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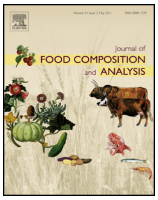

Original Research Article

Influence of cooking method on the nutrient composition of Spanish light lamb

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ABSTRACT

Thirty lambs were used to assess the influence of cooking methods on the nutritional composition of Spanish light lamb. With this aim, the left legs without shank, deboned and untrimmed of any adipose tissue, were analyzed raw. The right legs were analyzed after undertaking one of three cooking procedures: stewing, grilling or roasting. All cooking procedures increased the percentage of fat compared to the raw meat (9.6%), for equivalent sample quantities. This increment was mainly due to the increase in dry matter, from 28.5% in the raw product to 41.6% in roasted or stewed meat, caused by the water losses during cooking. Stewing caused the highest increase in fat, possibly due to fat absorption from the ingredients used in the recipe. This implied an extraordinary increment on the percentage of linoleic acid increasing from 5% to 11% of total fatty acids. *n*-3 fatty acids were less affected by cooking than *n*-6 fatty acids. Stewing could improve the fat quality according to cardiovascular indices, although the excess levels of fat should be taken into account. Moreover, cooking also caused the disappearance of B-vitamins to a higher extent than minerals, when expressed on a dry-matter basis. The composition of roasted or grilled lamb was very similar, even when cooking time was very different.

1. Introduction

The consumption of red meat has traditionally been associated with diets with high content of saturated fats (Ursin et al., 1993); therefore, it has been suggested to reduce their intake in order to prevent cardiovascular disease, which is a major cause of mortality in developed countries (Salter, 2013). Nevertheless, the relation between red meat intake and cardiovascular risk is unclear in many studies (McAfee et al., 2010). Also the consumption of animal products has been associated with chronic illnesses such as obesity (Lin et al., 2011). The excessive intake of calories and sedentary life have been considered as the main cause of overweight (Hill and Melanson, 1999; WHO, 2004) although there are more factors involved, among them, fat intake and food consumption habits (Moreno and Rodríguez, 2007).

Lamb consumption in Spain has decreased from 6.4 kg/per capita in 1990 to 2.2 kg/per capita in 2011 (MARM, 2011). This decrease might be indirectly related to the beliefs about the contribution of red meat to the total fat intake, since dietary guidelines recommend a reduction in the consumption of fat, particularly saturated fat that should contribute as low as possible within recommended guidelines, approximately less than 7% to the total energy intake (EFSA, 2010; NCEP, 2002). However, lamb is rich in other micronutrients, such as vitamins and minerals, whose intake is also affected by the decreased in meat consumption as a result of the reduction in fat intake. Nonetheless, consumption of lean red meat (lamb) or lean white meat (chicken) as part of the usual diet has been associated with a similar lipid response (Mateo-Gallego et al., 2012).

However, the intake recommendations in Spain are based on incomplete data, mainly from animals from different husbandry systems or references from raw samples, while red meat is usually consumed cooked. There are competing needs for the available resources to re-analyze old food data (Pennington, 2008). Production factors, such as breed, age, feeding system or food composition, have been shown as important constituents in the fatty acid composition of lamb (Enser et al., 1998; Sañudo et al., 2000) or mineral (Pieta and Patkowski, 2009). The interaction between the raw ingredients and the cooking procedure has, however, not been studied in depth, even though heat treatment

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has a significant impact on the composition and physicochemical characteristics of the final food (Ratnajothi, 2010). In the case of lamb, the different cooking methods may alter the nutritional composition, meaning that the more transformation the meat undergoes, the more modified its nutritional status (Rechcigl, 1986).

The aim of this study was to assess the influence of three common cooking procedures, under similar conditions that consumers use at home, on the fatty acid composition of a commercial cut, such as the leg, of the most consumed type of lamb in Spain (light lamb reared on concentrates).

2. Materials and methods

2.1. Materials

All reagents were of analytical grade (Panreac, Barcelona, Spain) and deionized water, supplied by a Milli-Q Water System (Millipore Corp., Billerica, MA, USA), was used throughout. For fatty acid analysis, methyl nonadecanoate ≥99.5% was used as internal standard (Sigma–Aldrich, Buchs, Switzerland). Nitric acid ≥65% (Merck, Darmstadt, Germany) was employed to digest the samples for mineral analysis and to prepare all standard solutions. Standard solutions of Fe and Zn were prepared by appropriated dilution of 1000 mg L^{-1} stock solutions (Servicio Central de Análisis, Universidad de Zaragoza, Spain). For B vitamin analysis the following standards from Sigma–Aldrich (Buchs, Switzerland) were used: cianocobalamin ≥98%, riboflavin ≥98% and niacin ≥99%.

