

Physicochemical characterization of water buffalo and bovine meat cuts

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Abstract

Buffalo meat has gained popularity worldwide due to its low fat and cholesterol content and sensory characteristics similar to beef. The objective of this study was to characterize and compare the physicochemical properties and consumer acceptance of three different cuts of meat: New York (NY), Leg Pulp (PI), and Rib Eye (RE) from 28 water buffalo and 28 beef selected in the south of Mexico. The physicochemical properties analyzed included pH, water activity (Aw), texture, water-holding capacity (WHC), and color (L*, a*, and b*), with triplicate measurements taken for both raw and cooked samples of each species. A hedonic analysis was performed to assess qualitative characteristics such as tenderness, juiciness, flavor, aroma, and overall acceptance, using a seven-point scale (1: "dislike moderately" to 7: "like extremely"). pH differed between raw and cooked NY cuts and between cooked NY and cooked PI cuts, with significant variation between the two species ($p < 0.05$). No significant differences in Aw were noted between the species for raw or cooked cuts ($p > 0.05$). For texture, significant differences were identified between raw and cooked NY and RE cuts of buffalo and beef ($p < 0.05$), while PI cuts showed no significant difference ($p > 0.05$). For WHC, significant differences were observed only in cooked NY cuts ($p < 0.05$); for the other cuts, WHC values were similar across raw and cooked species ($p > 0.05$). The L* and b* values of all three cuts increased after cooking ($p < 0.05$), whereas a* values decreased for all cuts of both species ($p < 0.05$). For overall acceptance, buffalo meat was most frequently rated as "Moderately like," while beef received the highest frequency for "Slightly like." The results suggest that buffalo meat is a promising consumer alternative, offering notable physicochemical and organoleptic properties. These attributes make buffalo meat viable for developing high-quality, value-added meat products.

Keywords: Meat, Quality, Sensory analysis, Acceptance

Introduction

The food industry has encountered numerous challenges due to the growing demand for products with specific quality characteristics. This has prompted the inclusion of various species beyond the traditional ones (pork,

beef, and poultry) to offer consumers products with appealing sensory, physicochemical, or functional properties (Charoux et al., 2017; Holman et al., 2018; Guerrero-Legarreta et al., 2020; Jaspal et al., 2021). Within the meat industry, different sectors define the scope and requirements for integrating companies into the market, where ensuring product quality and safety is essential for influencing the final consumer's purchasing decision. Physical attributes such as color and texture, closely related to freshness, serve as key evaluation parameters for consumers (Di Stasio & Brugiapaglia, 2021).

As a result, meat consumption from species such as water buffalo has become more prevalent (Alshdaifat et al., 2024). The water buffalo population in Mexico has grown significantly, with the species being introduced to the country in 1994. By 2023, the population will have reached approximately 60,000 individuals. This growth can be attributed to its remarkable nutritional, physicochemical, and organoleptic qualities, which align with healthier consumption habits. Water buffalo meat contains higher levels of polyunsaturated fats, protein, and minerals, as well as lower cholesterol, saturated fat, and calories. This information equips consumers and professionals with a better understanding of the health benefits of buffalo meat.

Several studies have demonstrated that, as with other species, numerous factors can influence the favorable characteristics of water buffalo meat, both intrinsic and extrinsic. Intrinsic factors include breed, gender, age, weight at slaughter, and feeding practices during rearing (Gallo & Huertas, 2016; Jainudeen & Hafez, 2016; Jaspal et al., 2021). However, buffalo cuts produced in Mexico remain poorly characterized. Additionally, changes in meat quality can occur when animals experience poor welfare during pre-slaughter handling or when post-mortem enzymatic processes are negatively affected, altering key meat parameters such as pH, texture, water-holding capacity (WHC), color, flavor, and aroma (Gallo & Huertas, 2016; Gallo et al., 2018; Rodríguez-González et al., 2022). This study aims to fill this gap by providing comparative benchmarks to assess these characteristics. Therefore, it is crucial to understand these parameters and compare them with those of conventional animals, such as bovine Bos, to develop appropriate methodologies and techniques, such as aging, cooling, and electrical stimulation. These methods could enhance the desired characteristics for consumers and improve shelf life, making the final product more appealing (Velotto et al., 2015; Holman et al., 2018; Andrade et al., 2021).

