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The Absence of Quality Standards on Meat Trade and its Implications to Retailers and Consumers

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Abstract

The study aimed to compare the regular veal commercialized in Portugal from different origins, namely crossbred beef calves from Portuguese production (PCB) and Holstein calves from Dutch (DHF), Spanish (SHF) and Portuguese (PHF) production.

Veal from SHF and PHF were associated with high pH being classified as DFD. Veal from Holstein calves of all origins displayed higher contents of SFA and MUFA and lower contents of PUFA and n-3PUFA than veal from PCB. It is also noteworthy that HF veal, no matter the origin, presented a larger amount of 18:1 *trans*-10 than 18:1 *trans*-11 and very low 18:2 *cis*-9, *trans*-11 which is indicative of deviation of biohydrogenation pathways (*i.e. trans*-10 shift). Regarding lipid quality indices, CBP revealed healthier indices than Holstein calves.

The study results revealed that veal obtained from different origins enclosed an undesirable variability with potential consequences to retailers profit and negative health concerns to consumers.

Keywords: Veal; pH; Fatty acids; Cholesterol; Vitamin E

Introduction

Portuguese production of beef is quite below the country needs, with the self-sufficiency rate estimated in 58%, which means that more than 40% of the overall beef sold in Portugal has to be acquired from other regions, representing around 68.3 thousand tons/year [1].

Among Portuguese consumers, price is the prime decision factor influencing beef acquisition [2]. Therefore, competitiveness of beef retail relies on the purchase of bovine carcasses at low price, which is essential to assure a constant delivery of beef to the domestic market. Spain and Netherlands are two of the main suppliers of beef to Portugal, accounting for 65.8% and 15.3% of total beef acquisition, respectively [1]. Bovine carcass value in the market is influenced by the conjugation of different factors as age, breed and the production system. Breed strongly influences beef cut category yields, and differences between beef and dairy breeds are well recognised, for this reason, carcasses from Holstein animals are less valorised than those of beef breeds, since it presents significantly lower yields of prime beef cuts, due to higher bone and lower muscle proportions [3]. On the other hand, age has a strong influence on meat sensory attributes, as colour and tenderness, characteristics that are much appreciated by consumers [4].

The quality of meat marketed in Portugal is poorly studied and the purchasing decisions are mainly based on price, deviating meat quality to a second plan, which is undesirable. Such situation contrasts with consumers demand for quality. Therefore, and despite a regular delivery of beef, it is associated with great variability which confuses consumers and creates distrust in the purchase act.

This research was planned to compare meat quality attributes of veal from the four major origins supplying the Portuguese market. The comparison encloses physicochemical parameters with highest impact on consumers purchasing choices (colour and texture/tenderness) and the nutritional quality of intramuscular fat, a prime issue on consumer's health.

Material and Methods

Animals and samples

Veal used in this study represented the regular veal commercialized in Portugal by one of

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the prime supermarket chains. Meat samples (n=10 from each variety) were obtained from carcasses of Holstein bull calves (age 10-12 months old) randomly selected among Dutch, Spanish and Portuguese production and from crossbreed beef bull calves from national production with equal age.

Sampling was performed throughout a 10 week period, between March and May 2016, and each carcass was randomly selected among those distributed in Portugal in a weekly base. Two meat samples with different thickness from each carcass were collected from longissimus lumborum muscle at the L1-L3 level. The sample with 3 cm thick were used for physicochemical analysis (colour assessment and Warner Bratzler Shear Force (WBSF) measurements), while the 1 cm thick samples were used for pH evaluation and assessment of intramuscular lipid composition (total fatty acid content, fatty acid profile, cholesterol and lipid-soluble antioxidant vitamin contents).

Meat samples were trimmed from the major connective and adipose tissues surrounding muscle tissue. The thicker sample was vacuum packaged, frozen and stored at -20°C until analysis, while the thinner one was blended on a food processor (Moulinex, France), and afterwards divided in two portions: one was weighted, frozen and stored at -20°C in a 50 ml container (Greiner, Germany), while the other was vacuum packaged, frozen and stored at -80°C.