2.2. Sampling

Thirty lambs, with 9.93 ± 0.60 kg of cold carcass weight, belonging to the label 'Ternasco de Aragon' Protected Geographical indication, were randomly selected 24 h after slaughtering at an EU-licensed abattoir. Their husbandry conditions included weaning at around 40 days of age and concentrate-based diet plus cereal straw ad libitum until slaughtering, under three months of age. This product represents two-thirds of the lamb production in Spain (MARM, 2011). Both legs were obtained following commercial procedures. The shank from each leg was discharged and the rest of the leg, untrimmed of surface adipose tissue, was individually vacuum packaged and kept at 2–4 °C in darkness for 4 days of ageing. In order to analyze the composition of the raw product, the left leg from each animal was deboned, cut into pieces and all muscles, together with connective tissue, intermuscular and subcutaneous fats were minced in a cutter SAMMIC-SK3 at 1700 rpm for 30 s. Then, a homogeneous sample per analysis was taken, vacuum packaged, immediately frozen and kept at −18 °C until analyzed.

2.3. Cooking procedure

The right legs were randomly assigned to one of three cooking procedures: grilling, stewing and roasting. The recipes were developed by the students of a local cooking school, adapted to the project, based on traditional recipes in the region. Legs were deboned prior to cooking. Legs used for grilling were sliced into 1 cm-thick steaks 2 h before cooking. Grilling was performed on an industrial single-plate grill at 200 °C with 10 mL virgin olive oil for all the steaks, which were turned over after 30 s and kept for approximately 1 extra min until reaching 75 °C internal temperature, measured with a Jenway thermometer with a penetration probe. The legs to be stewed were cut into pieces, placed individually on a stainless-steel pan, simmered with 10 mL virgin olive oil, 250 mL water and 30 g ground almonds, covered with a lid and kept on a cooker at 180 °C for approximately 1 h 15 min until reaching an internal temperature of 75 °C. The legs to be roasted were individually placed on a stainless-steel baking tray, covered with 10 mL virgin olive oil and cooked in a gas oven at 200 °C for approximately 1 h 15 min, turning once, until reaching 75 °C internal temperature. All cooked samples were sprinkled with common salt prior to cooking. Fifteen min after cooking and cooling, the meat was slightly shaken to remove excess juices or any other ingredient, cut into small pieces in the case of the stewed and roasted samples, and mixed and homogenized, as previously explained for the raw samples. Then, a minced sample was vacuum packaged for each analysis, frozen and kept at −18 °C until analysis was performed.

2.4. Proximate analysis

After thawing, minced samples were homogenized again with a mixer (Moulinex 320) prior to determination of dry matter (ISO, 1997), total fat (ISO, 1973), protein (ISO, 1978) with a conversion factor of 6.25 and ash (ISO, 1998). All analyses were performed in duplicate per animal.

2.5. Nutrient analyses

Fatty acids were extracted in chloroform:methanol (Bligh and Dyer, 1959). Methyl esters were obtained with KOH in methanol and analyzed by gas chromatography in a HP 6890 equipped with a flame ionization detector and an automatic injection system (HP 7683), and fitted with a SP 2560 column (100 m × 0.25 mm × 0.20 μm) with N_2 as a carrier gas and C19:0 as an internal standard. Complete details can be checked elsewhere (Carrilho et al., 2009).

Minerals were extracted with acidic digestion by nitric acid (Türkmen and Ciminli, 2007) and detection and quantification by ICP-MS (PerkinElmer ELAN 6000). Vitamins were analyzed after acid-enzymatic hydrolysis (Barna and Dworschak, 1994), Vitamin B3 (niacin) and B12 (cianocobalamin) were detected by a Waters HPLC with PDA detection (Lombardi-Boccia et al., 2005). Vitamin B2 (riboflavin) was determined using a Waters HPLC with fluorescence detection. Both methods used a Symmetry C18 column.

2.6. Statistical analysis

A General Lineal Model was applied with treatment (4 levels, raw and three cooking methods) as a fix effect using SPSS 14.0 for windows (IBM SPSS Statistics, SPSS Inc., Chicago, IL, USA). When significant, a Duncan test ($p \leq 0.05$) was used to assess differences in the mean values. The nutrient contribution of lamb has been assessed in relation to recommended dietary allowances (FESNAD, 2010).

3. Results and discussion

Table 1 shows the proximate composition of the leg of light lambs raw and after undergoing three cooking procedures. The dry matter (DM) significantly varied from 29.5% in the raw meat to 41.6% in both roast and stewed meat, with an intermediate value for grilled meat (37.4%). Differences between dry-heat and moist-heat cooking methods have previously been reported (Sainsbury et al., 2011) with higher losses of moisture in dry-heat cooking procedures. In the present study, the lower duration of grilling, even in sliced steaks, led to a lower moisture loss with stewing or roasting. Besides, stewing was done in chunks of meat, which might have increased the moisture loss in a moist-heat procedure in relation to the whole leg used in roasting, which is a dry-heat cooking method. Nevertheless, these are normal procedures of cooking for Spanish consumers.