Materials And Methods

Location: The samples were analyzed physicochemically and hedonically in the Food Science Laboratory at the Universidad Autónoma Metropolitana, Unidad Lerma, at Avenida de las Garzas 10, CP 52005, Lerma de Villada, State of Mexico, Mexico.

Selection and Handling of Meat Cuts: The selected meat cuts were New York (*Longissimus dorsi*, NY), leg pulp (*Biceps femoris*, PI), and ribeye (*Pectoralis profundus*, RE) (Temiskan et al., 2019), obtained from 28 water buffaloes and 28 bovines of the genus *Bos*, resulting in a total of 168 samples obtained from the 56 animals. The production units are located in southeastern Mexico, an area characterized by a humid subtropical climate (Cfa) according to the Köppen-Geiger classification. All cuts were purchased vacuum-sealed at a freezing temperature of -18°C. The physicochemical properties of pH, water activity (Aw), texture, water holding capacity (WHC), and color (L*, a*, and b*) were analyzed in triplicate for both raw and cooked samples from both species. Before raw sample analysis, the samples were thawed for 24 hours under refrigeration at a constant temperature of 4 °C.

Cooking of Meat Cuts: The cooking protocol was applied after physicochemical analysis of the raw samples. The cuts were placed in a water bath at 58-59 °C for 1.5 to 1.7 hours, until an internal temperature of 70 °C was reached, measured using a Metalmex Thermocarne thermometer (stainless steel, 12 cm height). After cooking, each cut was placed in a properly labeled container for further analysis of the same physicochemical parameters evaluated in the raw cuts.

Physicochemical Analysis of Meat Cuts

pH: The pH measurement was performed following the procedure outlined by Reséndiz-Cruz et al. (2022) using a portable HANNA pH meter (model HI99163, USA). The electrode was gently pressed against each sample surface, and triplicate readings were recorded for both raw and cooked cuts.

Water Activity (Aw): These were measured using an HBD5-MS2100W model device, following the method described by Beño et al. (2023). All determinations were conducted in triplicate. Results were expressed on a scale from 0 to 1.

Texture: These were assessed using a TAX.T2 device (Texture Technologies, New York) with TexturePro CT V1.9 Build 35® software. Samples measuring 1 x 1 x 4 cm³ were taken from both raw and cooked cuts of the three different meat types from both species. The cutting force was evaluated using a Warner-Bratzler blade and a TA10 probe.

Water-Holding Capacity (WHC): These were determined using the method reported by Guerrero-Legarreta et al. (2020). This method uses a 0.6 M NaCl solution retained by a homogenized meat sample. The results were expressed as 0.6 M NaCl solution retained per 100 g of meat.

Color: The color of the samples was assessed using a portable Hunter Lab colorimeter (CR-410, Konica-Minolta, Inc., Japan), following the methodology described by Ma et al. (2020). Three consecutive measurements were taken from the surface of each sample. Before measurement, the equipment was calibrated with reference coordinates of $L^*=94.7$, $a^*=0.3130$, and $b^*=0.3191$. The color values were expressed in terms of L^* (lightness), a^* (red/green), and b^* (yellow/blue). The meat was allowed to cool to room temperature after cooking for the cooked samples to prevent interference from water vapor during measurement.

Hedonic Analysis: This analysis was conducted through subjective evaluation of the qualitative characteristics: tenderness, juiciness, flavor, aroma, and overall acceptance, following the methodology outlined by Abdel-Naeem & Mohamed (2016), with modifications. Meat cuts from each treatment were grilled to an internal temperature of 70 °C. Rectangular pieces measuring approximately 1 x 1 x 3 cm² were then randomly cut and served at room temperature. A satisfaction survey was administered to 50 untrained panelists (24 males and 26 females) aged 20 to 31 years. The panelists assessed the samples using a seven-point hedonic scale (1 = dislike moderately, 2 = dislike slightly, 3 = neither like nor dislike, 4 = slightly like, 5 = moderately like, 6 = like very much, 7 = like extremely).

