Iranian Journal of Applied Animal Science

# Effect of Slaughter Weight, Carcass Weight and Sex on the Carcass Fatty Acid Composition of Boutsiko Breed Lambs

**Research Article**

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Received on: 7 Jan 2014
Revised on: 8 Feb 2014
Accepted on: 15 Feb 2014
Online Published on: Dec 2014

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Online version is available on: www.ijas.ir



## ABSTRACT

The aim of the present study was to assess the effect of slaughter and carcass weight, age at slaughter and sex on the fatty acid profile of the Greek Boutsiko sheep breed. Twenty lambs (ten females and ten males) were examined. The lambs were slaughtered at the age of 48 days. Carcasses were chopped in nine specific cuts and a random sample of 100 g was taken from each cut, with a total of 180 samples. From every ground sample a quantity of 2 g was taken for lipid extraction and preparation of fatty acid methyl esters. To predict the relationship of age, sex and weight on saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) a path analysis was adopted which tests all regression equations simultaneously. Age at slaughter was assumed to have an indirect impact via slaughter weight and carcass weight. Findings suggest that the model which uses slaughter weight instead of carcass weight, predicts better the fatty acid composition of Boutsiko breed lambs. As to the nutritional quality of the meat, the PUFA / SFA ratio was found relatively low while the ratio ω-6/ω-3 PUFA, was acceptable for human healthy nutrition. The best fatty acid composition was found for leg, shoulder and racks. It was concluded that producers may increase the age of slaughter, but that should be combined with their engagement in low cost diet modifications so as to improve production and cost efficiency and at the same time retain the quality of lamb meat.

KEY WORDS age, fatty acids, lambs, path analysis, sex, slaughter weight.

## INTRODUCTION

Today, consumers are more conscious of their health and prefer to consume lean meat. Knowing the chemical composition of meat is very important for clarifying its nutritional value, as well as for providing information that is useful for determining diets to specific population groups. The quantity and quality of fat in lambs is important not only for consumers, but also for the survival of the sheep industry itself since lambs with excess fat are not acceptable (Sanudo *et al.* 2000). Especially in Mediterranean Countries, consumers look for lamb meat with a reduced amount of fat (Castro *et al.* 2005). Muscle lipids are important in determining the nutritional quality of meat (Flynn *et al.* 1985). Various recommendations have been made in recent years regarding the importance of the relationship between certain fatty acids and human health (Wood *et al.* 2008; Montossi *et al.* 2013). The amount of fat in human diet and especially the proportion of saturated fatty acids have been considered as major risk factor in coronary heart diseases, and the ratio between polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) is one of the indices for the nutritional evaluation of fat (Hu *et al.* 1999; Nudda *et al.* 2013). Fatty acid (FA) composition and particularly saturated fatty acids, can affect lamb carcass quality (Caneque *et al.* 2005; Paim *et al.* 2014) and therefore knowledge of this composition is of great interest. Fatty acid composition of lamb meat depends on various factors such as breed (Arsenos *et al.* 2006), carcass weight (Santos-Silva *et al.* 2002), age at slaughter and sex (Smith *et al.* 2009). It is common practice for most researchers to use weight and age simultaneously in their studies since both have a common trend (Sanudo *et al.* 1998). Evidence suggests that older lambs and higher weights have a causal link with the level of fatness (Sanudo *et al.* 1998; Marino *et al.* 2008). Carcass weight is an important consideration in the categorization of lamb carcasses into commercial types. A specific carcass weight has its preference in every country and even in every region within countries (Muela, 2010). Small changes in carcass weight of lambs can result in large changes in carcass fatness (Velasco *et al.* 2000). According to Caneque *et al.* (2005) carcass weight affects fatness since as carcass weight increases, an increment in carcass fatness is observed, while lighter carcasses overall have lower carcass fatness and qualitatively better fatty acid composition (Caneque *et al.* 2005). Slaughter weight may also affect the degree of fatness and the fatty acid composition of lamb carcasses. Kemp *et al.* (1976) and Solomon *et al.* (1980), reported that subcutaneous fat depth increases as slaughter weight increases. Doney *et al.* (1988), showed heavier lambs at weaning, to be more likely to produce lean carcasses but only at low slaughter weights. Santos-Silva *et al.* (2002) found that when slaughter weight increased, total fatty acids increased as well. As to the age at which lambs are slaughtered, Skapetas *et al.* (2006), in a study on 40 male lambs of the mountain Greek sheep breed, concluded that the proportion of total fat in carcass increased as the slaughter age increased. A study done by Cifuni *et al.* (1999) on 20 Apulian ram lambs, also showed that slaughtered lambs at a young age performed better in their FA profiles, while Oriani *et al.* (2005), found that age did not dramatically modified lipid content and FA composition. Finally, there are numerous studies that consider sex. In general female sheep have the greater amount of fat (Bennett *et al.* 1991), but these results may vary depending on the weight range considered and the growth phase of either sex (Zygoyiannis *et al.* 1990). Vergara *et al.* (1999), concluded that sex had no influence on carcass weight or fatness while Horcada *et al.* (1998) observed, on Spanish lamb breeds, that there were no significant differences between sexes on fatty acid composition. Similarly, Enser *et al.* (1996), found no difference on fatty acid profiles between male and female lambs. They also reported that very few sex differences have been shown for intramuscular fatty acid composition. The objective of the present study was to identify the FA profile of lambs of the local Greek Boutsiko breed and investigate the effect of its intrinsic characteristics (age and sex) and the slaughter and carcass weight on saturated, monosaturated and polyunsaturated fatty acids.