Colour, pH and shear force measurements

The colour measurements were carried out with a Minolta CR 300 colorimeter (Konica Minolta Holdings Inc., Tokyo, Japan) with a C iluminant and a 2º standard observer in the CIELAB space, after 1 hour of blooming to allow oxygenation. In each sample, colour measurements were performed in triplicate, recording lightness (L^*), redness (a^*) and yellowness (b^*). The Chroma (C^*) was calculated as $\sqrt{(a^{*2}+b^{*2})}$, and the hue angle (hº) as $\tan^{-1}$ (b^*/a^*). The pH of each sample was measured in triplicate with a HI 99163 portable pH-meter (Hanna Instruments, USA). For the WBSF determination, the samples were thawed at 0–4°C for 24 h and were grilled using the same equipment and procedures previously reported (Monteiro, 2012) [2]. The veal sample resistance to shearing was recorded in a force-deformation plot. The maximum shear force in kg corresponded to the highest peak of the curve.

Analytical methods

The frozen samples stored in the 50 ml containers were lyophilized (−60°C and 2.0 h Pa) until constant weight using a lyophilisator Edwards Modulyo (Edwards High Vacuum International, West Sussex, UK). Lyophilized samples were then grounded and homogenized using a home-style coffee grinder and maintained desiccated at room temperature.

The fatty acid methyl esters were prepared from freeze-dried samples with 14% boric trifluoride in methanol [5] and further analysed by gas-liquid chromatography using a Shimadzu GC2010-plus (Shimadzu, Kyoto, Japan) with flame ionization detection and a fused-silica capillary column (BPX70, 60 m × 0.25 mm × 0.25 µm, SGE Europe Ltd, UK). Helium was used as carrier gas at a flow rate of 1 ml/min. The oven temperature was programmed to begin at 50ºC (kept for 1 min), raised to 150°C at 5 C°/min (kept for 1 min), raised at 1°C/min to 200°C (kept for 2 min), and finally raised at 3°C/min to 220°C. The injector and detector were maintained at 250°C.

The simultaneous determination of total cholesterol, tocopherols and tocotrienols was performed as previously described. The contents of total cholesterol, tocopherols and tocotrienols were estimated in duplicate for each sample based on the external standard technique from the standard curve of peak area versus compound concentration.

Lipid quality indices

The lipid quality indices and FA ratios were calculated as follows:

- Peroxidability Index (PI) = (% monoenoic × 0.025) + (% dienoic × 1) + (% trienoic × 2) + (% tetraenoic × 4) + (% pentaenoic × 6) + (% hexaenoic × 8) [6];

- Atherogenicity Index (AI) = (C12:0+4×C14:0+C16:0) / [(ΣMUFA+Σ(n−6) +Σ(n−3)] [7]

-Thrombogenicity Index (TI) = (C14:0+C16:0+C18:0)/ [(0.5×ΣMUFA)

+0.5×(n−6)+3×(n−3)+(n−3)/(n−6)] [7];

- Hypocholesterolemic/hypercholesterolemic ratio (h/H) = [(C18:1n−9 + C18:2n-6 + C18:3n-3 + C20:4n−6 + C20:5n-3 + C22:5n−3 + C22:6n-3) / (C14:0 + C16:0)] [8];

- Polyunsaturated/saturated FA (P/S) = [(18:2 n-6)+(18:3 n-3)/ (14:0+16:0+18:0)] [9]

- n-6 PUFA/n-3 PUFA (n-6/n-3) = [(∑n-6)/(∑n-3)].

Statistical analysis

The variables in study were subjected to analysis of variance (ANOVA), considering the type of veal as a single effect, using the GLM procedure of Statistical Analysis Systems Institute (SAS). Whenever a significant difference was detected in ANOVA, least squares means were compared for alpha = 0.05, using the LSD test adjusted by Tukey method.