Statistical Analysis

Data were analyzed using the generalized linear model procedure in the software program SAS (2025) (Package, SAS Inc., Cary, NC, USA). Significant differences between the treatments were analyzed using the PDIFF test, and the hedonic analysis was run with the Mann-Whitney U test. All studies showed a significant difference ($P < 0.05$).

Results and Discussion

Physicochemical Analysis of Meat Cuts

Table 1 presents the results for pH, water activity (A_w), texture, and water-holding capacity (WHC) of New York (NY), leg (PI), and rib eye (RE) cuts from buffalo and bovine of the genus *Bos*, measured in both raw and cooked samples.

pH

Similar pH values for the raw buffalo cuts were observed for the New York (NY) cut (6.01). The raw leg (PI) cut showed an increase of 0.14 units, and the raw rib eye (RE) cut showed 0.15 units, though these differences were not statistically significant ($p > 0.05$). Kandeepan et al. (2013) report that the normal final pH of buffalo meat ranges from 5.4 to 5.6. Our results show higher pH values compared to these reported ranges. However, studies suggest that several intrinsic and extrinsic factors can influence meat pH, including species, age, weight, production systems, and transportation. Significant differences were noted between the NY and PI cuts for the raw bovine cuts ($p < 0.05$), with raw PI pH 0.07 units higher than RE and 0.33 units higher than NY. The pH values obtained for the raw bovine cuts fall within the ranges reported in the literature (Wang et al., 2020). No significant differences in pH were found among the NY, PI, and RE cuts ($p > 0.05$) for the cooked buffalo cuts, with values ranging from 6.19 to 6.34. The RE cut showed a slight decrease in pH, down 0.04 compared with NY and 0.15 compared with PI, although these differences were not significant ($p > 0.05$). A similar trend was observed in cooked bovine, where the pH of the NY, PI, and RE cuts did not differ significantly, with values of 6.08, 6.15, and 6.15, respectively ($p > 0.05$). Generally, meat pH increases during cooking, likely because bonds involving imidazole, sulfhydryl, and hydroxyl groups break. Additionally, cooking at temperatures above 80°C contributes to the formation of free hydrogen sulfide (Oz et al., 2016).

When comparing buffalo and bovine cuts, the raw NY pH was significantly lower in bovine than in buffalo (5.74 vs 6.01, $p < 0.05$). For the PI cut, no significant difference was found between species ($p > 0.05$); however, raw buffalo PI had a higher pH than raw bovine PI, with a 0.08-unit increase in buffalo ($p > 0.05$). A similar pattern ($p > 0.05$) was found for raw RE cuts, with buffalo showing a higher pH (6.16 vs 6.00). Studies have also reported a higher final pH in buffalo meat compared to beef (5.56 vs 5.47, $p < 0.05$) (Naveena & Kiran, 2014). For cooked cuts, the NY cut differed between buffalo and bovine, with the buffalo NY cut showing a 0.15-unit higher pH than the bovine NY cut ($p < 0.05$). Cooked buffalo PI also had a higher pH than cooked bovine PI (6.34 vs 6.15, $p < 0.05$). However, for cooked RE cuts, no significant difference was revealed between the species, with pH values of 6.19 for buffalo and 6.15 for bovine ($p > 0.05$).

Table 1. Physicochemical variables in different cuts of bovine and water buffalo meat (pH, A_w , texture, and CRA).