Table 1
Proximate composition (100 g of edible portion) of the leg of light lambs reared on concentrates, raw, and after undertaken three cooking procedures.

	Raw	Roasted	Grilled	Stewed	RMSE	
n	30	10	10	10		
Dry matter	28.5 c	41.6 a	37.4 b	41.6 a	26.993	***
Fat	9.6 c	11.1 bc	12.1 b	14.8 a	8.510	***
Protein	17.6 c	25.7 a	21.8 b	25.6 a	16.368	***
Ash	3.0 c	4.7 a	4.8 a	3.8 b	3.506	***
Fat/DM	33.6 a	26.6 b	32.1 a	35.6 a	12.758	*
Protein/DM	61.9	61.9	58.5	61.7	5.693	ns
Ash/DM	10.5 bc	11.2 b	12.9 a	9.1 c	5.032	**

n: number of samples; DM: dry matter; RMSE: root mean square error; ns: not significant.
* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.
a, b, c: mean values in the same row with different letters differ significantly ($p \leq 0.05$).

The percentage of fat of the raw leg (9.6%, Table 1) was higher than current values assigned to lambs raised in similar intensive conditions (Díaz et al., 2005) even higher than older animals raised on pastures (Díaz et al., 2005). The fact that most analyses in the literature are done on a lean muscle such as *Longissimus dorsi* (LD) influences this comparison. A level of 2.41% of intramuscular fat in LD (Díaz et al., 2005) has been found in light male lambs from the same breed, origin and husbandry conditions as the ones used in our study. However, the consumption of lamb is never done in just one muscle; there is always a mixture of muscles plus some intermuscular and subcutaneous tissues that increases the amount of fat that is finally consumed, even if the consumer partially trims the food in the plate. In our case, a 4-fold increase has occurred between the fat content of the LD and the leg, considering all tissues.

Any cooking procedure increased the percentage of fat compared to the raw meat (Table 1), when considering the same weight of raw and cooked meat. This increment is mainly due to the increase in dry matter (DM), due to the water losses during cooking. However, we have considered the cooked meat that would be effectively eaten by the consumer. This is the reason why the water loss has not been taken into account and only 100 g of either raw or cooked food has been considered in the fatty acid analyses. The higher values in the fat percentage of stewed meat (41.6%, Table 1) may have been influenced by the additional ingredients during cooking, especially the almonds, even if they were mostly taking apart before the analysis. Therefore, the consumption of roasted lamb would imply the intake of 15.6% more fat and for grilled lamb of 20.6% more fat than the composition of the raw product. Stewed lamb under our cooking conditions showed a relative increase of 54.2% of fat in relation to the raw product, when it only increased 46.1% its dry matter. This would imply, firstly, that in a moist-heat cooking procedure lamb cannot lose most of its components due to a lower temperature of the liquid surrounding the food, and that the increase was mainly due to the absorption of fat from the ingredients used in the recipe (Librelotto et al., 2008).

The protein percentage followed the same tendency as the dry matter, increasing the percentage from the raw meat (17.6%), and significantly higher in long-time (roasting, 25.7%, and stewing, 25.6%) than in short-time cooking methods (grilling, 21.8%). These significant differences disappear when data are related to the amount of dry matter (Table 1). Therefore, no loss of protein was observed during cooking or due to the method of cooking, although the increase in percentage was highly correlated to the loss of moisture.

Table 2
Fatty acid composition (% of total fatty acids) of the leg of light lambs reared on concentrates, raw and after undertaken three cooking procedures.