## MATERIALS AND METHODS

### Experimental design and animal management

The study was carried out with twenty lambs of the Boutsiko sheep breed (ten females and ten males) in the mountainous area of Metsovo, Greece. The measurement of lambs' weight was carried out every 7 days from birth. Also measurements of body weights were taken before and after their slaughter. During the suckling phase the lambs were fed supplementary unchopped lucerne hay and concentrated mixture (corn, barley, soy flour, sunflower flour, cotton pie, salt, limestone powder and nutrition supplement). The diet balancing product (Millaphos Pro) contained the following components: calcium, sodium, phosphorus and magnesium (Table 1).

**Table 1** Composition and chemical analysis of concentrated feed

| Ingredients | % | Chemical composition | % |
|---|---|---|---|
| Corn (%) | 50 | Moisture (%) | 11.8 |
| Barley (%) | 15 | Ash (%) | 4.9 |
| Soybean meal (%) | 12 | Crude protein (%) | 13.6 |
| Sunflower meal (%) | 10 | Crude fiber (%) | 7.0 |
| Cotton cake (%) | 10 | Fat (%) | 3.4 |
| Salt (%) | 0.5 | Carbohydrates (%) | 59.3 |
| Limestone powder (%) | 0.5 | Total energy (kcal/100) | 322 |
| Vitamin-mineral premix (%) | 2 | Calcium (%) | 18 |
| - | - | Sodium (%) | 6 |
| - | - | Phosphorous (%) | 5.5 |
| - | - | Magnesium (%) | 3 |

### Sampling procedure and fatty acid analysis

Lambs were slaughtered at 47.9 ± 4.1 days of age. The empty body weight was calculated by subtracting the weight of the stomach content from the fasted live weight. The dissection of lamb carcasses took place within 24 hours after slaughter in the following anatomical cuts: 1) shoulder, 2) leg, 3) rack, 4) loin, 5) rear flank, 6) breast ribs, 7) scrag-end, 8) kidney fat and 9) lamb membrane. A random sample of nine cuts each of 100 g was taken from each carcass, cut and stored frozen at -25 ˚C for subsequent lipids extraction. All defrosted samples were milled through 1-mm mesh screen. From every ground sample a quantity of 2 g was taken for lipid extraction and preparation of fatty acid methyl esters (FAMES).

Total lipids were extracted with a cold mixture of chloroform and methanol (2:1 v/v) following the method described. Fatty acids were converted to methyl esters according to the AFNOR method (1984). FAMES were extracted with 6 mL of hexane using vortex. The separated hexane layer was dried with the addition of anhydrous sodium sulphate (2-3 g) 2 h and filtered. The residue was washed twice with 2 mL hexane, dried in rotary evaporator and then re-dissolved in 2 mL hexane.

The resulting FAMES were analyzed by using a gas chromatograph consisted of an SSI liquid chromatography pump (model 300; Scientific Systems Inc., State College, PA) equipped with an SSI pulse damper (model LP-21 LO pulse) and a UV-Vis detector (SPD-10 AV; Shimadzu Co., Kyoto, Japan). A Hewlett-Packard, Model HP 3396 Series II electronic integrator (Avondale, PA) was used for recording and quantifying the chromatographic peaks.