Results and Discussion

Beef colour, pH and Warner Bratzler shear force

Data on veal ultimate pH, colour parameters (L^*, a^*, b^*, hº, C^*) and WBSF are presented in Table 1. Meat pH showed some significant differences between groups (P<0.001). Among veal from Holstein calves, the Spanish veal displayed the highest pH value (6.2), while Dutch veal displayed the lowest value (5.5) diverging significantly in between, while the Portuguese Holstein calves presented a halfway value for veal pH (5.9), not differing significantly from other meats obtained from Holstein calves (P>0.05). Veal from crossbred beef calves displayed the lowest pH values (5.4), not differing significantly from the pH values observed on veal from Dutch and Portuguese Holstein calves. Meat displaying a pH value >6.0 is classified as Dark, Firm and Dry (DFD) [10]. Thus meat from Spanish Holstein calves should be classified as DFD, while meat from Portuguese Holstein calves is near the threshold of DFD meat.

DFD meat is consequence of glycogen depletion in muscle during the pre-slaughter period. The absence of sufficient amounts of glycogen at muscle level after slaughter does not allow the formation of proper lactic acid content and the subsequent pH decline. Therefore, the ultimate conditions for conversion of muscle into meat are not gathered [11]. Meat with pH values higher than 6.0 is undesirable because of its dark colour, high variation in tenderness, increased water holding capacity, poor palatability and low microbiologic stability [12]. DFD meat is also a problem for industry, since high ultimate pH allows rapid bacteria proliferation and the development of precocious spoilage odours, which become evident at lower bacterial cell densities [4].

Table 1: Beef colour parameters (L*, a*, b*, hº and C*), Warner Bratzler Shear Force (WBSF) and pH of longissimus lumborum muscle from veal with different genetic background or origins.

	Veal				Statistics	
Type	**Holstein-Friesian**			**Crossbred beef**	**SEM**	**P**
Origin	Spain	Netherlands	Portugal	Portugal		
pH	6.18^{a}	5.51^{b}	5.87^{a,b}	5.42^{b}	0.1124	<0.0001
L*	30.87^{b}	35.20^{a}	36.11^{a}	37.59^{a}	1.0025	0.0003
a*	15.52^{b}	18.03^{a}	14.34^{b}	14.20^{b}	0.5742	<0.0001
b*	1.42^{b}	3.66^{a}	3.00^{a,b}	3.08^{a,b}	0.5629	0.0481
hº	3.51	5.73	5.49	4.90	7.0543	0.3486
C*	15.79^{b}	18.44^{a}	14.75^{b}	14.55^{b}	0.5741	<0.0001
WBSF (kg)	4.87	6.78	5.54	7.75	0.837	0.0825

Different superscripts in the same row diverge significantly (P < 0.05).

Table 2: Total cholesterol content (mg/100 g of muscle), total fatty acid content (mg/100 g of muscle), partial sums of fatty acids (% w/w) and nutritional indices of longissimus lumborum muscle from veal with different genetic background or origin.

	Veal				Statistics	
Type	**Holstein-Friesian**			**Crossbred beef**	**SEM**	**P**
Origin	**Spain**	**Netherlands**	**Portugal**	**Portugal**		
Total cholesterol	44.55	45.06	46.85	42.78	7.69	0.379
Total fatty acids	6.37^{b}	8.52^{a}	7.13^{a,b}	4.29^{c}	0.55	<0.0001
Partial sums						
∑ SFA	40.60^{a}	40.14^{a}	37.95^{a}	33.68^{b}	0.69	<0.0001
∑ SFA linear	40.35^{a}	39.70^{a,b}	37.52^{b}	33.02^{c}	0.69	<0.0001
∑ SFA branched	0.25^{c}	0.44^{b}	0.43^{b}	0.67^{a}	0.02	<0.0001
∑ DMA	5.88^{b,c}	4.79^{c}	6.79^{b}	9.09^{a}	0.39	<0.0001
∑ MUFA	33.83^{b}	40.67^{a}	30.87^{b}	25.72^{c}	1.27	<0.0001
∑ MUFA *trans*	4.69^{a}	2.64^{b}	3.46^{a,b}	2.52^{b}	0.34	0.0003
∑ MUFA *cis*	29.14^{b}	38.02^{a}	27.41^{b,c}	23.19^{c}	1.17	<0.0001
∑ PUFA	19.30^{b,c}	13.82^{c}	23.75^{b}	30.47^{a}	1.44	<0.0001
∑ n-3PUFA	0.81^{b}	1.32^{b}	1.20^{b}	8.36^{a}	0.27	<0.0001
∑ n-6PUFA	18.34^{a}	12.40^{b}	22.37^{a}	22.01^{a}	1.29	<0.0001
∑ n-3LCPUFA	0.55^{b}	0.90^{b}	0.86^{b}	5.66^{a}	0.15	<0.0001
∑ n-6LCPUFA	4.71^{b}	4.14^{b}	6.87^{a}	7.15^{a}	0.41	<0.0001
∑ Others	0.38^{c}	0.57^{b}	0.64^{b}	1.03^{a}	0.04	<0.0001
Nutritional Indices						
P/S	0.35^{b,c}	0.22^{c}	0.44^{a,b}	0.55^{a}	0.04	<0.0001
n6/n3	22.77^{a}	9.60^{c}	18.77^{b}	2.70^{d}	0.50	<0.0001
AI	0.58^{a}	0.54^{a}	0.47^{b}	0.39^{c}	0.02	<0.0001
TI	1.39^{a}	1.28^{a,b}	1.23^{b}	0.66^{c}	0.04	<0.0001
h/H	1.64^{c}	1.82^{b,c}	2.11^{b}	2.47^{a}	0.09	<0.0001