	Raw	Roasted	Grilled	Stewed	RMSE	
n	30	10	10	10		
C10:0	0.23	0.26	0.25	0.17	0.130	ns
C12:0	0.50	0.62	0.49	0.34	0.375	ns
C14:0	4.85	5.19	4.86	3.56	2.328	ns
C14:1	0.18	0.19	0.19	0.15	0.070	ns
C15:0	0.74 a	0.77 a	0.71 a	0.58 b	0.277	*
C15:1	0.10 a	0.02 b	0.03 b	0.04 b	0.151	***
C16:0	24.03 a	24.39 a	23.87 a	20.36 b	6.224	***
C16:1 *n*-9	2.65 a	2.57 a	2.71 a	2.27 b	0.662	**
C17:0	2.04	2.06	1.81	1.75	0.558	ns
C17:1	1.08	1.10	0.97	0.96	0.259	ns
C18:0	13.40	12.91	12.58	11.38	3.229	ns
C18:1 *n*-9	34.89 b	34.48 b	36.27 ab	38.30 a	5.917	*
C18:1 *n*-11	1.35	1.39	1.31	1.45	0.195	ns
tC18:2 *n*-6	0.06	0.06	0.06	0.05	0.010	ns
C18:2 *n*-6	5.04 b	5.30 b	5.25 b	11.05 a	9.869	***
C20:0	0.11 b	0.11 b	0.14 a	0.15 a	0.071	***
C18:3 *n*-6	0.06	0.06	0.05	0.05	0.010	ns
C20:1 *n*-11	0.14	0.14	0.15	0.15	0.032	ns
C18:3 *n*-3	0.50	0.47	0.58	0.42	0.205	ns
Total CLA	0.66 a	0.62 ab	0.65 a	0.51 b	0.230	*
C20:2 *n*-6	0.05	0.05	0.05	0.04	0.010	ns
C22:0	0.14 b	0.14 b	0.14 b	0.20 a	0.100	**
C20:2 *n*-3	0.02	0.02	0.02	0.02	0.005	ns
C20:3 *n*-6	0.10	0.09	0.08	0.07	0.045	ns
C22:1 *n*-9	0.01	0.01	0.01	0.01	0.003	ns
C20:3 *n*-3	0.06	0.05	0.06	0.06	0.010	ns
C20:4 *n*-6	0.91	0.86	0.77	0.74	0.305	ns
C20:5 *n*-3	0.09	0.08	0.09	0.06	0.055	ns
C22:6 *n*-3	0.09	0.09	0.09	0.07	0.045	ns
% SFA	46.04 a	46.47 a	44.83 a	38.49 b	12.524	***
% MUFA	40.41 b	39.91 b	41.64 ab	43.32 a	5.164	*
% PUFA	7.63 b	7.76 b	7.76 b	13.14 a	9.102	***
% *n*-6	6.21 b	6.42 b	6.27 b	12.00 a	9.566	***
% *n*-3	0.76	0.72	0.83	0.62	0.281	ns
n-6/*n*-3	9.03 b	9.47 b	8.64 b	20.88 a	19.767	***
PUFA/SFA	0.17 b	0.17 b	0.17 b	0.35 a	0.298	***
ATT	0.22	0.21	0.23	0.19	0.063	ns
I1	2.09 b	2.02 b	2.11 b	2.53 a	0.753	**
AI	0.62 a	0.65 a	0.60 a	0.43 b	0.322	***
TI	7.94 a	7.86 a	7.33 a	4.71 b	5.238	***

n: number of samples; RMSE: root mean square error; ns: no significant.
* $p \leq 0.05$.
** $p \leq 0.01$.
*** $p \leq 0.001$.
a, b: mean values in the same row with different letters differ significantly ($p \leq 0.05$); Total CLA: sum of conjugated linoleic acid isomers; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids. ATT = (C20:3 *n*-3 + C20:5 *n*-3)/C20:4 *n*-6; I1 = (C18:0 + C18:1 *n*-9)/C16:0; AI = (C12:0 + C14:0 + C16:0)/(*n*-3 PUFA + *n*-6 PUFA + MUFA); TI = (C14:0 + C16:0 + C18:0)/(3*n*-3 PUFA + 0.5*n*-6 PUFA + *n*-3 PUFA/*n*-6 PUFA).

Only the percentages of C15:0, C15:1, C16:0, C16:1, C18:1 *n*-9, C18:2 *n*-6, C20:0, CLA and C22:0 out of the 29 fatty acids shown (Table 2) were significantly affected by the cooking method. Except for C20:0, with less levels in roasted lamb, the rest of fatty acids were found in similar percentages in roasted and grilled lamb. This fact, together with the similar fat percentage, would indicate that the use of a dry-heat cooking method at high temperature (grilling or roasting) would alter the fatty acid composition in a similar way when they reach the same internal temperature, independently of the length of the cooking procedure, since they differed from over a minute to over one hour. Similar results have been found with other dry-heat cooking methods (Maranesi et al., 2005).

Among major fatty acids, the largest differences between treatments appeared for palmitic and linoleic acids (Table 2). The percentage of palmitic acid largely decreased in stewed lamb versus grilled, roasted or the raw meat ($p \leq 0.001$) with an 18% decrease in relation to the composition of the raw sample.

Although not significant ($p \leq 0.1$), stearic acid also showed a decreased of 18% in comparison with the raw product. Long length heat treatment would favour the melting of saturated fatty acids. The main difference between stewing and roasting, also considered a long length cooking method, was the presentation of the food, where the leg was cut in chunks for the stew, which would allow a longer temperature action to a larger surface, thus losing more compounds, whereas the entire leg was used in the roast minimising the exposed surface area to the heat. However, oleic acid and linoleic acid, increased extraordinary in the stew in relation to the other treatments. The high content in oleic acid (71%) and linoleic acid (21%) of almonds (Maguire et al., 2004) may have contributed to such a large difference.

