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A Comparative Study on Meat Quality Characteristics of Murrah Buffalo and Nellore Cattle Commercialized in Southeastern Brazil

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Abstract: Murrah buffalo and Nellore cattle meat commercialized in Southeastern Brazil were evaluated during aging. Ribeye steaks (*Longissimus thoracis* muscle) were analyzed during four wet aging times (0, 7, 14, and 21 days) stored at 2 ± 1 °C. The water holding capacity (WHC) decreased ($p < 0.05$) during aging (0.41 to 0.28), with buffalo meat having ($p < 0.05$) lower pH and a higher WHC than beef. Lower myofibrillar fragmentation index and shear force (WBsSF) values were observed ($p < 0.05$) in buffalo meat. Soluble collagen content increased ($p < 0.05$) during aging, with lower ($p < 0.05$) values in buffalo meat. Buffalo meat had ($p < 0.05$) higher metmyoglobin percentages, being darker (lower L* values) and with a higher red color intensity (higher C* values) than beef. There was a difference between buffalo meat and beef volatile compound profiles, with greater variation in the beef profile during aging, probably due to differences in lipid oxidation and proteolysis. It can be concluded that buffalo meat is very similar to that of Zebu cattle, with less variation during aging and greater tenderness than beef. Therefore, buffalo meat is a good alternative source for fresh marketing and processing of high-quality meat products.

Keywords: tenderness; myofibrillar fragmentation; color; volatile compound profile

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1. Introduction

Population growth is a global concern, as statistics suggest that a 70% increase in food production would be necessary to meet the predicted needs by 2050; for the meat sector, world production is expected to double, especially in developing countries [1]. Therefore, for production expansion of high biological value foods, the development of buffalo (*Bubalus bubalis*) livestock becomes an alternative since they are important milk, meat, and leather sources. Although this species is still scarcely explored in most countries, it seems promising for filling a market niche, as buffalo meat has high nutritional and sensory qualities. In addition, despite having great similarity in phenotypic and anatomical characteristics, buffaloes do not compete with bovine cattle for the same breeding space [2].

In Brazil, the marketed beef is from cattle raised in a grass-based system whose genetics are strongly influenced by Zebu breeds (*Bos indicus*), such as Nellore, which tend to present leaner carcasses with lower tenderness and marbling meat. Consequently, the beef in domestic markets has excessive variation in palatability, making it difficult to target desired levels of tenderness and product consistency [3]. On the other hand, the buffalo herd is predominantly composed of animals of the Murrah, Mediterranean, Jafarabadi, and

Carabao breeds. However, buffalo meat quality has not yet been well-studied due to the lack of carcass standardization [4].

In Brazil, cattle production systems based on pastures are mainly located in the central Western, Northern, and Northeastern regions of the country. Due to its double aptitude (meat and milk production), buffalo breeding occurs on small and medium farms with a non-homogeneous distribution, such as in the Southeastern region dominated by dairy farming [5]. The exploitation of dairy farming in conjunction with meat production is an important factor that aggravates the offer of low-quality meat, since in addition to young buffaloes, dairy females at the end of production, unproductive, or even with reproductive problems are also destined for slaughter to be sold as meat [4].

Several studies have already evaluated the differences between cattle and buffalo meat quality [6–10] as well as the effects of aging on buffalo meat quality [11–13]. However, comparative studies on the aging process of beef and buffalo meat quality are still scarce, and, to the best of our knowledge, no comparative study has focused on the volatile compound differences of these species. Providing clear evidence of the differences in the overall quality of buffalo meat and beef during aging is essential for the industry to understand the opportunities to reach new markets for buffalo meat as well as to im-prove the palatability of its products. Therefore, this study aimed to evaluate the differences in quality characteristics (color, texture, and water holding capacity) and volatile profiles of commercialized meat from Murrah buffalo and Nellore cattle dur-ing aging.