Different superscripts in the same row diverge significantly (P < 0.05).

Regarding veal colour measurements, Spanish veal displayed the lowest L* value, being significantly lower than all other groups, which revealed no significant differences in between (P>0.05). Dutch veal presented the highest a* value, which represents a redder meat, and no significant differences were observed between the Spanish and Portuguese veal types. Dutch veal displayed a significantly higher b* value than Spanish veal (P<0.05), while the Portuguese veal displayed an intermediate value, not differing significantly from other veal types (P>0.05). The highest redness and yellowness from Dutch veal resulted in the highest C*, which is a reflex of these two colour coordinates and depends on ultimate meat pH [13]. No significant differences were observed in h^0 value between veal groups, which means that the wavelength of reflected light is similar [14]. With the exception of Spanish Holstein veal, the L* values (35.2-37.6) are in the range of values previously found on autochthonous bovine breeds (35.0-39.0) [15]. On the other hand, the values observed in this study for a* (14.2-18.0) and b* (1.40-3.66) are on the edge of values previously observed on autochthonous bovine breeds for a*(15.9-18.2) and b* (1.9-3.1) [15].

The lower L* values observed on Spanish veal represent a darker colour, which is consistent with their higher pH value. On the other

Table 3: Intramuscular fatty acid profile (g/100 g of total FA) of longissimus lumborum muscle from veal with different genetic background or origins.