The behaviour of palmitic and stearic acids was reflected in the percentage of saturated fatty acids (SFA) (Table 2), where stewed lamb showed 8 points less in percentage of SFA than raw lamb. Although not significantly different from the raw product, grilled lamb, which was also cooked sliced and therefore, with a large surface contact with the heat, showed a decreased in SFA versus raw or roasted meat. The percentage of unsaturated fatty acids followed the opposite tendency, especially polyunsaturated fatty acids (PUFA), in higher proportion in stewed than in raw, roasted or grilled meat, mainly due to the composition of n-6 fatty acids, of which linoleic acid is the major fatty acid. The fact that n-3 PUFA are structural lipids that are less susceptible to alterations by cooking has been suggested as a hypothesis (Kouba et al., 2008) for the less impact of cooking in this group of fatty acids than in others. This explains why no significant differences were found in any individual n-3 fatty acids or in the group of all n-3 fatty acids. As a consequence, stewed lamb showed a very high n-6/n-3 PUFA ratio, far away from the recommendations (DHSS, 1994) although it had a more favourable PUFA/SFA ratio than the rest of treatments, close to the desirable 0.4. The ratio (I1) between the not hypercholesterolaemic major fatty acids (C18:0 + C18:1) and the major hypercholesterolaemic fatty acid (C16:0) (Banskalieva et al., 2000), was significantly higher in the stew than in the rest of treatments. This better ratio was also found in the atherogenic (AI) and thrombogenic (TI) indices (De Lorenzo et al., 2001), where stewed lamb showed a decreased of 31% and 41% for AI and TI respectively in relation to the raw product and the other cooking procedures analyzed.

The effect of cooking on minerals and vitamin B content was of greater importance than the type of cooking in all variables analyzed (Table 3), except for the content of Zn in relation to the content of dry matter.

The amount of minerals found were a bit higher than those found in suckling lamb [1.1 mg Fe/100 g; 2.2 mg Zn/100 g (Miguelez et al., 2008)], since the weight and age at slaughter are higher in light lambs, such as 'Ternasco de Aragón', than in suckling lambs, and this contributes to the mineral status of the animal. On the other hand, they were lower than those found in Icelandic lamb [1.5 mg Fe/100 g; 2.8 mg Zn/100 g (Reykdal et al., 2011)] or in Australian lamb [1.9 mg Fe/100 g; 3.0 mg Zn/100 g (Greenfield et al., 1987)] in animals considered older and heavier than the type of animals studied in the current work. All of this supports the need for knowledge of the composition of local products in order to accurately recommend appropriated patterns of consumption. Differences in mineral content among the treatments were more pronounced when related to the total product ($p \leq 0.001$) than to the dry matter content ($p \leq 0.05$ or $p \leq 0.01$). In both minerals analyzed (Table 3), the amount in the fresh leg was significantly lower than in any of the cooked lamb, maybe due to the dehydration during cooking that increased the amount of dry matter per 100 g of food. These differences were more important in the case of Zn than in the case of Fe, because no significant differences were found among the different cooking treatments in iron content, and roasted lamb showed higher zinc content than stewed or grilled lamb. Whereas the fresh lamb did not differ significantly from stewed or grilled lamb in Fe content when referred to DM basis, with a significant lost of 18% in the roast, the amount of Zn was significantly reduced in a 17.5% with the stewed lamb, but increased in 8.2% in the roasted. This was probably due to the lost of minerals diluted in the water during stewing that did not affect Fe as much as Zn.

The amount of vitamin B2 found in the light lamb 'Ternasco de Aragón' was half and the amount of vitamin B3 was three-fold than the amount found in Australian lamb (Greenfield et al., 1987). The different techniques used in each analysis may partially explain these findings (Ball, 1998; Koontz et al., 2005). Differences in vitamin B content among treatments were not significant when referred to the whole product (Table 3), with the exception of vitamin B3, which showed higher content in the cooked leg than in the raw leg. The lack of differences and similar values among all the treatments, coincidentally with the findings of Heerden et al. (2007) in South African lamb, would imply the same rate of disappearance of B-vitamins during cooking than the increase in dry matter, since they are water-soluble. This fact is supported by their content in relation to the dry matter of the food. No significant differences were found among the different methods of cooking lamb, but all samples were different from the raw product, which shows the lost during the cooking process. However,

Table 3

Minerals and vitamin B content of the leg of light lambs reared on concentrates, raw and after undertaken three cooking procedures.