2. Materials and Methods

Eight boneless ribeye rolls (M. *Longissimus thoracis*; LT) of each specie, Murrah buffalo (30 months old) and Nellore cattle (24 months old), were obtained 48 h postmortem directly from commercial plants in Southeastern Brazil. Brazilian legislation (Ordinance n. 723 of 12/23/2022 from the Ministry of Agriculture, Livestock, and Supply, Brazil) determines that for the claim of "aged beef", the cuts must be stored vacuum-packed at a temperature between −1° C and 4° C for a minimum period of 12 days. Therefore, each LT sample was cut into four 5 cm thick sections that were individually identified, weighed, vacuum-packed (BS420; R.Baião, Ubá, Brazil) in nylon-polyethylene plastic (90 µm thick and oxygen transmission rate of 30–60 $cm^3/m^2/day/atm$) and randomized at four aging times (0, 7, 14, and 21 days), conducted in a climatic chamber (EL202; Eletrolab Indústria e Comércio Ltd., São Paulo, Brazil) at 2 ± 1 °C. The proximate composition of the buffalo (73.64% moisture, 21.42% protein, 2.39% fat, and 2.45% ash) and bovine (73.41% moisture, 22.37% protein, 2.27% fat, and 1.95% ash) LT muscle was determined before aging using a near infrared (NIR) device (FoodScanTM; FOSS Analytical A/S, Hillerod, Denmark). At each aging time, steaks were removed from the packaging, dabbed dry using paper towels, and weighed again to determine the purge percentage (%). Two steaks (one of 2.50 cm thickness for color, cooking loss, and shear force analyses) were cut out of the loin sections, and the LT muscle was used to conduct the analyses.

The pH of LT muscle was evaluated with an insertion electrode at three different points of one steak, using a portable pH meter (HI99163; Hanna Instruments, Woonsocket, RI, USA), and about 300 mg was obtained in triplicate to determine the water holding capacity (WHC) by the filter paper pressure method (FPPM) as described by [14] being expressed as the ratio of pressed meat area/exudate liquid area. Then, the steak was ground to obtain samples for collagen analysis, myofibrillar fragmentation, and volatile compound profiles. Soluble and insoluble collagen fractions were separated after heating at 77 °C for 70 min, and the collagen content (mg/g) was quantified by determining the amount of hydroxyproline amino acid, as proposed by [15], and described by [16]. The degree of myofibrillar fragmentation was evaluated by the fragmentation index (FI) method as described in [14]. Lower FI values indicate increased proteolysis of the myofibrillar protein structure.

Instrumental color and myoglobin redox forms were measured using a portable spectrophotometric CM-700d (Konica Minolta Sensing Inc., Osaka, Japan), with an 8 mm

aperture size, illuminant A, 10° observer angle, and in both specular components included (SCI) and excluded (SCE) modes. Five readings were taken at different points on the 2.5 cm thick steak surface after blooming for 60 min at room temperature, and the lightness (L*), redness (a*), yellowness (b*), chroma (C*), and hue angle (h) values were recorded in SCE mode. Reflectance values from 400 to 700 nm (every 10 nm) in the SCI mode were used to estimate the percentages of oxymyoglobin (OMb), deoxymyoglobin (DMb), and metmyoglobin (MMb) by the mathematical method proposed by [17]and described by [16].

After color readings, the 2.5 cm thick steak was weighted and cooked on a preheated (200 °C) striated grill (SCGE model; Croydon, Duque de Caxias, Brazil) until 71 °C in the geometric center (accompanied with a thermocouple) [14]. After cooling at room temperature for 4 h, the steak was weighed again and the cooking loss (%) calculated. Shear force was measured in the cooked sample by the Warner–Bratzler square Shear Force (WBsSF) method proposed by [18], using a TA.XT plus Texture Analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK). The maximum force (N) to completely shear each core was recorded, and the average was obtained for each steak.