	Veal					Statistics	
Type	**Holstein-Friesian**				**Crossbred beef**	**SEM**	**P**
Origin	**Spain**	**Netherlands**	**Portugal**		**Portugal**		
C14:0	1.87^{a}	1.83^{a}	1.41^{a,b}		1.06^{b}	0.13	0.0003
C14:1c9	0.31^{a,b}	0.34^{a}	0.20^{b,c}		0.16^{c}	0.03	0.0004
C15:0	0.33^{a}	0.34^{a}	0.26^{b}		0.32^{a}	0.02	0.0073
C16:0	23.04^{a}	22.06^{a}	19.71^{b}		17.93^{c}	0.44	<0.0001
C16:1c9	2.24^{a}	2.48^{a}	1.61^{b}		1.19^{b}	0.13	<0.0001
a-C17:0	0.13^{c}	0.23^{b}	0.23^{b}		0.32^{a}	0.01	<0.0001
C17:1c9	0.49^{b}	0.81^{a}	0.47^{b}		0.43^{b}	0.05	<0.0001
C18:0	14.90^{a}	15.28^{a}	15.94^{a}		13.45^{b}	0.40	0.0008
C18:1t10	3.39^{a}	1.37^{b,c}	2.26^{a,b}		0.97^{c}	0.34	<0.0001
C18:1t11	0.35^{b}	0.52^{b}	0.55^{b}		1.08^{a}	0.10	0.0001
C18:1t12	0.30^{a}	0.21^{b}	0.17^{b}		0.17^{b}	0.01	<0.0001
C18:1c9	23.05^{b}	31.05^{a}	22.09^{b,c}		18.20^{c}	0.02	<0.0001
C18:1c11	2.24	2.26	2.21		2.38	0.07	0.339
C18:1c12	0.21	0.21	0.24		0.22	0.03	0.746
C18:1c13	0.19^{a,b}	0.25^{a}	0.15^{b,c}		0.12^{c}	0.02	<0.0001
C18:1c15	0.15^{b}	0.27^{a}	0.15^{b}		0.22^{a}	0.02	<0.0001
C18:2n-6	13.54^{a}	8.16^{b}	15.40^{a}		14.71^{a}	0.91	<0.0001
C18:3n-3	0.25^{b}	0.42^{b}	0.34^{b}		2.70^{a}	0.13	<0.0001
CLA(*cis*-9,*trans*-11)	0.03^{b}	0.08^{b}	0.06^{b}		0.19^{a}	0.02	<0.0001
C20:3n-6	0.77^{c}	0.65^{c}	1.09^{b}		1.36^{a}	0.07	<0.0001
C20:4n-6	3.35^{b}	2.91^{b}	4.84^{a}		5.43^{a}	0.30	<0.0001
C20:5n-3	0.14^{b}	0.20^{b}	0.19^{b}		2.18^{a}	0.05	<0.0001
C22:4n-6	0.49^{b}	0.47^{b}	0.77^{a}		0.28^{c}	0.04	<0.0001
C22:5n-3	0.36^{b}	0.61^{b}	0.59^{b}		2.85^{a}	0.09	<0.0001
C22:6n-3	0.05^{b}	0.08^{b}	0.07^{b}		0.55^{a}	0.02	<0.0001
Others*	0.98^{b}	1.05^{a}	1.06^{a}		1.15^{a}	0.04	0.036
DMAs							
DMA-C16:0	3.19^{b}	2.45^{c}	3.32^{b}		4.96^{a}	0.19	<0.0001
DMA-C18:0	1.89^{b}	1.80^{b}	2.59^{a}		3.07^{a}	0.19	<0.0001
DMA-C18:1	0.80^{b}	0.54^{c}	0.87^{b}		1.06^{a}	0.08	<0.0001

*Representing the sum to co-eluted fatty acids (namely i-C17:0+C16:1, C18:1t6 to t9, C18:1c14+t16 and C20:2n-6+C21:0).
Different superscripts in the same row diverge significantly (P < 0.05).

hand, veal from crossbred beef calves showed the lowest pH value and the highest L* value. Besides pH, meat colour is determined by the amount and chemical state of heme pigments, mainly myoglobin, responsible for 95% of total meat iron after slaughter [16].

[17] showed that DFD meat (pH ≥ 6.1) had a significant influence on all colour variables (L*, a*, b*, C* and h°), and that DFD meat was associated with reduced L*, a*, b*, C* and h°, which is in agreement with our results, since veal from Spanish origin was associated with lower L*, a* and b*. On the other hand, Dutch veal displayed higher values of a*, which may be dependent of pigment (myoglobin) content and its redox state [4].

No statistical significant differences were observed in WBSF between groups (p=0.08). Although, Spanish veal tended to be the less hard (P=0.08) which can result from the highest pH presented by this beef type, since DFD beef is recognized as being tender, due to the highest muscle enzyme activity post-mortem. The high pH and the low WBSF values obtain in meat from Portuguese and Spanish Holstein calves seem to be in accordance with the aforementioned. The high WBSF observed on crossbred veal produced in Portugal has been previously identified in another study and is associated with the lack of ageing, as is sold only two days after slaughter [2].

Fatty acid profile, partial sums, total content and lipid quality indices

The total fatty acid and total cholesterol content of meat, as well as fatty acid partial sums and ratios, and lipid quality indices are presented in Table 2, while the detailed fatty acid profile is presented in Table 3.