**Statistical analysis**

The main statistical tools used in the present study are mediation and path analysis. First simple correlation coefficients were obtained in order to find possible significant relationships between variables. Taking into consideration the results of correlation analysis, a mediation analysis was carried out and then, accordingly the hypothesized models were drawn in a form of path diagram and tested for goodness of fit. To assess whether slaughter weight or carcass weight can be considered as mediators of the relationship between age and fatty acids, the causal step procedure of Baron and Kenny (1986) was adopted. The following regression models were used in our examination:

$Y= a_1 + b_1 X + e_1$
$M= a_2 + b_2 X + e_2$
$Y= a_3 + b_3 X + b_4 M + e_3$

Where:
a: the independent variable X (age) must be significantly related to the dependent variable Y ( SFA or MUFA or PUFA) (model 1).
b: the effect of X on the mediator M (here, CW or SW) must be significant (model 2).
c: the significance of X is reduced when M is in the model as a predictor (model 3).
d: comparison of $b_1$ with $b_3$.

If $b_3$ is not significant and its value is smaller than $b_1$ then M completely mediates the effect of X on Y. But if $b_3$ is significant and remains smaller than $b_1$, then partial mediation is inferred. Multiple mean comparisons were made using Duncan's multiple range test. Statistical analysis was conducted using SPSS (2011) and AMOS 7.0. Variables are expressed in natural logarithm form (excluding the variable of sex), to reduce data variances and facilitate the comparison of coefficients.

## RESULTS AND DISCUSSION

Table 2 presents the means of fatty acids for the nine lamb cuts together with their significant difference produced by ANOVA.

On a literature review basis, the values for the saturated fatty acids (SFA) receive high values while for the polyunsaturated (PUFA) are comparatively low. The lamb membrane received the highest SFA amount (54, 60%) and was significantly different (P<0.05) from the other eight cuts, where no significant difference among them was found. The same cut had the lowest MUFA percentage content (33, 5%, P<0.05), with the highest to be observed in the cuts of racks and leg. The cuts of leg, racks and shoulder appeared to be the richest in PUFA content (P<0.05). From the other hand the higher ratio PUFA/SFA was found for leg, racks and shoulder (P<0.05). Higher ratio ω6/ω3 was found for the loin (5.8, P<0.05), the breast ribs (5.2, P<0.05) and the scrag end (4.97, P<0.05).

With respect to the nutritional value of different carcass cuts, the most favorable were leg, rack and shoulder. The ratio of PUFA / SFA was found away from the optimal value of 4.5 (Enser *et al.* 1996) which is mainly due to the low values of PUFA. More favorable results were linked to the ω3 / ω6 PUFA ratio, essential for the health quality of meat. Most carcass cuts have values which are below the limit of 4 (Bartoň *et al.* 2007). However, the high values of loin and breast ribs raise the total average to 4.14.

Direct comparison of the present results with the findings of other studies should be handled with care since there is variability in processing related to diets, live weight at slaughter, slaughter age, production systems, etc. Similarities exist in slaughtered weight and age with the study of Beriain *et al.* (2000), in which values of the three categories of fatty acids are found to be similar with those of the present study.

Before conducting path analysis, the variables of the model were checked to find out whether they are related significantly to each other. Table 3 shows the results of the Pearson's correlation for the six observed variables. Results suggest that there is a high positive relationship between slaughter weight (SW) and carcass weight (CW) with the three types of fatty acids (P<0.05). Age and sex were found to be correlated only with MUFA near the borderlines of 5% (P=0.054) and 10% (P=0.101) level of significance, respectively. Carcass weight (CW) did not show any relationship with age and sex. However, SW was significantly correlated with age, and this result may imply the presence of a mediation relationship. The correlation between the two weights was highly significant.

The results of mediation analysis are reported in Table 4. The dependent variables were the three components of fatty acids, the independent variable was represented by age and the hypothesized mediators are CW and SW. Models 1-3 showed the direct effect of age to the three dependent variables. Age was found to be a significant predictor only for MUFA.