	Raw	Roasted	Grilled	Stewed	RMSE	
n	30	10	10	10		
Fe mg/100 g food	1.22 b	1.46 a	1.55 a	1.66 a	0.788	***
Zn mg/100 g food	2.51 c	3.98 a	3.03 b	3.04 b	2.342	***
Vit B2 mg/kg food	1.11	1.16	1.10	1.13	0.084	ns
Vit B3 mg/kg food	126.97 b	156.80 a	151.40 a	158.50 a	64.663	*
Vit B12 μg/kg food	19.13	19.70	20.00	20.80	2.737	ns
Fe mg/100 g DM	4.31 a	3.53 b	4.18 a	4.00 ab	1.252	*
Zn mg/100 g DM	8.88 ab	9.61 a	8.15 bc	7.32 c	3.206	**
Vit B2 mg/kg DM	3.93 a	2.79 b	2.94 b	2.72 b	2.503	***
Vit B3 mg/kg DM	447.78 a	377.79 b	405.80 b	381.06 b	138.941	***
Vit B12 μg/kg DM	67.51 a	47.40 b	53.58 b	50.11 b	39.167	***

n: number of samples; DM: dry matter; RMSE: root mean square error; ns: not significant.

* $p \leq 0.05$.

** $p \leq 0.01$.

*** $p \leq 0.001$.

a, b, c: mean values in the same row with different letters differ significantly ($p \leq 0.05$).

Table 4
Contribution of 100 g of edible portion of cooked lamb to the nutrient allowances (RDA values) of males and females, aged 20–49 years.

	Unit	RDA		% contribution		% contribution		% contribution	
		Males	Females	Roasted		Grilled		Stewed	
				Males	Females	Males	Females	Males	Females
Iron (Fe)	mg	10.0	18.0	16.2	8.1	17.2	8.6	18.4	9.2
Zinc (Zn)	mg	15.0	15.0	41.9	56.8	31.9	43.3	32.0	43.4
Vitamin B2	mg	1.6	1.3	7.2	8.9	6.9	8.5	7.1	8.7
Vitamin B3	mg	18.0	14.0	87.1	112.0	84.1	108.1	88.0	112.8
Vitamin B12	μg	2.0	2.0	98.5	98.5	100.0	100.0	104.0	104.0

cooking would not affect the disappearance of vitamins in the same rate, due to their instability to heat, light and liquid (Lombardi-Boccia et al., 2005). Harris and Karmas (1975) observed a reduction of 10% of vitamin B12 and up to 70% of vitamin B2 after cooking. In our study, although lamb cooked at different methods did not show different levels of those two vitamins, shorter cooking length (grilling) had lower losses than long cooking length (roasting or stewing), with a lost of 25% in the amount of vitamin B2 or 20% in vitamin B12 in the case of grilled versus raw lamb. However, when compared to other meat products, lamb is a good source of vitamins, especially B12 (Badiani et al., 1998).

The nutrient contribution of lamb undertaken three different cooking methods (Table 4) has been assessed according to the recommended dietary allowances (RDA) in Spain for males and females, aged 20–49 years (FESNAD, 2010). These RDA are similar for minerals and cyanocobalamin, and slightly higher for riboflavin and niacin, than the dietary reference intakes by the American Institute of Medicine (1998, 2001). A 100 g portion of cooked leg (with all adipose, connective and muscular tissues involved) would provide an average of 12.9% iron, 41.5% zinc, 7.9% vitamin B2, 98.6% vitamin B3 and 100.8% vitamin B12 of the RDA. Nevertheless, the contribution to the RDA would be higher in males for Fe, and lower in Zn, vitamin B2 and vitamin B3 than for females. In any case, stewing the lamb would contribute in a higher extent to the RDA of iron, niacin and cyanocobalamin, and roasting the meat would increase the contribution to the RDA of zinc and riboflavin.

4. Conclusion

Although most lamb composition data are based on raw meat, this study has shown that cooking processes greatly influence the final composition of edible lamb. This effect is mainly due to the increase in dry matter that changes fat content, in particular. Hardly any differences were found between dry-heat cooking methods, even when cooking times were considerably different. A moist-heat cooking method such as stewing influences the fatty acid composition of the product on a larger scale, mainly due to the composition of the ingredients added to the recipe and their possibility of interacting with the food, increasing especially the percentage of n-6 PUFA. Except for the ratio n-6/n-3, stewing may improve the fat quality of lamb according to cardiovascular indices, although the increment in the level of fat due to the ingredients of the recipe should be taken into account.

Cooking processes without distinction heavily modified the composition of minerals and B-vitamins. Minerals were more affected by cooking than vitamins, increasing the amount in the edible portion due to an increase in dry matter, whereas, except for vitamin B3, the amount of vitamins in cooked meat did not differ from the levels in raw meat. However, cooking caused more B-vitamins to disappear than minerals, when expressed on a dry matter basis. In conclusion, lamb is a good source of minerals and vitamins, especially Zinc and vitamin B12.