Volatile compound (VOC) separation and identification were performed in unaged (0 days) and aged (21 days) samples by headspace solid phase microextraction (SPME) using a QP2010 Plus gas chromatograph (GC)/mass spectrometer (MS) device (Shimadzu®, Kyoto, Japan). Individual portions of two steaks at each sampling time were ground at once to obtain a pooled sample. About 2.5 g of pooled meat was sealed in a 22 mL vial with a PTFE-faced silicone septum (Supelco, Bellefonte, PA, USA), and the VOCs were extracted using a divinylbenzene/carboxen/polydimethylsiloxane fiber (DVB/CAR/PDMS, 10 mm length, 30–50 µm thick layer; Supelco Bellefonte, PA, USA). The following conditions were used: extraction temperature of 60 °C; equilibrium time of 10 min; and extraction time of 45 min. After extraction, the fiber was exposed in the GC inlet for 2 min at 250 °C in splitless mode for thermal desorption. VOCs were separated with a SLB®-5MS capillary column (5% phenyl–95% dimethylsiloxane; 30 m × 0.25 mm i.d., 0.25 µm film thickness; Supelco, Bellefonte, PA, USA), and helium was used as the carrier gas with a flow rate of 1 mL/min. Initially, the oven temperature remained at 35 °C/2 min, then increased at a rate of 2 °C/min until it reached 80 °C, then increased to 150 °C at a rate of 4 °C/min, and then increased to 230 °C at a rate of 8 °C/min. The MS detected ions within the 45–350 Da mass range in the electron impact mode at 70 eV and a solvent cut at 0.55 min. The temperature of the detector interface and ion source remained at 250 °C and 200 °C, respectively. VOCs were identified by comparing the mass spectra obtained with mass spectra provided by the software database (Wiley 8 and FFNSC 1.2), and the retention indexes obtained experimentally were compared to data reported in the literature through the injection of a series of alkane homologs (Supelco, Bellefonte, PA, USA). The areas of each peak were calculated using the GCMS Solutions program (Shimadzu®, Kyoto, Japan), and the data were presented as the total ion count (TI × 104).

The experiment was conducted in a factorial scheme 2 (species; S) × 4 (aging times; A). The influence of the main factors and their interaction on meat quality characteristics was determined by analysis of variance (ANOVA) and, when necessary, Tukey's test was used to separate means. Statistical analyses were performed using the SAS GLM procedure (SAS software, version 9.2; Statistical Analysis System Institute Inc., Cary, NC, USA) at a *p*-value of 0.05. An exploratory analysis was conducted to evaluate the VOCs identified within the studied effects. To normalize the data, the peak areas of specific VOCs were transformed into log10 before being submitted to a principal component analysis (PCA), which was conducted using Sensomaker software® version 1.91 (UFLA, Lavras, Brazil).

3. Results and Discussion

3.1. Quality Characteristics

The effects of species and aging time on the meat quality characteristics of Murrah buffalo and Nellore cattle are described in Table 1.

Table 1. Effects of species (S), aging time (A), and their interaction (S × A) on meat (M. *Longissimus thoracis*) quality characteristics of Murrah buffalo and Nellore cattle.