**Table 2** Fatty acid composition (percentage of total fatty acids) of Butsiko lambs' carcass cuts

| | Leg (Mean±SE) | Kidney fat (Mean±SE) | Racks (Mean±SE) | Breast ribs (Mean±SE) | Loin (Mean±SE) | Scrag end (Mean±SE) | Membrane (Mean±SE) | Rear flank (Mean±SE) | Shoulders (Mean±SE) |
|---|---|---|---|---|---|---|---|---|---|
| C10:0 | 0.38±0.01$^{a}$ | 0.48±0.01$^{c}$ | 0.41±0.01$^{ab}$ | 0.40±000$^{a}$ | 0.44±0.01$^{bc}$ | 0.62±0.01$^{e}$ | 0.54±0.01$^{d}$ | 0.47±0.01$^{c}$ | 0.41±0.01$^{ab}$ |
| C12:0 | 0.66±0.03$^{a}$ | 0.75±0.02$^{ab}$ | 0.70±0.02$^{a}$ | 0.66±0.02$^{a}$ | 0.75±0.03$^{ab}$ | 0.99±0.02$^{d}$ | 0.89±0.03$^{cd}$ | 0.84±0.03$^{bc}$ | 0.75±0.03$^{ab}$ |
| C14:0 | 7.28±0.26$^{ab}$ | 6.59±0.19$^{a}$ | 7.65±0.25$^{abc}$ | 7.39±0.25$^{ab}$ | 7.62±0.30$^{abc}$ | 8.75±0.26$^{cd}$ | 9.01±0.34$^{d}$ | 8.69±0.28$^{cd}$ | 7.83±0.30$^{bcd}$ |
| C 15:0 | 0.60±0.02$^{b}$ | 0.52±0.02$^{a}$ | 0.59±0.02$^{b}$ | 0.60±0.02$^{b}$ | 0.63±0.02$^{bcd}$ | 0.68±0.02$^{d}$ | 0.67$^{c}$±0.02$^{d}$ | 0.68±0.03$^{d}$ | 0.61±0.02$^{bc}$ |
| C 16:0 | 26.86±0.27$^{b}$ | 24.30±0.29$^{a}$ | 27.21±0.31$^{b}$ | 27.09±0.29$^{b}$ | 26.95±0.28$^{b}$ | 27.91±0.37$^{b}$ | 27.73±0.37$^{b}$ | 27.06±0.37$^{b}$ | 26.77±0.41$^{b}$ |
| C 17:0 | 0.93±0.03$^{a}$ | 0.84±0.03$^{a}$ | 0.88±0.03$^{a}$ | 0.88±0.03$^{a}$ | 0.90±0.03$^{a}$ | 0.87±0.03$^{a}$ | 0.89±0.02$^{a}$ | 0.92±0.03$^{a}$ | 0.90±0.03$^{a}$ |
| C 18:0 | 12.73±0.18$^{abc}$ | 19.27±0.31$^{e}$ | 13.17±0.18$^{bc}$ | 13.48±0.16$^{cd}$ | 13.39±0.15$^{c}$ | 12.42±0.17$^{ab}$ | 14.25±0.22$^{d}$ | 12.87±0.20$^{abc}$ | 12.22±0.12$^{a}$ |
| C 20:0 | 0.66±0.02$^{e}$ | 0.57±0.01$^{d}$ | 0.69±0.02$^{e}$ | 0.37±0.02$^{a}$ | 0.44±0.01$^{ab}$ | 0.46±0.01$^{b}$ | 0.54±0.02$^{cd}$ | 0.50±0.02$^{bc}$ | 0.55±0.02$^{cd}$ |
| C 22:0 | 0.10±0.00$^{d}$ | 0.03±0.00$^{b}$ | 0.11±0.00$^{d}$ | 0.07±0.00$^{c}$ | 0.00±0.00$^{a}$ | 0.00±0.00$^{a}$ | 0.07±0.00$^{c}$ | 0.00±0.00$^{a}$ | 0.08±0.00$^{c}$ |
| **Σ SFA** | **50.20±0.77$^{a b}$** | **53.33±0.79$^{ab}$** | **51.40±0.75$^{ab}$** | **50.94±0.69$^{ab}$** | **51.12±0.72$^{ab}$** | **52.69±0.79$^{ab}$** | **54.60±0.93$^{b}$** | **52.03±0.87$^{ab}$** | **50.12±0.85$^{ab}$** |
| C 14:1 | 0.41±0.01$^{b}$ | 0.26±0.01$^{a}$ | 0.41±0.00$^{b}$ | 0.48±0.00$^{e}$ | 0.43±0.01$^{bc}$ | 0.47±0.01$^{de}$ | 0.41±0.01$^{b}$ | 0.44±0.01$^{cd}$ | 0.42±0.01$^{cde}$ |
| C 15:1 | 0.67±0.01$^{c}$ | 0.75±0.01$^{a}$ | 0.51±0.01$^{b}$ | 0.77±0.00$^{b}$ | 0.47±0.01$^{b}$ | 0.81±0.01$^{b}$ | 0.80±0.01$^{b}$ | 0.80±0.00$^{b}$ | 6.55±0.00$^{b}$ |
| C 16:1 trans | 0.64±0.01$^{c}$ | 0.55±0.01$^{a}$ | 0.73±0.01$^{d}$ | 0.57±0.01$^{ab}$ | 0.60±0.02$^{bc}$ | 0.52±0.01$^{a}$ | 0.60±0.01$^{bc}$ | 0.57±0.01$^{ab}$ | 0.61±0.01$^{bc}$ |