Veal from Holstein calves presented higher total fatty acid contents, independently of their origin, than veal from crossbred beef calves (P<0.05). Nevertheless, Dutch and Spanish Holstein veal

Table 4: Total vitamin E, prime tocopherols (α-tocopherol and γ-tocopherol), β-carotene and the Peroxidability Index (PI) of longissimus lumborum muscle from veal with different genetic background or origins.

	Veal						Statistics	
Type	**Holstein-Friesian**				**Crossbred beef**		**SEM**	**P**
Origin	**Spain**	**Netherlands**	**Portugal**		**Portugal**			
Total vitamin E*	1.44^{c}	1.14^{c}	2.35^{b}		2.91^{a}		0.15	<0.0001
-tocopherol*	1.23^{c}	1.01^{c}	1.98^{b}		2.81^{a}		0.14	<0.0001
γ-tocopherol*	0.21^{b}	0.13^{c}	0.37^{a}		0.10^{c}		0.01	<0.0001
β-carotene*	0.05^{b}	0.03^{b}	0.11^{a}		0.11^{a}		0.01	<0.0001
PI	36.4^{b,c}	31.5^{c}	48.5^{b}		82.2^{a}		3.3	<0.0001

* µg/g of meat; PI = peroxidability index.
Different superscripts in the same row diverge significantly (P < 0.05).

displayed the highest and lowest total fatty acid content, differing significantly in between, while the Portuguese Holstein veal presented a halfway content, not differing significantly from the other origins. The high intramuscular total fatty acid content found in Holstein veal compared with those from crossbred beef cattle might be due to the feeding management, as Holstein calves are weaned much earlier (6 weeks *versus* 6 months) and thus are fed high density diets for a longer period than calves of crossbred beef cattle. Moreover, Holstein animals start to deposit fat earlier than continental beef breeds which means that at same age they would have different carcass composition [3].

Independently of the origin, veal from Holstein calves displayed higher contents of total SFA and MUFA and lower content of total PUFA, *n*-3PUFA and long chain *n*-3PUFA (*n*-3LCPUFA) than crossbred beef calves. The muscle fatness affect directly the fatty acid profile, since phospholipids and triacylglycerols present distinct fatty acid profiles and phospholipids remains quite constant in muscle cell membranes while the triacylglycerols accumulates when muscle get fatter [18]. This explains why veal displaying the lowest total fatty acid content (crossbred beef calves), presented the lowest total SFA and total MUFA content, which are the most predominant fatty acids of triacylglycerols [18], as well as the highest PUFA and DMA content, associated to phospholipids. Dimethylacetals (DMA) are formed from cleavage of plasmalogens, a group of glycerophospholipids which are structural components of cellular membranes [19], for that reason leaner meat present an higher proportion of phospholipids, including plasmalogens.

Fatty acid profile presented herein is similar to those previously reported in both veal and beef by other authors [20,21] with 18:1 cis-9, 16:0, 18:0, 18:2n-6 and 20:4n-6 comprising the majority of fatty acids.

Besides the effect of muscle fatness, differences observed between veal from dairy and crossbred beef cattle could also be dependent of different feeding management during the finishing period, as higher percentages of 18:0, 18:1*trans*-11, 18:2*cis*-9, *trans*-11, 18:3*n*-3,20:5*n*-3, 22:5*n*-3, 22:6*n*-3, as observed on Portuguese crossbred beef veal, are usually found in higher amounts on beef from pasture grazing systems relatively to meat from animals fed on concentrate feeding [22,21].

It is noteworthy that Holstein veal, no matter the origin presented a larger amount of 18:1*trans*-10 than 18:1*trans*-11 and very low 18:2 *cis*-9, *trans*-11, which is indicative of the occurrence of altered biohydrogenation pathways (i.e. *trans*-10 shift) characteristic of ruminants fed high concentrate diets [23]. Considering the potential health effects of 18:1*trans*-11 and 18:2*cis*-9, *trans*-11 and the deleterious health effects of 18:1*trans*-10 [24] the fatty acid profile of Holstein veal can be considered less favourable than crossbred beef veal.