	Specie		Aging (Days)					*p*-Value		
Characteristics [(1)]	**Buffalo**	**Bovine**	**0**	**7**	**14**	**21**	**SEM**	**S**	**A**	**S × A**
pH	5.58 ^{B}	5.68 ^{A}	5.62	5.62	5.64	5.64	0.01	<0.001	0.615	0.984
Purge (%)	1.01	1.59	0.00	1.53	1.89	2.17	0.13	<0.001	<0.001	0.022
Water holding capacity, WHC	0.37 ^{A}	0.30 ^{B}	0.41 ^{a}	0.32 ^{b}	0.32 ^{b}	0.28 ^{b}	0.01	<0.001	<0.001	0.253
Cooking loss (%)	21.22 ^{B}	23.21 ^{A}	21.80	21.11	22.52	23.06	0.45	0.010	0.463	0.101
Collagen content										
Total collagen, TC (mg/g)	1.49 ^{B}	1.99 ^{A}	1.53	1.73	1.89	1.69	0.07	<0.001	0.079	0.073
Insoluble collagen (mg/g)	1.27 ^{B}	1.64 ^{A}	1.29	1.51	1.60	1.32	0.06	<0.001	0.115	0.056
Soluble collagen (mg/g)	0.22 ^{B}	0.34 ^{A}	0.24 ^{b}	0.22 ^{b}	0.29 ^{ab}	0.37 ^{a}	0.02	<0.001	0.005	0.309
Soluble collagen (% TC)	14.57	17.33	16.15 ^{b}	12.31 ^{b}	14.35 ^{b}	21.12 ^{a}	0.94	0.111	0.016	0.539
Fragmentation index, FI	394	441	447	427	390	367	10	0.194	0.003	0.006
Shear force, WBsSF (N)	35.82 ^{B}	56.40 ^{A}	58.31 ^{a}	51.21 ^{b}	41.39 ^{c}	33.53 ^{d}	2.37	<0.001	<0.001	0.186
Myoglobin redox forms										
Oxymyoglobin, OMb (%)	62.77 ^{A}	67.11 ^{B}	62.31	66.44	67.02	64.80	1.02	0.036	0.236	0.711
Deoxymyoglobin, DMb (%)	7.82 ^{A}	18.37 ^{B}	18.91 ^{a}	12.08 ^{b}	11.17 ^{b}	9.96 ^{b}	1.01	<0.001	0.002	0.855
Metmyoglobin, MMb (%)	29.41 ^{A}	14.52 ^{B}	18.77	21.48	21.81	25.24	1.19	<0.001	0.365	0.296
CIE color										
Lightness, L*	41.38 ^{B}	43.67 ^{A}	41.64 ^{b}	43.12 ^{ab}	43.59 ^{a}	42.03 ^{ab}	0.32	<0.001	0.026	0.307
Redness, a*	25.18 ^{A}	21.50 ^{B}	22.22	24.29	23.67	22.94	0.37	<0.001	0.093	0.506
Yellowness, b*	16.84 ^{A}	14.57 ^{B}	14.32 ^{b}	16.38 ^{a}	16.27 ^{a}	15.87 ^{a}	0.25	<0.001	0.001	0.487
Chrome, C*	30.30 ^{A}	26.00 ^{B}	26.44 ^{b}	29.30 ^{a}	28.74 ^{a}	27.91 ^{ab}	0.44	<0.001	0.030	0.494
Hue, h (°)	33.76	34.19	32.72 ^{b}	33.99 ^{b}	34.67 ^{ab}	34.86 ^{a}	0.25	0.200	0.004	0.686

SEM = standard error of mean (n = 64); WBsSF = Warner–Bratzler square Shear Force. [(1)] Means followed by different letters differ ($p < 0.05$), between species (^{A,B}) by the F test and between aging ($^{a–d}$) by Tukey's test.

Lower pH values ($p < 0.05$) were observed for buffalo meat than for beef, but they were within the range considered normal for both buffalo (5.4–5.6) and cattle (5.5–5.8) [9]. Although [4] reported that the glycogen levels (74 to 106 mmol glucose equivalent/kg) of Murrah buffaloes immediately after slaughter were within the typical muscle glycogen reserve of well-fed and resting bovines, the lower pH observed in buffalo meat than cattle in this experiment suggests a higher postmortem glycolytic rate or less chronic stress during slaughter. Lower pH values for buffalo meat than beef were also reported by other authors [7,9,19], although [6] observed a higher pH value for buffalo meat and [20] did not observe differences between species.

Meat's ultimate pH is related to its water holding capacity (WHC), which is an important parameter for meat quality because it influences protein extractability/solubility; poor WHC results in high water releases as drip, purge, or cooking loss [21]. However, purge and cooking loss are also indicators of meat WHC, and the differences observed between these characteristics and the WHC measured by FPPM are also due to their form of measurement [16]. A significant interaction was found for meat purge values between species and aging times, while WHC values were affected by both factors without interaction and the cooking loss values only by the species. Overall, despite having higher pH values, beef had ($p < 0.05$) the lowest WHC values, which resulted in greater water losses. Beef purge increased approximately 1% more during aging (Figure 1), and the cooking losses were higher than those of buffalo meat. Accordingly, ref. [8] also observed lower cooking losses in buffalo meat than in beef.