| C 16:1 cis | 1.85±0.01$^{b}$ | 1.87±0.01$^{de}$ | 1.97±0.01$^{cde}$ | 1.89±0.01$^{bcd}$ | 1.86±0.02$^{bc}$ | 1.93±0.02$^{bcde}$ | 1.51±0.02$^{a}$ | 1.90±0.02$^{bcd}$ | 1.89±0.02$^{e}$ |
| C 17:1 | 0.65±0.02$^{b}$ | 0.20±0.02$^{ab}$ | 0.48±0.02$^{a}$ | 0.62±0.02$^{ab}$ | 0.60±0.02$^{ab}$ | 0.63±0.02$^{ab}$ | 0.55±0.02$^{a}$ | 1.02±0.02$^{c}$ | 0.64±0.01$^{b}$ |
| C 18:1 trans | 0.95±0.01$^{f}$ | 0.78±0.01$^{de}$ | 0.69±0.01$^{c}$ | 0.82±0.02$^{e}$ | 0.76±0.02$^{cde}$ | 0.71±0.02$^{cd}$ | 0.38±0.01$^{a}$ | 0.71±0.02$^{c}$ | 0.60±0.02$^{b}$ |
| C 18:1 cis | 28.14±0.37$^{d}$ | 32.34±0.36$^{cd}$ | 31.99±0.37$^{bcd}$ | 33.11±0.37$^{d}$ | 32.58±0.37$^{cd}$ | 30.99±0.39$^{bc}$ | 28.74±0.34$^{a}$ | 30.61±0.34$^{b}$ | 31.59±0.35$^{bcd}$ |
| C 18:1 ω7 | 0.56±0.01$^{b}$ | 0.64±0.01$^{cd}$ | 0.69±0.01$^{d}$ | 0.55±0.01$^{ab}$ | 0.49±0.01$^{a}$ | 0.62±0.01$^{c}$ | 0.56±0.01$^{b}$ | 0.59±0.01$^{bc}$ | 0.92±0.01$^{e}$ |
| C 20:1 | 0.08±0.00$^{a}$ | 0.13±0.03$^{b}$ | 0.09±0.00$^{b}$ | 0.07±0.00$^{a}$ | 0.07±0.00$^{a}$ | 0.05±0.00$^{a}$ | 0.06±0.00$^{a}$ | 0.08±0.00$^{a}$ | 0.07±0.00$^{a}$ |
| **Σ MUFA** | **38.20±0.41$^{c}$** | **37.39±0.40$^{bc}$** | **37.33±0.41$^{bc}$** | **38.34±0.40$^{c}$** | **37.60±0.40$^{bc}$** | **36.10±0.43$^{b}$** | **33.05±0.38$^{a}$** | **36.16±0.39$^{b}$** | **37.17±0.39$^{bc}$** |
| C 18:2ω6 trans | 1.51±0.01$^{f}$ | 0.63±0.01$^{a}$ | 1.18±0.01$^{e}$ | 0.96±0.01$^{d}$ | 0.81±0.01$^{c}$ | 0.60±0.01$^{a}$ | 0.75±0.01$^{b}$ | 0.61±0.02$^{a}$ | 1.14±0.02$^{e}$ |
| C 18:2ω6 cis | 2.11±0.02$^{f}$ | 2.00±0.02$^{e}$ | 1.91±0.02$^{bcd}$ | 1.83±0.01$^{a}$ | 1.97±0.02$^{de}$ | 1.87±0.01$^{ab}$ | 1.95±0.01$^{de}$ | 1.94±0.01$^{cde}$ | 1.88±0.01$^{abc}$ |
| C 18:3ω3 trans | 0.39±0.01$^{f}$ | 0.17±0.01$^{c}$ | 0.23±0.01$^{d}$ | 0.12±0.01$^{b}$ | 0.12±0.01$^{b}$ | 0.06±0.00$^{a}$ | 0.21±0.02$^{d}$ | 0.30±0.03$^{e}$ | 0.20±0.03$^{cd}$ |
| C 18:3ω3 cis | 0.59±0.01$^{f}$ | 0.53±0.01$^{de}$ | 0.55±0.01$^{e}$ | 0.42±0.01$^{b}$ | 0.36±0.01$^{a}$ | 0.44±0.01$^{b}$ | 0.50±0.00$^{cd}$ | 0.48±0.01$^{c}$ | 0.52±0.01$^{de}$ |
| **Σ PUFA** | **4.60±0.05$^{d}$** | **3.33±0.04$^{b}$** | **3.87±0.04$^{c}$** | **3.33±0.04$^{b}$** | **3.26±0.04$^{b}$** | **2.96±0.03$^{a}$** | **3.41±0.03$^{b}$** | **3.33±0.03$^{b}$** | **3.74±0.03$^{c}$** |
| **PUFA / SFA** | **0.092±0.00$^{d}$** | **0.062±0.00$^{b}$** | **0.075±0.00$^{c}$** | **0.065±0.00$^{b}$** | **0.064±0.00$^{b}$** | **0.056±0.00$^{a}$** | **0.063±0.00$^{b}$** | **0.064±0.00$^{b}$** | **0.075±0.00$^{c}$** |
| **C18:2ω6 / C18:3ω3** | **3.70±0.03$^{b}$** | **3.77±0.05$^{b}$** | **3.91±0.06$^{bc}$** | **5.20±0.14$^{d}$** | **5.80±0.16$^{e}$** | **4.97±0.08$^{d}$** | **3.77±0.03$^{b}$** | **3.28±0.04$^{a}$** | **4.17±0.06$^{c}$** |

