatgtgtgatgcatttgtaggtacctggaaacttgtctccagtgaaaactttgat  240
Allele B   181  ------------------------------a-----------------------------  240

Allele A   241  gattacatgaaagaagtgggtaaggaaatgcattgttgaatggctgggattataactttt  300
Allele B   241  ------------------------------------------------------------  300

Allele A   301  tctctag                                                      307
Allele B   301  -------                                                      307
```

Fig. 2. Sequences of the two detected amplicons in exon 1 of the FABP4 gene in Ossimi lambs

Effect of the FABP4 Genotype on the Studied Traits in Egyptian Ossimi Lambs

The effects of FABP4 genotype on live performance (*i.e.,* growth, feed efficiency and body indices) and carcass traits are presented in Tables 2 and 3, respectively. The presented results in Table 2 show that the FABP4 genotype had high significant effect ($P < 0.01$) on most live performance traits (*i.e.,* post-weaning daily gain, marketing weight, feed intake, skeletal muscle index, feed efficiency and body mass index). Moreover, results in Table 3, show that the FABP4 genotype had high significant ($P < 0.01$) effect on hot carcass weight and tail (%).

Results indicated that polymorphism within FABP4 gene may be associated with most live performance and some carcass traits. In the association analyses, the polymorphism FABP4 significantly affected the post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index, skeletal muscle index, hot carcass weight and tail (%). Results observed in the present study, showed that BB genotype had higher values for the previous traits compared to the other two genotypes (AA and AB genotypes). These results agree with the previous findings in sheep (**Xu *et al.,* 2011; Yan *et al.,* 2012; Ibrahim *et al.,* 2014; Yan *et al.,* 2018**) and cattle (**Michal *et al.,* 2006; Hoashi *et al.,* 2008; Barendse *et al.,* 2009; Lee *et al.,* 2010; Sung *et al.,* 2012**). In pigs FABP4 genotype was found to be linked to the quantitative trait locus that has been reported to affect porcine fat deposition and growth performance (**Gerbens *et al.,* 2001; Damon *et al.,* 2006; Ojeda *et al.,* 2006**). In addition, other studies have been studied the polymorphisms in FABP4 genotype and revealed significant associations for the detected polymorphisms with growth and feed efficiency traits in cattle (**Zinder *et al.,* 2016**), body fat content and abdominal fat in chicken (**Luo *et al.,* 2006; Wang *et al.,* 2006; Wang *et al.,* 2009**). Conversely, other studies (**Shin *et al.,* 2012; Ardicli *et al.,* 2017**) found no association of FABP4 genotype with carcass traits in cattle.

It was observed that, variation in the bovine FABP4 has been associated with growth and meat production (**Jurie *et al.,* 2007**). Additionally, the FABP4 found to affect the growth and intramuscular fat deposition in the muscle. In this respect, **Jurie *et al.* (2007)** found that, the FABP4 expression at both the protein and mRNA levels and this bovine FABP4 was associated with carcass traits. Growth and intramuscular fat levels depend on the balance between the synthesis and the degradation of triacylglyceride and the intracellular trafficking of fatty acid by FABPs (**Barendse *et al.,* 2009; Hocquette *et al.,* 2010**). Furthermore, variation in porcine FABP4 has also been reported to be associated with body fat content, and possibly with growth (**Gerbens *et al.,* 1998**). **Damon *et al.* (2006)** reported that, the association between body fat content and FABP4 was at the protein level and not the mRNA level in a population, however, other study (**Gerbens *et al.,* 2001**) found that it was the mRNA level and not the protein level of FABP4 that was associated with body fat content.

Effect of the Presence/Absence of Fabp4 Alleles in Lambs Genotype on the Studied Traits

The results of the second set of analysis concerned the effect of the absence/presence of alleles in the FABP4 genotype on live performance (*i.e.,* growth, feed efficiency and body indices) and carcass traits are presented in Tables 4 and 5, respectively. The presented results in Table 4 show that the presence of alleles B and A were significantly ($P < 0.01$) associated with most of live performance traits, including post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index and skeletal muscle index. Moreover, the presence of allele B in the genotype (particularly the homozygous genotype BB) was significantly ($P < 0.01$) associated with the high values of the previous traits (*i.e.,* post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index).