Variable	Buffalo							Bovine						
	NY		PI		RE		EEM	NY		PI		RE		EEM
	Raw	Cooked	Raw	Cooked	Raw	Cooked		Raw	Cooked	Raw	Cooked	Raw	Cooked	

pH	6.01 ^d	6.23 ^{ab}	6.15 ^{bcd}	6.34 ^a	6.16 ^{bcd}	6.19 ^{abc}	0.03	5.74 ^c	6.08 ^{bcd}	6.07 ^{cd}	6.15 ^{bcd}	6.00 ^d	6.15 ^{bcd}	0.02
Aw	0.92 ^b	0.92 ^b	0.93 ^{ab}	0.92 ^b	0.92 ^b	0.92 ^b	0.004	0.93 ^{ab}	0.92 ^b	0.95 ^a	0.93 ^{ab}	0.93 ^b	0.93 ^{ab}	0.01
Texture	3.68 ^f	4.99 ^a	4.10 ^d	5.14 ^a	3.73 ^f	5.02 ^a	0.02	3.91 ^c	4.31 ^c	4.26 ^{cd}	5.14 ^a	3.94 ^c	4.74 ^b	0.03
CRA	28.84 ^a	23.35 ^d	26.28 ^b	21.11 ^c	28.79 ^a	23.67 ^c	0.05	28.66 ^a	23.63 ^c	26.51 ^b	21.09 ^c	28.59 ^a	23.47 ^{cd}	0.05

NY : New York; PI:leg; RE: Rib eye; Aw: Water activity; CRA: Water holding capacity; EEM: Standard error of the mean.

^{a-g} Different line letters denote significant differences (P < 0.05).

Table 2. Physicochemical color variables in different cuts of water buffalo and bovine.

Variable	Buffalo							Bovine						
	NY		PI		RE		EEM	NY		PI		RE		EEM
	Raw	Cooked	Raw	Cooked	Raw	Cooked		Raw	Cooked	Raw	Cooked	Raw	Cooked	
L*	39.70 ^f	47.68 ^b	42.72 ^{de}	47.82 ^b	35.45 ^g	47.48 ^{bc}	0.65	44.61 ^{cd}	51.66 ^a	41.47 ^{ef}	50.00 ^{ab}	36.31 ^g	48.48 ^b	0.34
a*	18.48 ^b	8.13 ^c	20.84 ^a	7.98 ^c	17.97 ^b	8.69 ^c	0.2	21.35 ^a	6.30 ^d	20.84 ^a	8.13 ^c	17.72 ^b	7.42 ^{cd}	0.28
b*	7.58 ^{de}	10.52 ^c	7.13 ^{ef}	12.51 ^{ab}	5.91 ^g	12.39 ^{ab}	0.24	8.43 ^d	11.89 ^b	7.13 ^{ef}	13.12 ^a	5.97 ^g	12.33 ^{ab}	0.18

NY New York; PI leg; RE Rib eye; L* = Lightness; a* = red/green coordinates; b* = yellow/blue coordinates; EEM standard error of the mean

^{a-g} Different letters indicate significant differences, p < 0.05.

Table 3. Mean values of physical meat characteristics obtained through a hedonic evaluation (sensorial test) of water buffalo and bovine meat.

Variable	Species	N	Mean range	P value
Texture	Buffalo	50	51.48	0.730
	Bovine	50	49.52	
Juiciness	Buffalo	50	54.74	0.134
	Bovine	50	46.26	
Flavor	Buffalo	50	47.06	0.226
	Bovine	50	53.94	
Aroma	Buffalo	50	44.62*	0.039
	Bovine	50	56.38	
Acceptability	Buffalo	50	49.97	0.852
	Bovine	50	51.03	

The range analysis conducted with the Mann-Whitney U test shows a significant difference (* P < 0.05).

Water Activity (Aw)

Water activity (Aw) is crucial in determining meat shelf life as it influences water availability for microbial growth and impacts chemical and enzymatic activity during food preservation. Tapia et al. (2020) report that raw meat typically has an Aw ranging from 0.95 to 0.99. In the raw buffalo cuts, no significant differences in Aw were observed across the three cuts. However, Baran et al. (2023) found that water buffalo meat exhibited higher Aw values, exceeding 0.99. For the raw bovine cuts, statistical similarity was reported among the NY, PI, and RE cuts (Aw values of 0.93, 0.95, and 0.93, respectively; p>0.05). However, Aw differed significantly between PI and RE, with RE reduced by 0.02 units compared to PI (p<0.05). These differences in Aw values may be attributed to muscle size and the fibrous composition of muscle tissue. In cooked buffalo cuts, Aw remained consistent across NY, PI, and RE cuts, all measuring 0.92 (p>0.05). For the cooked bovine cuts, statistical similarity was also reported between the NY, PI, and RE cuts (Aw values of 0.92, 0.93, and 0.93, respectively; p>0.05). No significant differences were observed between species by cut for Aw (p>0.05).