SE: standard error.
SFA: saturated fatty acid; MUFA: monounsaturated fatty acids and PUFA: polyunsaturated fatty acid.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).

**Table 3** Correlation coefficients

| | Sex | Age | Slaughter weight | Carcass weight | SFA | MUFA |
|---|---|---|---|---|---|---|
| Age | -0.248 | - | - | - | - | - |
| Slaughter weight (SW) | -0.315 | 0.377*** | - | - | - | - |
| Carcass weight (CW) | -0.335 | 0.313 | 0.978* | - | - | - |
| SFA | 0.164 | 0.306 | 0.586* | 0.591* | - | - |
| MUFA | -0.377*** | 0.316 | 0.640* | 0.663* | 0.606* | - |
| PUFA | -0.160 | 0.437*** | 0.583* | 0.554** | 0.795* | 0.701* |

SFA: saturated fatty acid; MUFA: monounsaturated fatty acids and PUFA: polyunsaturated fatty acid.
* (P<0.05); ** (P<0.01) and *** (P<0.01).

**Table 4** Regression tests of mediation

| Model tested | $b_1$ | $b_2$ | $b_3$ | $b_4$ |
|---|---|---|---|---|
| 1. SFA-Age | 0.232 (0.200) | - | - | - |
| 2. MUFA-Age | 0.243 (0.050)* | - | - | - |
| 3. PUFA-Age | 0.164 (0.179) | - | - | - |
| 4. CW-Age | - | 0.581 (0.174) | - | - |
| 5. SW-Age | - | 0.648 (0.101)* | - | - |
| 6. SFA-Age-CW | - | - | 0.106 (0.523) | 0.217 (0.023)* |
| 7.MUFA-Age-CW | - | - | 0.143 (0.169) | 0.172 (0.006)* |
| 8.PUFA-Age-CW | - | - | 0.083 (0.466) | 0.140 (0.034)* |
| SFA-Age-SW | - | - | 0.083 (0.628) | 0.230 (0.031)* |
| MUFA-Age-SW | - | - | 0.129 (0.239) | 0.176 (0.011)* |
| PUFA-Age-SW | - | - | 0.059 (0.604) | 0.162 (0.023)* |

SFA: saturated fatty acid; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acid; SW: slaughter weight and CW: carcass weight.
* (P<0.05).

Estimation of model 4, revealed a non significant effect of age on CW, which means that Baron and Kenny's second condition is not satisfied. Consequently, it is unlikely for CW to function as a mediator in the relationship of age to any of the three types of fat acids. In contrast, when SW was chosen as a mediator there was evidence of significant mediation. Age was found to be an important predictor of SW at the borderlines of 10% significance level (model 5).