Moreover, veal from the crossbred beef calves contained a significantly (P<0.001) lower percentage of total SFA (33.7 *versus* 39.6% of total fatty acids) and presented higher percentage of branched SFA (BCFA). BCFA in ruminant tissues arise from the digestion of rumen microorganisms and the absorption of bacterial structural lipids, the content found on ruminant tissues is dependent of rumen bacterial biomass outflow [25]. These fatty acids revealed an inhibitory effect on fatty acid synthesis in tumour cells [26], which has been recognised as a useful approach in cancer therapy, since cancer cells are more dependent on fatty acid biosynthesis than healthy cells [27].

Regarding fatty acid ratios and lipid quality indices, the values found in veal from crossbred beef calves revealed a healthier profile, displaying significantly higher P/S and h/H indices and lower TI, AI and n6/n3 indices than veal from Holstein calves. On the other hand, veal from the Portuguese Holstein calves displayed the most favourable results in the lipid quality indices among Holsteins, except for the n6/n3 index.

Within the *trans*-octadecenoates, major intermediates formed during rumen biohydrogenation, vaccenic acid can be regarded as a "beneficial *trans*" fatty acid, because of its conversion into rumenic acid, a fatty acid with important health attributes. More recently, it has been suggested that vaccenic acid, itself, could have beneficial health effects [28,29].

In the past, fatty acid ratios were regarded as a useful tool to evaluate the health effect of the fatty acids. However, their value as indicators of lipid quality has been questioned, once the P/S, was only based on the chemical structure of FA, which may not be adequate to evaluate the nutritional value of fat, because it considers that all SFA are harmful and ignore the effects of MUFA [8]. Moreover, nowadays it is well known that only a few saturated fatty acids, namely lauric (C12:0), myristic (C14:0), and palmitic (C16:0) acids, raise LDL-cholesterol and HDL-cholesterol, being considered hypercholesterolemic fatty acids [30]. On the other hand, the n-6/n-3 index assumes that lowering n–6 PUFA intake would have the same health effects as increasing n–3 PUFA intake, which is not correct [31]. The Atherogenicity (AI) and Thrombogenicity (TI) indices, as the hypo/Hypercholesterolemic (h/H) index, are also used as lipid quality indicators and regarded as more appropriated indicators as they focus on the fatty acid contribution to endogenous cholesterol

synthesis, and the contribution of fatty acids to cardiovascular diseases.

It is important to notice that the BCFA, have been neglected in their contribution to human health, as they are not included in any of the nutritional indices. Nevertheless, BCFA have shown some anti-cancer activity against various cancer cell lines, and such cytotoxicity was comparable to that of conjugated linoleic acid. Meat from the Portuguese crossbred calves displayed significantly higher contents of BCFA than meat from Holstein animals, independently of their origin [26].

According to [32], the nutritional quality of beef lipid fraction is not solely dependent of nutritional indices, but is also dependent on the amount of long chain PUFA (LCPUFA) with recognized health beneficial effects, like the *n*−3 PUFA (20:5*n*−3 and 22:6 *n*−3), therefore, it was suggested the ingestion of 150 mg/day of EPA+DHA in order to prevent chronic diseases. A portion of 150 g of veal, a normal serving steak, contributes with 0.01-0.18 mg, representing just 0.01-0.12% of the recommended content. Despite veal low contribution to EPA+DHA ingestion, veal from the Portuguese crossbred beef calves provides 4.9-9.7 times more EPA+DHA than veal from Holstein calves, independently of their origin.

Total cholesterol

The total cholesterol contents in veal of all groups are displayed in Table 2. The total cholesterol content comprises free and esterified cholesterol present in the muscle. No significant differences were observed among groups in total cholesterol content, which was expected, since veal samples were all obtained from the similar portion of the same muscle (the cranial portion of sirloin), and differences in cholesterol content are commonly observed between different muscles, due to differences in their muscle fibre composition [33].

Total cholesterol in a regular serving portion (150 g fresh veal) would only contribute with 16.2% of the recommended maximum daily cholesterol intake (300 mg per day) [34]. The total cholesterol content obtain herein (42.8-46.9 mg/100 g of muscle) is in agreement with the cholesterol content previously quantified in veal and beef of several Portuguese autochthonous breeds [35,36].