Texture

Raw buffalo cuts showed similar texture values between NY and RE (3.68 vs 3.73, p>0.05). However, NY and RE textures differed significantly from PI's (p<0.05), with increases of 0.42 and 0.37, respectively. For the raw bovine cuts, the texture of PI was 0.35 units higher than NY (p<0.05) and 0.32 units higher than RE (p<0.05). However, the texture values for NY and RE in bovine were similar (3.91 vs 3.94, p>0.05). According to Baran et al. (2023), the structural composition of muscle tissue, particularly the myofibrillar proteins, plays a key role in determining the texture of meat, for the cooked buffalo cuts, similar texture values were observed between NY, PI, and RE (4.99, 5.14, and 5.02, p>0.05). In contrast, cooked NY differed significantly from PI (4.31 vs. 5.14, p<0.05) and RE (4.31 vs. 4.74, p<0.05). Between species, raw PI texture was similar for bovine and buffalo (4.26 vs. 4.10, p>0.05). However, raw NY cuts differed, with buffalo NY (3.68) having lower texture values than bovine NY (3.91) (p<0.05). Similarly, raw RE cuts showed a 0.21-unit increase in texture in bovine RE compared with buffalo RE. For the cooked cuts, buffalo NY had 0.68 units higher texture than the same cut from bovine (p<0.05), and cooked buffalo RE showed a 0.28-unit increase compared to cooked bovine RE (p<0.05). However, for the PI cut, the texture values