Once SW was included in models 1-3, the statistical significance of age on fat acids diminished. Furthermore, the coefficients of age ($b_3$) in models 9-11 are not statistically significant and also are smaller than the coefficients of age ($b_1$). This finding is an indication that CW completely mediates the effect of age on fatty acid composition.

Figure 1 and Figure 2 presents the two theoretical models (model 1 and model 2) in a path diagram form with SFA, MUFA, PUFA, SW and CW being the endogenous variables, and age with sex being the exogenous.

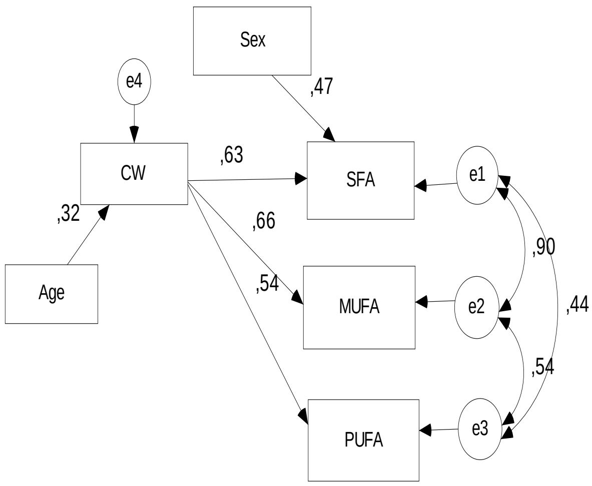


**Figure 1** Path diagram: model 1 carcass weight (CW)

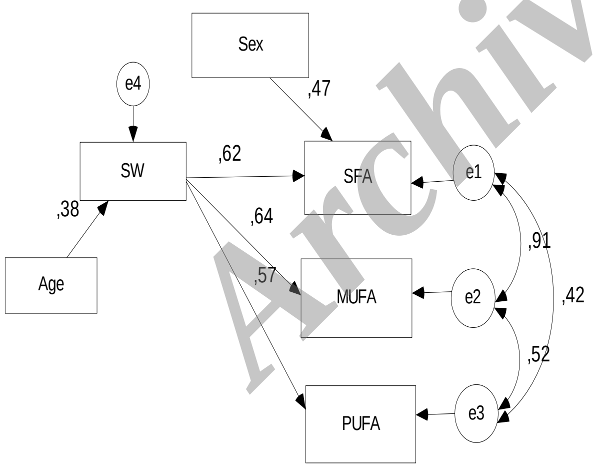


**Figure 2** Path diagram: model 2 slaughter weight (SW)

Given that the three types of fatty acids are related, we allowed their measurement errors to correlate with each other. Numbers in path diagrams represents standardize regression weights, which show the direct effect between variables. Absolute values less than 0.10 show a small effect, values around 0.30 a medium effect and values greater than 0.50 a large effect (Shrout and Bolger, 2002).

According to the results, none of the direct effects can be considered small. Estimations with the use of MLE technique revealed that the data from model 2 exhibit a better fit form than model 1 (Tables 5 and 6).

**Table 5** Regression weights and model 1 (CW) fit statistics

| | | | Estimate | SE | CR | P-value |
|---|---|---|---|---|---|---|
| CW | <--- | Age | 0.581 | 0.399 | 1.455 | 0.146 |
| MUFA | <--- | CW | 0.197 | 0.052 | 3.814 | *** |
| SFA | <--- | CW | 0.324 | 0.072 | 4.520 | *** |
| PUFA | <--- | CW | 0.154 | 0.055 | 2.780 | 0.005 |
| SFA | <--- | Sex | .074 | 0.009 | 7.963 | *** |
| Chi-square ($\chi^2$) | RMSEA | GFI | TLI | IFI | $\chi^2$ (CMIN/DF) | |
| 6.433 | 0.000 | 0.919 | 1.020 | 1.008 | 0.919 | |

RMSEA: root mean square error of approximation; GFI: goodness of fit index; TLI: tucker-lewis index; IFI: incremental fit index; CR: critical region and CMIN / DF: chi square / degree of freedom ratio.
SE: standard error.
SFA: saturated fatty acid; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acid and CW: carcass weight.
*** (P<0.001).