Higher WHC values, measured by the FPPM, have been attributed to the degradation of cytoskeletal proteins during postmortem proteolysis, which leads to a smaller reduction in the fiber diameter, allowing greater space availability for intracellular water molecules and decreasing their release to the extracellular space ("drip channels") and, subsequently, exudation from the muscle [14,21]. This is consistent with the highest ($p < 0.05$) postmortem proteolysis observed in these meats in the first days of aging (Figure 2) and could explain the discrepancy observed between WHC and purge. In purge, the negative pressure of vacuum packaging exuded only the water contained in the extracellular spaces, while in FPPM, an external mechanical force induces the expulsion of both intracellular and extracellular water [14,16]. Therefore, reduced water content in the extracellular spaces in beef (due to higher purge), associated with better intracellular water arrangement due

to cytoskeletal protein degradation in Buffalo meat, probably explains the differences in WHC values between these species.

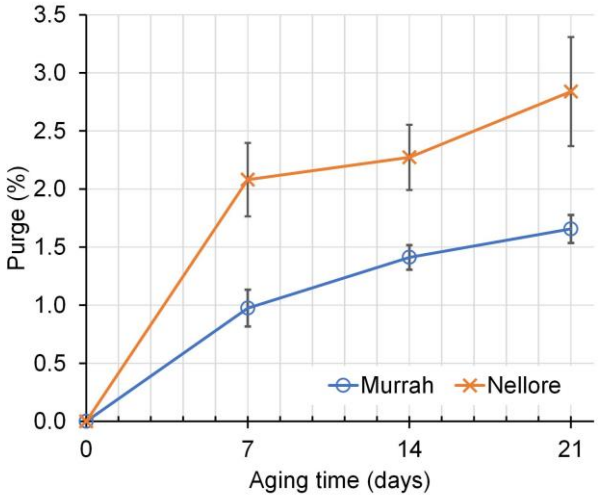

Figure 1. Purge (%) of *L. thoracis* muscle from Murrah buffalo and Nellore cattle during aging. The bars represent the standard error of the mean.

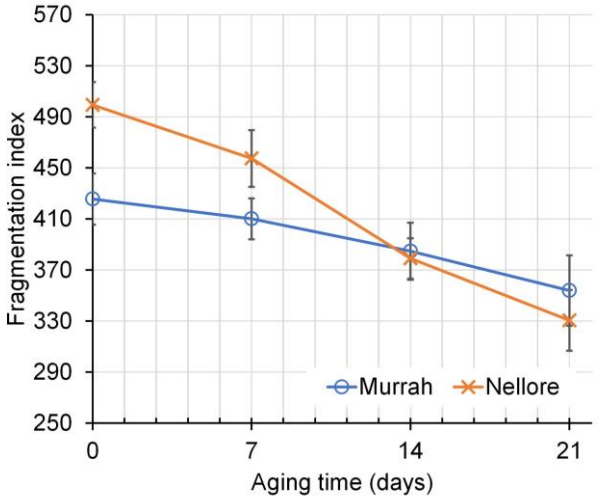

Figure 2. Myofibrillar fragmentation (fragmentation index; FI) of *L. thoracis* muscle from Murrah buffalo and Nellore cattle during aging. The bars represent the standard error of the mean.

In addition to the higher pH and lower WHC values, higher ($p < 0.05$) collagen contents, especially the insoluble fraction, may also contribute to the higher beef cooking losses. The connective tissue network contributes to the longitudinal shrinkage of muscle fibers during cooking, acting as an additional factor to promote the expulsion of water into the extracellular environment [16]. The lower total collagen content in buffalo meat than beef was also observed by [8,9], while [16] also reported a higher content of soluble collagen in beef than in buffalo meat.