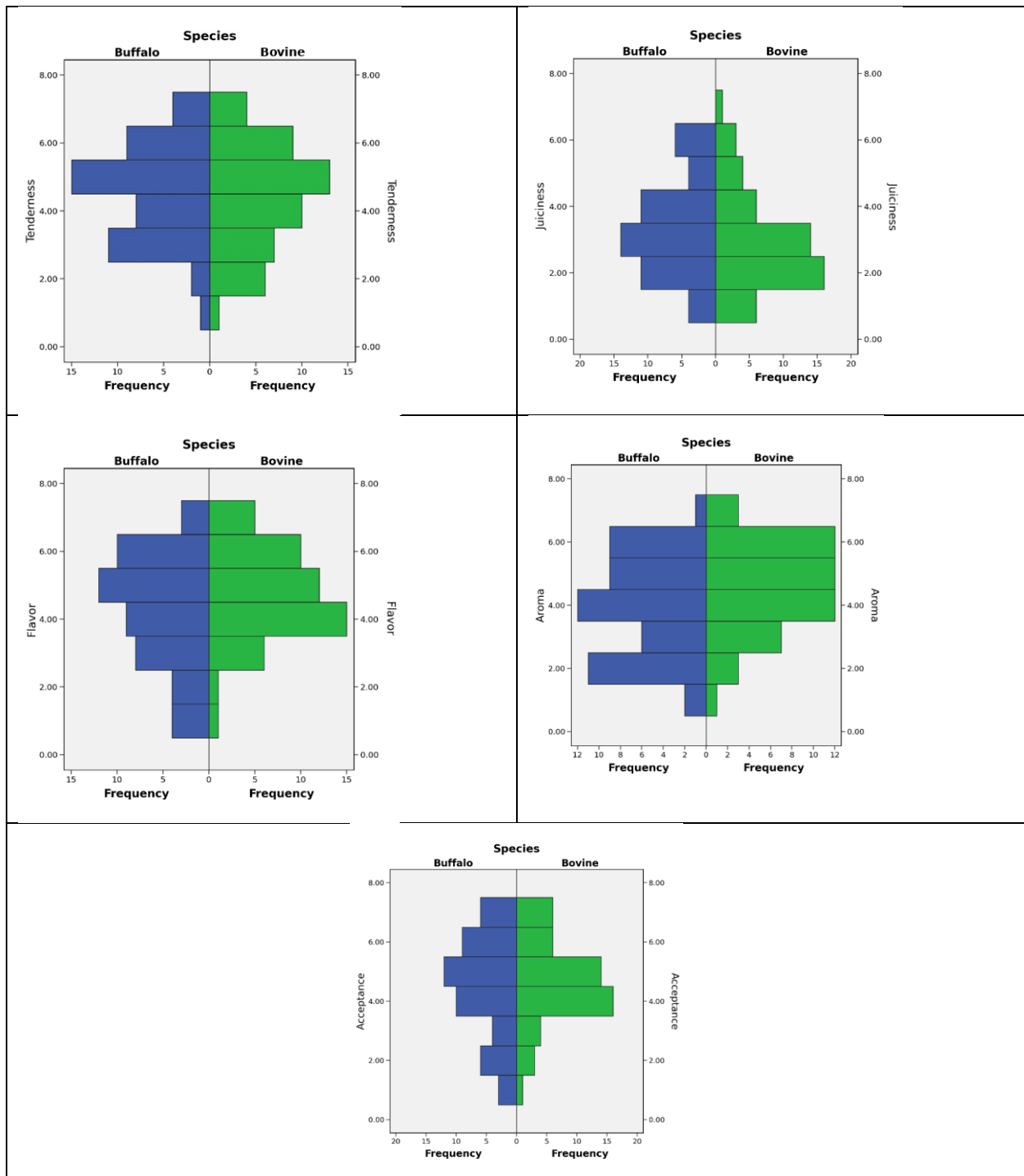


Figure 1. Sensory acceptance results for buffalo and beef meat obtained from 7-point hedonic scales. N=100

were the same between species (5.14, $p>0.05$). In both species, texture was significantly lower ($p<0.05$) in raw cuts than in cooked cuts. This increased tenderization in cooked meat can be explained by increased muscle contraction and greater collagen solubilization (Madhusankha & Thilakarathna, 2021).

Water Holding Capacity (WHC)

Water holding capacity (WHC) refers to the ability of meat tissues to retain free water (not chemically bound) when subjected to external forces, such as cutting and chopping. For the raw buffalo cuts, differences in WHC were observed between NY and PI (28.84 vs. 26.28, $p<0.05$), as well as between PI and RE (26.28 vs. 28.79, $p<0.05$). These results are similar to those of Kiran et al. (2015), who found significant differences in WHC when analyzing two

buffalo muscle types (psoas major and longissimus lumborum). For the raw beef cuts, NY and RE showed similar WHC values ($p>0.05$), but NY decreased by 2.15 units compared to PI and RE by 2.08 units compared to PI ($p<0.05$). Caraveo et al. (2014) obtained higher values when analyzing WHC in beef stored at 4 °C on day 0 of storage. The differences in WHC values may be attributed to animal age, muscle type, fat content, pH, time elapsed after slaughter, and storage temperature (refrigeration and/or freezing) (Angel-Rendon et al., 2020). Additionally, storage time influences the decrease in WHC due to factors such as the post-mortem pH decline rate, ice crystal formation, high ionic strength, protein denaturation, and drip loss (Kandeean et al., 2013). For the cooked buffalo cuts, significant differences were observed across all cuts ($p<0.05$), with the highest water holding capacity (WHC) in RE, followed by NY and, finally, PI, showing differences of 0.32 and 2.56 units, respectively. Similarly, WHC differed between NY and PI in cooked bovine cuts, with a decrease of 2.54 units, with NY higher ($p<0.05$). RE showed similar WHC to NY ($p>0.05$) but differed from PI ($p<0.05$). For both species, WHC values were higher in raw meat than in cooked meat ($p<0.05$). Heat applied during cooking reduces WHC by denaturing myofibrillar proteins and solubilizing connective tissue. Therefore, cooking method, temperature, and time must be considered (Naqvi et al., 2021). Finally, regarding differences in WHC between species, a significant difference was observed only in the cooked NY cuts, where bovine had a higher WHC than buffalo by 0.28 units ($p<0.05$). No significant differences were found between species ($p>0.05$) for all other raw and cooked cuts.