**Table 6** Regression weights and model 2 (SW) fit statistics

| | | | Estimate | SE | CR | P-value |
|---|---|---|---|---|---|---|
| SW | <--- | Age | 0.648 | 0.365 | 1.776 | 0.076 |
| MUFA | <--- | SW | 0.205 | 0.056 | 3.628 | *** |
| SFA | <--- | SW | 0.338 | 0.079 | 4.303 | *** |
| PUFA | <--- | SW | 0.175 | 0.058 | 3.046 | 0.002 |
| SFA | <--- | Sex | 0.074 | 0.009 | 7.971 | *** |
| Chi-square ($\chi^2$) | RMSEA | GFI | TLI | IFI | $\chi^2$ (CMIN/DF) | |
| 5.874 | 0.000 | 0.911 | 1.039 | 1.016 | 0.839 | |

RMSEA: root mean square error of approximation; GFI: goodness of fit index; TLI: tucker-lewis index; IFI: incremental fit Index; CR: critical region and CMIN / DF: chi square / degree of freedom ratio.
SE: standard error.
SFA: saturated fatty acid; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acid and CW: carcass weight.
*** (P<0.001).

In both models the estimated value of $x^2$ accept the null of a good fit (P>0.05). However, this test was too sensitive to the size of the samples and therefore other criteria should be taken into consideration in the evaluation of the model fit. Although estimations of root mean square error of approximation (RMSEA), goodness of fit index (GFI), tucker-lewis index (TLI) and incremental fit index (IFI) and (CMIN/DF) lie within the recommended level of acceptance, the indices performed better in the model with slaughter weight (SW) present. Moreover, the p-value of the path coefficient loading of age to carcass weight was smaller than the conventional 0.05 and 0.10 significance levels (P=0.151).

This was an indication that age does not have a very significant impact on CW and could be dropped from the model. In the second model, the corresponding effect of age to SW was found significant at 10% level and retained as an explanatory variable, given also the acceptable values of goodness of fit indices. Its unstandardized coefficient receives the value of 0.648 (Table 5), which means that given the average age at slaughter (47.9 days), then a 2% change in age (almost a day) would result in 1.30% change in SW. The largest impact of this change was on SFA content, and less on MUFA and PUFA content. The variable of sex was also found to be a significant predictor of SFA (P<0.01), and consequently the impact on SFA when age changes will be even higher if the lamb is male.

The results of the path analysis suggest that age is a significant explanatory variable for the three types of fatty acids when weight at slaughter, and not carcass weight, functions as a mediator variable. Variations in levels of age significantly accounts for variations in slaughter weight, which in turn significantly accounts for the variations of SFA, MUFA and PUFA.

The positive relation among the variables indicates that the higher the age the higher the carcass weight will be, which will lead to higher levels of SFA, MUFA and PUFA. The positive relation between slaughter weights with fatty acids is in line with the findings of Santos-Silva *et al.* (2002), with the exception that the effect on SFA was negative. In contrast to these results, Cifuni *et al.* (1999) found that SFA increased with age at slaughter. Sex in the present study was found to have an impact only on saturated fat acids. Horcada *et al.* (1998), observed no significant differences between sexes in total saturated and unsaturated fatty acids. However, the females had significantly higher proportions of pentandecanoic (C15:0), palmitic (C16:0) and of palmitoleic (C16:1) than the males. In this study, it can be concluded that the lack of any important differences in the unsaturated fatty acid content between the two genders, is an indication that at low slaughter weight, sex has no effect on the nature and composition of fat. Combining this view, with the evidence that when lambs slaughtered at heavier weights contain higher levels of fat than required by the current markets, it will be sensible to slaughter lambs at about half the potential carcass weight. On the other hand there is evidence that increasing the slaughter age of lambs will have favorable results on the profitability of farmers without any harmful consequences on the quality of carcass or meat of lamb (Skapetas *et al.* 2006). Larger carcasses and greater meat yields means better distribution of production and processing costs.

## CONCLUSION

The results of this work shows that the best fatty acid profile can be found in legs, racks and shoulder. Age at slaughter is an important factor determining the content of fatty acids via its positive effect on slaughter weight instead of carcass weight. Sex was found to have an impact only on saturated fatty acid profile. Farmers can become more productive with a more desirable fatty acid composition in lamb carcasses, by balancing a higher slaughter age with low cost feeding practices; this in turn will upgrade the lipid metabolism and affect the deposition of fat in order to increase nutritional quality of lamb.


## ACKNOWLEDGEMENT

The authors thank the technician Apostollos Dollpatsis for the help in the slaughter of lambs and carcass dissection.


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