Regarding the aging time, the increase ($p < 0.05$) in purge is consistent with the reduction ($p < 0.05$) observed in WHC from the 7th-day aging. Purge increases during aging are explained by the natural separation of fibers and muscle bundles and the formation of drip channels with the gradual release and drainage of intracellular water into the extracellular space [14,21]. Despite the WHC differences, the cooking losses of both meats did not change ($p > 0.05$) with aging time. According to [21], although the water lost during cooking is generally higher in meat that has been aged, at cooking temperatures of 60–70 °C only 55–58% of the variation in cooking loss is explained by WHC. The results reported

in the literature about aging effects on cooking losses are conflicting, with some studies reporting an increase in beef [14] and in buffalo meat [11], while [12] reported a lack of differences in buffalo meat as observed in this experiment.

From the collagen fractions, only soluble collagen content and percentage increased ($p < 0.05$) with aging, which could be associated with proteolytic activity and can contribute to meat tenderness. In this sense, myofibrillar fragmentation is often used as a tenderness predictor for beef [14] and buffalo meat [13]. The fragmentation index (FI) of both types of meat reduced with aging, but buffalo meat had ($p < 0.05$) greater myofibrillar fragmentation (lower FI) at days 0 and 7 of aging, with a proteolytic rate about two times lower than beef (Figure 2).

The shear force was lower ($p < 0.05$) in buffalo meat than beef and decreased ($p < 0.05$) during aging, regardless of species. Significantly higher tenderness (lower shear force) in buffalo meat might be due to greater proteolysis and lower collagen content compared to beef, as previously described. Lower values for shear force in buffalo meat than Zebu beef were also reported in the literature [7,10,20]. Moreover, in this experiment, buffalo meat could be considered "tender" and beef had "intermediate tenderness" by [22] classification, considering the thresholds (WBsSF < 53 N for "tender meat" and >69 N for "tough meat") obtained using the overall equation suggested by [18] to convert WBSF to WBsSF values.

Regarding the color characteristics, none of the myoglobin redox forms or instrumental color indices were affected ($p > 0.05$) by the interaction between species and aging time. However, significant differences were observed between species, with buffalo meat having higher metmyoglobin (MMb) and lower deoxymyoglobin (DMb) and oxymyoglobin (OMb) than beef. This suggests a lower stability of the heme pigment in buffalo meat.

Overall, buffalo meat had the same red tone (h value) as beef but was darker (lower L* values) and had a more intense color (higher C* values). Lower L* values in the buffalo meat may be due to the lower blooming (OMb formation) observed, since [14] reported that higher OMb content also contributed to higher L* values in beef. However, the higher MMb proportion in buffalo meat (twice that in beef) must have also contributed to the final color. Moreover, ref. [23] reported that the myoglobin content in buffalo meat (0.393 g/100 g) is almost twice as high as that in bovine meat (0.209 g/100 g), which is in agreement with the highest values of redness (a* value) and chroma (C*) observed in this experiment for buffalo meat. Higher ($p < 0.05$) yellowness (b* values) values were also observed for buffalo meat than beef. All these differences are consistent with the lower L* [7,10,19] and higher a* [6,19] and b* [10,19] values reported for buffalo meat when compared with beef.

During aging, an inconsistent change in L* values and a slight increase in b* and C* values were observed, regardless of species. These changes are consistent with observations reported by [12] that the aging time did not affect the L* and a* values of buffalo meat, but the b* values increased linearly during 21 days of aging. In Nellore and Aberdeen Angus beef, ref. [14] reported a slight increase in L*, a*, b*, and C* values in the first 7 days of aging that remained constant until the end of the aging period. It is interesting to note that an increase in hue angle (h value) was also observed during aging. The hue angle describes the development of a hue color from red to yellow; lower and higher angles indicate reddish and yellowish hues, respectively [16]. Therefore, although the increase in MMb values during aging was not significant, the decrease in h values indicates a certain degree of meat discoloration. Ref. [14] reported a high correlation (r = 0.70) between h values and MMb content in beef. Anyway, although significant, the color shifts seem to be rather limited in nature and may not be perceived by consumers.