Moreover, results in Table 5 show that the presence of alleles B and/or A were significantly ($P < 0.01$) associated with some carcass traits including, hot carcass weight and neck (%). Additionally, the presence of allele B in the genotype was significantly ($P < 0.01$) associated with the high values of hot carcass weight and neck (%). Present results of the absence/presence

Table 2. Least square means and their standard errors for growth traits, feed intake, feed efficiency and body indices in Ossimi lambs according to the FABP4 genotypes

Trait	Genotype			Significance
	AA	AB	BB	
Growth traits				
Weaning weight (Kg)	23.84 ± 0.51	24.81 ± 1.32	24.95 ± 1.03	0.542
Post-Weaning daily gain (g/day)	80.11^{a} ± 3.16	91.93^{ab} ± 5.88	102.68^{b} ± 5.28	0.004
Marketing weight (Kg)	58.61^{a} ± 1.42	64.85^{ab} ± 3.84	69.38^{b} ± 1.60	0.002
Feed efficiency traits				
Feed intake (g)	184.22^{a} ± 3.47	199.14^{ab} ± 10.78	208.32^{b} ± 3.45	0.005
Feed efficiency (%)	31.75^{a} ± 0.26	32.53^{ab} ± 0.23	33.28^{b} ± 0.26	0.012
Body indices				
Body mass index	77.45^{a} ± 1.25	81.58^{ab} ± 3.44	85.09^{b} ± 1.47	0.016
Skeletal muscle index	54.28^{a} ± 0.78	53.42^{a} ± 1.71	59.07^{b} ± 0.48	0.008
Body index	79.51 ± 0.95	82.90 ± 1.94	80.28 ± 1.49	0.336
Relative body index	95.15 ± 1.11	98.22 ± 1.58	96.49 ± 1.99	0.483

Significance level * refers to significance at ($P < 0.05$) and ** refers to significance at ($P < 0.01$)

Table 3. Least square means and their standard errors for carcass traits in Ossimi lambs according to the FABP4 genotypes

Trait	Genotype			Significance
	AA	AB	BB	
Hot carcass weight (Kg)	32.852^{a} ± 1.18	36.56^{ab} ± 3.31	39.85^{b} ± 1.57	0.008
Dressing percentage (%)	50.18 ± 0.76	49.63 ± 1.59	51.94 ± 1.30	0.213
Neck (%)	6.97 ± 0.18	6.96 ± 0.49	8.22 ± 0.52	0.073
For-legs (%)	24.65 ± 0.40	25.81 ± 1.91	23.95 ± 0.39	0.274
Ribs (%)	16.43 ± 0.26	17.21 ± 1.27	15.96 ± 0.26	0.274
Loin (%)	12.31 ± 0.48	9.92 ± 0.44	12.09 ± 1.00	0.073
Hind-legs (%)	26.72 ± 0.50	26.69 ± 1.46	24.82 ± 0.23	0.179
Abdominal fat (%)	2.67 ± 0.21	2.61 ± 0.38	2.63 ± 0.34	0.335
Tail (%)	8.86^{a} ± 0.55	$9.03a^{b}$ ± 2.36	10.68^{b} ± 1.43	0.001

Significance level * refers to significance at ($P < 0.05$) and ** refers to significance at ($P < 0.01$)

Table 4. Association of the presence / absence of FABP4 alleles with growth traits, feed intake, feed efficiency and body indices in Egyptian Ossimi lambs

Trait	Allele being assessed	LSM ± SE				Significance
		N	Absent allele	N	Present allele	
Growth traits						
Weaning weight (Kg)	A	6	24.81 ± 1.03	24	24.02 ± 0.47	0.471
	B	20	23.84 ± 0.51	10	24.87 ± 0.77	0.266
Post-Weaning daily gain (g/day)	A	6	102.68 ± 5.28	24	82.08 ± 2.90	0.003
	B	20	80.10 ± 3.15	10	98.38 ± 4.12	0.002
Marketing weight (Kg)	A	6	69.38 ± 1.60	24	59.64 ± 1.39	0.003
	B	20	58.60 ± 1.42	10	67.57 ± 1.83	0.001
Feed efficiency traits						
Feed intake (g)	A	6	208.32 ± 3.45	24	186.71 ± 3.49	0.007
	B	20	184.22 ± 3.47	10	204.65 ± 4.66	0.005
Feed efficiency (%)	A	6	33.28 ± 0.26	24	31.88 ± 0.23	0.007
	B	20	31.75 ± 0.26	10	32.98 ± 0.21	0.005
Body indices						
Body mass index	A	6	85.09 ± 1.47	24	78.14 ± 1.20	0.010
	B	20	77.45 ± 1.25	10	83.69 ± 1.62	0.006
Skeletal muscle index	A	6	59.07 ± 0.48	24	54.14 ± 0.70	0.002
	B	20	54.28 ± 0.78	10	56.81 ± 1.14	0.077