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References

Badiani, A., Nanni, N., Gatta, P.P., Bitossi, F., Tolomelli, B., Manfredini, M., 1998. Nutrient content and retention in selected roasted cuts from 3-month-old ram lambs. Food Chemistry 61, 89–100.

Ball, G.F.M., 1998. Bioavailability and Analysis of Vitamins in Foods. Chapman & Hall, London, UK.

Banskalieva, V., Sahlu, T., Goetsch, A.L., 2000. Fatty acid composition of goat muscles and fat depots: a review. Small Ruminant Research 37, 255–268.

Barna, E., Dworschak, E., 1994. Determination of thiamine (vitamin B1) and riboflavin (vitamin B2) in meat and liver by high-performance liquid chromatography. Journal of Chromatography 668, 359–363.

Bligh, E., Dyer, W.J., 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology 37, 911–914.

Carrilho, M.C., Lopez, M., Campo, M.M., 2009. Effect of the fattening diet in the development of the fatty acid profile in rabbits from weaning. Meat Science 83, 85–95.

De Lorenzo, A., Petroni, M.L., De Luca, P.P., Anfreoli, A., Morini, P., Innocente, I., Perriello, G., 2001. Use of quality control indices in moderately hypocaloric Mediterranean diet for treatment of obesity. Diabetes, Nutrition and Metabolism 14, 181–188.

DHSS (Department of Health and Security), 1994. Report on Health and Social Subjects No. 46. In: Nutritional Aspects of Cardiovascular Disease. HMSO, London.

Díaz, M.T., Álvarez, I., De la Fuente, J., Sañudo, C., Campo, M.M., Oliver, M.A., Font i Furnols, M., Montossi, F., San Julián, R., Nute, G.R., Cañeque, V., 2005. Fatty acid composition of meat from typical lamb production systems of Spain, United Kingdom, Germany and Uruguay. Meat Science 71, 256–263.

EFSA (European Food Safety Authority), 2010. Panel on Dietetic Products, Nutrition, and Allergies (NDA); Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. EFSA Journal 8, 1461–1568.

Enser, M., Hallett, K.G., Hewett, B., Fursey, G.A.J., Wood, J.D., Harrington, G., 1998. Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. Meat Science 49, 329–341.

FESNAD, 2010. Federación Española de Sociedades de Nutrición AyDF. Ingestas Dietéticas de Referencia (IDR) para la población española. Ediciones Universidad de Navarra, Pamplona (in Spanish).

Greenfield, H., Kuo, Y.L., Hutchison, G.I., Wills, R.B.H., 1987. Composition of Australian foods. 33. Lamb. Food Technology in Australia 39, 202–207.

Harris, R.S., Karmas, E., 1975. Nutritional Evaluation of Food Processing. AVI Publ. Co, Wesport.

Heerden, S.M., Schönfeldt, H.C., Kruger, R., Smit, M.F., 2007. The nutrient composition of South African lamb (A2 grade). Journal of Food Composition and Analysis 20, 671–680.

Hill, J.O., Melanson, E.L., 1999. Overview of the determinants of overweight and obesity: current evidence and research issues. Medicine and Science in Sports and Exercise 31, S515–S521.

ISO, 1973. Meat and meat products – Determination of total fat content. ISO 1443:1973. International Organization for Standardization, Geneva, Switzerland.

ISO, 1978. Meat and meat products – Determination of nitrogen content. ISO 937:1978. International Organization for Standardization, Geneva, Switzerland.

ISO, 1997. Meat and meat products – Determination of moisture content. ISO 1442:1997. International Organization for Standardization, Geneva, Switzerland.

ISO, 1998. Meat and meat products – Determination of total ash. ISO 936:1998. International Organization for Standardization, Geneva, Switzerland.

Koontz, J.L., Plillips, K.M., Wunderiach, K.M., Exler, J., Holden, J.M., Gebhardt, S.E., Haytowitz, D.B., 2005. Comparison of total folate concentrations in foods determined by microbiological assay at several experienced US commercial laboratories. Journal of AOAC International 88, 805–813.

Kouba, M., Benatmane, F., Blochet, J.E., Mourot, J., 2008. Effect of a linseed diet on lipid oxidation, fatty acid composition of muscle, perirenal fat, and raw and cooked rabbit meat. Meat Science 80, 829–834.

Librelotto, J., Bastida, S., Serrano, A., Cofrades, S., Jiménez-Colmenero, F., Sánchez-Muniz, F.J., 2008. Changes in fatty acids and polar material of restructures low-fat or Walnut-added steaks pan-fried in olive oil. Meat Science 80, 431–441.