3.2. Volatile Profile

Fifteen volatile compounds (VOCs) were identified in buffalo meat and beef (Table 2), being classified as alcohols (n = 5), aldehydes (n = 8), and ketones (n = 2). Overall, eight compounds (1-octanol, benzaldehyde, decanal, heptanal, hexanal, nonanal, octanal, and tetradecanal) were identified in both species, while three compounds were identified only

in buffalo meat (phenylacetaldehyde, 2-heptanone, and octan-3-one) and four only in beef (1-heptanol, 1-nonanol, 1-octen-3-ol, and 2-phenylethanol).

Table 2. Volatile compounds (total ion count × 10^3) of meat (*L. thoracis*) from Murrah buffalo and Nellore cattle before (unaged) and after 21 days of aging (aged).

		Murrah		Nellore			
No.	**Compound**	**Unaged**	**Aged**	**Unaged**	**Aged**	**Mean**	**SEM**
	ALCOHOLS						
1	1-Heptanol	nd	nd	nd	26	26	3
2	1-Nonanol	nd	nd	nd	36	36	4
3	1-Octanol	151	23	285	126	146	21
4	1-Octan-3-ol	nd	nd	3	51	27	4
5	2-Phenylethanol	nd	nd	nd	354	534	46
	ALDEHYDES						
6	Benzaldehyde	287	175	105	207	194	46
7	Phenylacetaldehyde	32	1334	nd	nd	683	177
8	Decanal	30	nd	37	nd	34	12
9	Heptanal	95	nd	84	nd	90	19
10	Hexanal	620	1051	119	nd	597	129
11	Nonanal	2336	709	1806	520	1343	241
12	Octanal	474	52	234	60	205	58
13	Tetradecanal	253	276	79	439	262	32
	KETONES						
14	2-Heptanone	7175	3008	nd	nd	5092	687
15	Octan-3-one	23	72	nd	nd	48	17
	ΣALCOHOLS	151	23	288	773		
	ΣALDEHYDES	4127	3597	2464	1226		
	ΣKETONES	7198	3080	nd	nd		

SEM = standard error of mean (n = 16); nd = not detected.

To illustrate the differences between species and aging times and assist in the discussion of effects, a PCA graph was created based on individual VOCs, describing 83.01% of the total variation (Figure 3). The first principal component (PC1) indicated a distinct difference between unaged and aged meats, while the second principal component (PC2) explained the differences between species. This suggests that aging favors the distinct formation of volatile compounds in beef and buffalo meat.

As expected in vacuum-packed red meats, aldehydes are the main products. and they are derived from lipid oxidation. From the wide range of secondary compounds formed from lipid peroxidation (including alkanes, alkenes, aldehydes, ketones, alcohols, esters, acids, and hydrocarbons), aldehydes are considered the most important because they possess low threshold values and are the major contributors to the development of off-flavors and off-odors and, consequently, to rancid sensory perception [24,25]. Aging favors the lipid oxidation process due to factors such as the oxidation of heme-iron and the enzymatic proteolysis that release precursors for the synthesis of aromatic compounds [26]. Therefore, an increase in the content of aldehydes is expected after 21 days of aging. Of the detected aldehydes, decanal, heptanal, nonanal, and octanal were more correlated with unaged meats, while hexanal and tetradecanal were correlated with aged meats from buffalo and bovine, respectively.

Hexanal is the dominant aldehyde produced during oxidation, indicating lipid oxidation of meat more effectively than any other volatile component [25]. This suggests that matured buffalo meat was at a higher oxidation stage than beef, and this is reinforced by the high correlation of that meat with other compounds associated with lipid oxidation, such as ketones, especially 2-heptanone. The presence of 2-heptanone has been proposed as an indicator of a greater extent of lipid oxidation in pork meat and suggested as respon-

sible for the differences in the aroma of oxidized cooked meat [27]. From the aldehydes detected, only phenylacetaldehyde was found in buffalo meat, especially in the aged ones. Phenylacetaldehyde is a product of the degradation of the amino acid phenylalanine and is characterized by a slightly sweet taste and honey-like odor [28]. Finally, the benzaldehyde was more correlated with buffalo meats (unaged and aged), but, although it is formed by arachidonic acid and linoleic acid degradation, it could also be formed through a non-lipid route [29].