Body index	A	6	80.28 ± 1.49	24	80.08 ± 0.88	0.916
	B	20	79.51 ± 0.95	10	81.33 ± 1.19	0.264
Relative body index	A	6	96.49 ± 1.99	24	95.66 ± 0.98	0.712
	B	20	95.15 ± 1.11	10	97.18 ± 1.32	0.280

Significance level * refers to significance at ($P < 0.05$) and ** refers to significance at ($P < 0.01$)

Table 5. Association of the presence/absence of FABP4 alleles with carcass traits in Egyptian Ossimi lambs

Trait	Allele being assessed	LSM ± SE				Significance
		N	Absent allele	N	Present allele	
Hot carcass weight (Kg)	A	6	39.85 ± 1.57	24	33.47 ± 1.13	0.013
	B	20	32.85 ± 1.18	10	38.54 ± 1.60	0.009
Dressing percentage (%)	A	6	51.94 ± 1.30	24	50.09 ± 0.68	0.232
	B	20	50.18 ± 0.76	10	51.02 ± 1.02	0.530
Neck (%)	A	6	8.22 ± 0.52	24	6.97 ± 0.16	0.006
	B	20	6.97 ± 0.18	10	7.72 ± 0.40	0.064
For-legs (%)	A	6	23.95 ± 0.39	24	24.84 ± 0.44	0.340
	B	20	24.65 ± 0.40	10	24.69 ± 0.79	0.953
Ribs (%)	A	6	15.96 ± 0.26	24	16.56 ± 0.29	0.340
	B	20	16.43 ± 0.26	10	16.46 ± 0.53	0.953
Loin (%)	A	6	12.09 ± 1.00	24	11.91 ± 0.44	0.860
	B	20	12.31 ± 0.48	10	11.22 ± 0.69	0.209
Hind-legs (%)	A	6	24.82 ± 0.23	24	26.72 ± 0.46	0.056
	B	20	26.72 ± 0.50	10	25.56 ± 0.63	0.177
Abdominal fat (%)	A	6	2.63 ± 0.34	24	2.66 ± 0.18	0.940
	B	20	2.67 ± 0.21	10	2.62 ± 0.24	0.895
Tail (%)	A	6	10.68 ± 1.43	24	8.89 ± 0.57	0.197
	B	20	8.86 ± 0.55	10	10.02 ± 01.22	0.329

Significance level * refers to significance at ($P < 0.05$) and ** refers to significance at ($P < 0.01$)

of alleles in the FABP4 genotype have been consistent with the previous findings in sheep (**Xu *et al.,* 2011; Yan *et al.,* 2012; Ibrahim *et al.,* 2014; Yan *et al.,* 2018**). In cattle, **Sung *et al.* (2012)** found that, the absence /presence of alleles in the FABP4 genotype had a significant effect on carcass weight and marbling score. Also, it was found that FABP4 is a very important candidate gene for the quantitative trait locus and which affects fatty acid deposition and growth performance in pigs (**Ojeda *et al.,* 2006**) and chicken (**Wang *et al.,* 2006**). On the other hand, some studies (**Shin *et al.,* 2012 and Ardicli *et al.,* 2017**) did not detect an association between the absence/presence of the alleles in the FABP4 genotype and carcass traits in cattle. The present results support the idea that FABP4 variation may be affect positively the growth and carcass traits in Egyptian Ossimi lambs.

Conclusions

The results obtained here show that the FABP4 is a polymorphic gene. The identified polymorphisms for the FABP4 were found to be associated with the most important economic traits in Egyptian Ossimi lambs; therefore our results suggest that detection of FABP4 genotype could be used as a useful and helpful tool in genetic improvement programs for Egyptian Ossimi lambs. The B allele of FABP4 had a positive effect on post-weaning daily gain, marketing weight, feed intake, feed efficiency, body mass index and hot carcass weight in sheep. Hence selection for B allele against A allele in FABP4 gene may lead to increase the growth performance and meat production of lambs that will increase the economic benefits of lamb breeders. However, further studies with large number of Egyptian Ossimi sheep and other local breeds of sheep are needed to confirm these results.