Lipid soluble antioxidants

The longissimus lumborum total vitamin E (α- and γ-tocopherols) and β-carotene contents are depicted in Table 4. α-Tocopherol was the major vitamin E homologue in veal, ranging between 1.0 and 2.8 μg/g of meat (84.3-96.6% of total vitamin E), while γ-tocopherol was accountable for 0.10-0.37 μg/g of meat (3.4-15.7% of vitamin E). Veal from the crossbred beef calves had higher contents of total vitamin E and α-tocopherol than veal from Holstein calves. The β-carotene content in veal from national production (independently of the genetics) was more than twice the value observed on veal from Spain and Netherlands ($P<0.05$). Veal from Spain and Netherlands showed no significant differences in between on the aforementioned variables, displaying the lowest values of all groups for total vitamin E, α-tocopherol and β-carotene. Regarding γ-tocopherol, Portuguese Holstein calves displayed the highest γ-tocopherol content (0.37 μg/g of meat) followed by the Spanish Holstein veal (0.21 μg/g of meat) and Dutch Holstein veal (0.13 μg/g of meat). Veal from Portuguese crossbred beef calves presented the lowest γ-tocopherol value (0.10 μg/g of meat), but not significantly different from the Dutch veal. Previously, a study performed in veal from Portuguese native breeds raised on pasture showed similar γ-tocopherol contents (0.09-0.12 μg/g of meat) [36].

All veal groups displayed a total vitamin E content below the minimum value required to retard lipid oxidation (3.0 μg/g of meat), [37] which can compromise meat colour stability and lipid oxidative prevention. Portuguese veal from crossbred beef animals presented the highest value which was close to the aforementioned minimum value required to retard lipid oxidation (2.91 μg/g of meat). The β-carotene content found on veal from calves raised in Portugal suggests that the feeding regime of these animals included fresh green forage, considering that green forage are richer in β-carotene and also in α-tocopherol [38,39]. β-Carotene is an important fat-soluble antioxidant that quenches sites localised within the hydrophobic region of biological membranes, contrasting with the scavenging activity of α-tocopherol close to the membrane surface [40]. The higher β-carotene and α-tocopherol contents of veal from crossbred animals suggest that this meat is less prone to lipid oxidation and displays for a longer period the red cherry colour appreciated by consumers. However, beef from crossbred beef bulls presented also the highest peroxidability Index (PI) being more prone to lipid peroxidation, due to the higher unsaturation degree of its fatty acid profile.

Conclusion

The study results confirmed that veal obtained from different origins enclosed an intrinsic and undesirable variability with potential consequences to retailers profit and negative health concerns to consumers. Spanish veal received the DFD classification, which encloses a variety of unfavourable features to both consumers and retailers, which recommend their avoidance. On the other hand, veal from Spain and Netherlands revealed a lipid profile similar to beef obtained from intensive production systems based on concentrate feeding, and low concentration of major lipid-soluble antioxidants. Among veal from national production, it was observed important differences between the two varieties in comparison. Veal from crossbred beef displayed a healthier lipid profile and higher contents of major lipid-soluble antioxidants. Nevertheless, veal from all varieties in comparison displayed vitamin E content below the concentration that is required to delay the oxidation process.

In Europe, beef market value is associated with the animal's genetic background and carcass classification, while the animal's feeding management and diet composition has no influence on beef market value, despite their influence on meat composition.

The study revealed that the national limitations on beef production recommend the establishment of quality standards that should be used throughout negotiation. Such standards, as the establishment of a meat pH limit would be particularly useful to avoid acquisition of DFD meat. The establishment of quality standards on vitamin E content seems to be of great value to the retailer, since vitamin E is of prime importance has it delays the development of oxidation reactions, stabilizing the appreciated red-cherry colour of beef for a longer period. On the other hand, the establishment of standards on the nutritional quality of meat lipid profile, does not seem realistic at this point, still, we think that it would contribute to the improvement of meat nutritional value and the valorisation of less intensive feeding regimes.

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