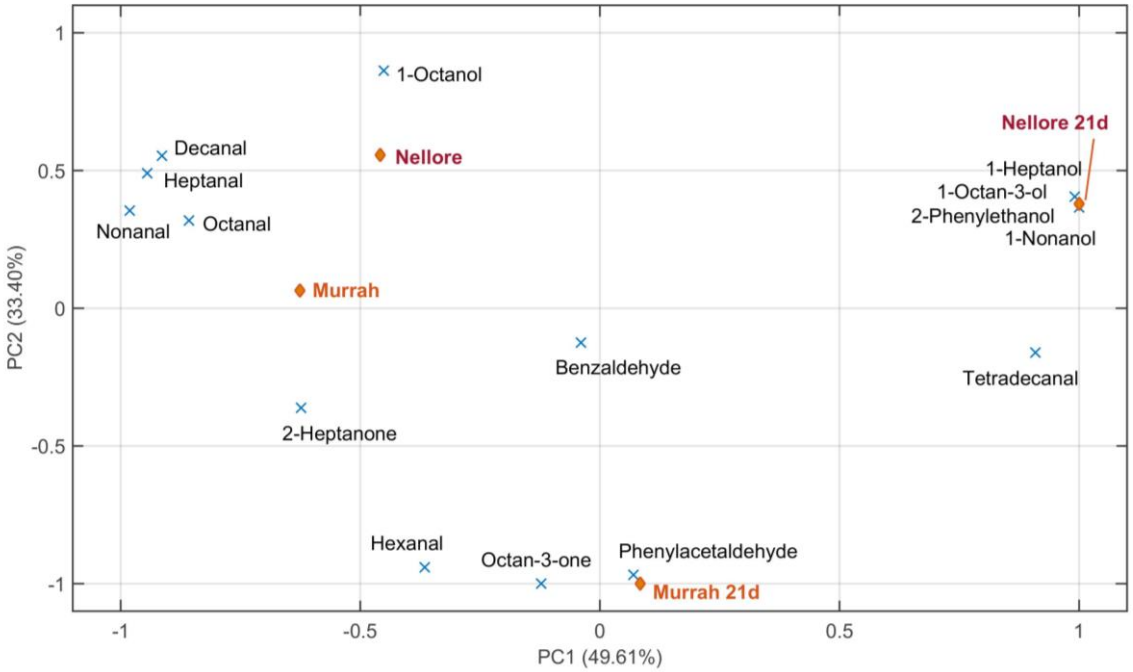

Figure 3. Principal component analysis (PCA) of volatile compounds of *L. thoracis* muscle from Murrah buffalo and Nellore cattle before and after 21 days (21 d) of aging.

Beef had a greater correlation with alcohol-function VOCs than buffalo meat, especially after 21 days. These seem to be consistent since alcohol compounds are usually products of the reaction of amino acids with lipid oxidation compounds [27].

The difference between species was expected, as volatile compound formation depends on intramuscular lipid composition. Tissues with a higher degree of polyunsaturated fat are expected to produce higher overall concentrations of volatile compounds derived from lipid oxidation [25]. In this context, a difference in the lipid profile between beef and buffalo meat was reported, in which buffalo meat has a higher unsaturated fatty acid content than beef [19,30]. Moreover, differences in postmortem proteolysis during aging also contributed to differences between species in terms of the volatile compounds formed.

4. Conclusions

The results of the present study confirm the high potential of buffalo meat for fresh marketing. Its characteristics were very similar to those of Zebu beef, presenting a greater proteolysis postmortem, which conferred not only greater tenderness but also a lesser variation during aging. This probably contributes to a lesser inconsistency in the consumer's perception of tenderness due to marketing at different aging times. However, the volatile compound profile suggests that buffalo-aged meat had higher lipid oxidation than beef. Moreover, aging favored the distinct formation of volatile compounds in beef and buffalo meat, which indicates that there might be a sensory difference between these meats. Thus, further studies would be necessary to better understand these aspects.

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