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التباين الوراثى لجين FABP4 فى الأغنام وعلاقته بالأداء خلال حياة الحيوان وصفات الذبيحة فى حملان الأغنام الاوسيمي

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الهدف من هذة الدراسة هو تحديد التعددية الأليلية والوراثية لجين (FABP4) وعلاقته مع صفات النمو (وزن الفطام - معدل النمو اليومى بعد الفطام – وزن التسويق) وصفات الكفاءة الغذائية (معدل تناول الغذاء – والكفاءة الغذائية) ومقاييس الجسم (مؤشر كتلة الجسم – مؤشر عضلات الهيكل– مؤشر الجسم – مؤشر الجسم النسبي) وصفات الذبيحة (وزن الذبيحة الساخن - نسبة التصافى (%) - الرقبة (%) - الأرجل الأمامية (%)- الضلوع (%) - القطن (%) - الأرجل الخلفية (%) – دهن البطن (%) - الذيل (%) فى ٣٠ من ذكور حملان الأغنام الأوسيمى المصرية، واستخدم لتحديد التعددية الاليلية والوراثية تقنية (PCR-SSCP)، تحليل (PCR-SSCP) حدد وجود اليلين هما (B و A) وكان تكرراهما (٠,٧٣ و٠,٢٧ علي التوالي)، ووجود ثلاث تراكيب وراثية هي (BB و AB وAA) وكان تكرراها (٠,٢٠ و٠,١٣ و٠,٦٧ علي التوالي)، أوضحت النتائج أن التركيب الوراثى لجين (FABP4) له تأثير معنوي ($P < 0.05$) على كل من الكفاءة الغذائية ومؤشر كتلة الجسم عالى المعنوية ($P < 0.01$) على كل من معدل النمو اليومى بعد الفطام ووزن التسويق ومعدل تناول الغذاء ومؤشر عضلات الهيكـل ووزن الذبيحة الساخن والذيل (%)، هذا بالإضافة إلى أن التركيب الوراثى لجين (FABP4) له تأثير عالى المعنوية ($P < 0.01$) على كل من معدل النمو اليومى بعد الفطام ووزن التسويق ومعدل تناول الغذاء ومؤشر عضلات الهيكـل ووزن الذبيحة الساخن والذيل (%)، بينما كان له تأثير غير معنوي علي باقى الصفات المدروسة (وزن الفطام - مؤشر الجسم – مؤشر الجسم النسبي - نسبة التصافى (%) - الرقبة (%) - الأرجل الأمامية (%) - الضلوع (%) - القطن (%) - الأرجل الخلفية (%) - دهن البطن(%))، أوضحت نتائج وجود الاليل (A) فى التركيب الوراثي له تأثير معنوي ($P < 0.05$) علي كلا من مؤشر كتلة الجسم ووزن الذبيحة الساخن. بينما له تأثير عالي المعنوية ($P < 0.01$) على كل من معدل النمو اليومى بعد الفطام ووزن التسويق ومعدل تناول الغذاء والكفاءة الغذائية ومؤشر عضلات الهيكـل الرقبة (%)، كما أوضحت نتائج وجود الاليل (B) فى التركيب الوراثي له تأثير عالي المعنوية ($P < 0.01$) على كل من معدل النمو اليومى بعد الفطام ووزن التسويق ومعدل تناول الغذاء والكفاءة الغذائية ومؤشر كتلة الجسم ووزن الذبيحة الساخن، النتائج المتحصل عليها أظهرت وجود ارتباط بين جين FABP4 (الاليل B) مع معدل النمو اليومى بعد الفطام ووزن التسويق ومعدل تناول الغذاء والكفاءة الغذائية ومؤشر كتلة الجسم ووزن الذبيحة الساخن فى حملان الأغنام الأوسيمي المصرية، وبالتالى فان تطبيق الانتخاب المساعد بالواسمات الوراثية باستخدام جين FABP4 يساعد علي زيادة هذه الصفات كما يساعد علي زيادة القيمة الاقتصادية من إنتاج الأغنام.

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