Lin, Y., Bolca, S., Vandevijvere, S., De Vriese, S., Mouratidou, T., De Neve, M., Polet, A., Van Oyen, H., Van Camp, J., De Backer, G., De Henauw, S., Huybrechts, I., 2011. Plant and animal protein intake and its association with overweight and obesity among the Belgian population. British Journal of Nutrition 105, 1106–1116.

Lombardi-Boccia, G., Lanzi, S., Aguzzi, A., 2005. Aspects of meat quality: trace elements and B vitamins in raw and cooked meats. Journal of Food Composition and Analysis 18, 39–46.

Maguire, L.S., O'Sullivan, S.M., Galvin, K., O'Connor, T.P., O'Brien, N.M., 2004. Fatty acid profile, tocopherol, squalene and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. International Journal of Food Sciences and Nutrition 55, 171–178.

Maranesi, M., Bochicchio, D., Montellato, L., Zaghini, A., Paglica, G., Badiani, A., 2005. Effect of microwave cooking or broiling on selected nutrient contents, fatty acid patterns and true retention values in separable lean from lamb rib-loins, with emphasis on conjugated linoleic acid. Food Chemistry 90, 207–218.

MARM, 2011. Ministerio de Medio Ambiente, Rural y Marino. Spanish Ministry of Environmental, Rural and Marine affairs. Official statistics. http://www.marm.es (in Spanish).

Mateo-Gallego, R., Perez-Calahorra, S., Cenarro, A., Bea, A.M., Andres, E., Horno, J., Ros, E., Civeira, F., 2012. Effect of lean red meat from lamb v. lean white meat from chicken on the serum lipid profile: a randomised, cross-over study in women. British Journal of Nutrition 107, 1403–1407.

McAfee, A.J., McSorley, E.M., Cuskelly, G.J., Moss, B.W., Wallace, J.M.W., Bonham, M.P., Fearon, A.M., 2010. Red meat consumption: an overview of the risks and benefits. Meat Science 84, 1–13.

Miguelez, E., Zumalacarregui, J.M., Osorio, M.T., Figueira, A.C., Fonseca, B., Mateo, J., 2008. Quality traits of suckling-lamb meat covered by the protected geographical indication ''Lechazo de Castilla y Leon'' European quality label. Small Ruminant Research 77, 65–70.

Moreno, L.A., Rodríguez, G., 2007. Dietary risk factors for development of childhood obesity. Current Opinion in Clinical Nutrition and Metabolic Care 10, 336–341.

NCEP (National Cholesterol Education Program), 2002. Treatment Panel III Final Report on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Third Report of the National Cholesterol Education Program (NCEP) Expert Panel). Circulation 106, 3143–3421.

Pennington, J.A.T., 2008. Applications of food composition data: data sources and considerations for use. Journal of Food Composition and Analysis 21, S3–S12.

Pieta, M., Patkowski, K., 2009. The content of mineral elements in two lamb genotypes dependent on the system of maintenance. Journal of Elementology 14, 527–537.

Ratnajothi, H., 2010. The impact of heat-moisture treatment on molecular structures and properties of starches isolated from different botanical sources. Critical Reviews in Food Science and Nutrition 50, 835–847.

Rechcigl, M., 1986. Handbook of Nutritive Value of Processed Foods. CRC Press, Florida, USA.

Reykdal, O., Rabieh, S., Steingrimsdottir, L., Gunnlaugsdottir, H., 2011. Minerals and trace elements in Icelandic dairy products and meat. Journal of Food Composition and Analysis 24, 980–986.

Sainsbury, J., Schönfeldt, H.C., Van Heerden, S.M., 2011. The nutrient composition of South African mutton. Journal of Food Composition and Analysis 24, 720–726.

Salter, A.M., 2013. Dietary fatty acids and cardiovascular disease. Animal 7, 163–171.

Sañudo, C., Enser, M., Campo, M.M., Nute, G., María, G., Sierra, I., Wood, J.D., 2000. Fatty acid composition and sensory characteristics of lamb carcasses from Britain and Spain. Meat Science 54, 339–346.

The Institute of Medicine, 1998. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. The National Academy Press, Washington, DC, USA.

The Institute of Medicine, 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. The National Academy Press, Washington DC: USA.

Türkmen, M., Ciminli, C., 2007. Determination of metals in fish and mussel species by inductively coupled plasma-atomic emission spectrometry. Food Chemistry 103, 670–675.

Ursin, G., Zeigler, R.G., Subar, A.F., Graubard, B.I., Haile, L.W., Hoover, R., 1993. Dietary patterns associated with a low fat diet in the national health examination follow up study: identification of potential confounders for epidemiological analysis. American Journal of Epidemiology 137, 916–917.

WHO (World Health Organization). (2004). Global Strategy on diet and Physical Activity. World Health Assembly 57.17. Geneva.