Color

The color of meat plays a crucial role in its quality and consumer acceptance. This variable was expressed through parameters of L^* (lightness), a^* (+red/-green), and b^* (+yellow/-blue), which are shown in Table 2. In the raw buffalo cuts, the L^* value for the PI cut was 3.02 and 7.27 units higher ($p<0.05$) compared to the NY and RE cuts, respectively. A significant difference was also observed between the L^* values of NY and RE cuts (39.70 vs 35.45, $p<0.05$). In the raw bovine cuts, the L^* value of NY was 3.14 and 8.3 units higher ($p<0.05$) than that of the PI and RE cuts, respectively. For the cooked buffalo cuts, no significant differences were found among the three cuts, with an average L^* value of 47.66 ($p>0.05$). In the cooked bovine cuts, the L^* value of NY was similar to that of PI (51.6 vs 50.0, $p>0.05$), but the L^* value of RE was 3.18 units lower than that of NY ($p<0.05$). When comparing raw buffalo and bovine cuts, the L^* values for the PI and RE cuts were similar ($p>0.05$), whereas the L^* value of NY was higher in bovine than in buffalo (44.61 vs 39.70, $p<0.05$). Hassan et al. (2018) found higher L^* values in bovine (40.08 vs 37.09, $p<0.05$). According to Madhusankha & Thilakarathna (2021), buffalo meat tends to be darker than bovine meat, which can be attributed to factors such as a higher rate of myoglobin oxidation, lower marbling content, and higher myoglobin levels in buffalo compared to other livestock species (ranging from 2.7 to 9.4 mg g⁻¹). These myoglobin levels can be influenced by muscle type and the animal's age (Kandeean et al., 2013). Finally, the cooked bovine NY cut had the highest L^* value (51.66), significantly higher than all buffalo cuts ($p<0.05$).

The L^* values for all three cuts in both species increased significantly with cooking ($p<0.05$). This finding is consistent with the results of Oz et al. (2016), who observed an increase in L^* values in beef steaks when subjected to seven different cooking methods: frying in oil, using a hot plate, boiling, microwave cooking, baking, and cooking in a pan with or without oil. The obtained L^* values ranged from 40.05 to 41.81, while the initial value in the raw steaks was 35.56. The L^* value in meat increases with cooking methods such as sous-vide and boiling, while dry/heat methods reduce it (Oz & Zikarov, 2015).

The a^* parameter, associated with oxymyoglobin, reflects the bright red color of fresh meat. In the raw buffalo cuts, the a^* value for PI increased by 2.36 units compared to NY ($p<0.05$) and by 2.87 units compared to RE ($p<0.05$). Andrade et al. (2022) reported an a^* value of 16.00 for buffalo *L. lumborum* muscle, while Hassan et al. (2018) found an a^* value of 22.05 for buffalo meat. For raw bovine cuts, the a^* values for NY and PI were similar (21.35 vs 20.84, $p>0.05$), but the RE cut showed a significant decrease ($p<0.05$), with reductions of 3.63 and 3.12 units, respectively, compared to NY and PI. Kim et al. (2019) reported similar a^* values for beef, ranging from 19.08 to 22.07. The higher a^* values in the raw cuts of both species can be attributed to a higher content of soluble sarcoplasmic proteins, which contribute to the meat's red color (Hassan et al., 2018).

No significant differences in a^* values were noted among the three cuts for cooked buffalo meat, with an average value of 8.26 ($p>0.05$). In cooked bovine cuts, the a^* value for NY was statistically similar to that of cooked RE (6.3 vs 7.42, $p>0.05$), while the a^* value for PI was 1.83 units higher and significantly different from NY ($p<0.05$), but similar to cooked RE (8.13 vs 7.42, $p>0.05$). After cooking, the a^* value decreased significantly ($p<0.05$) in all three cuts of both species. This decrease may be related to myoglobin denaturation during cooking, which shifts the meat from bright red or pink to dull brown or pale tones (Jeong et al., 2018; Angel-Rendon et al., 2020). Differences in a^* values between bovine and buffalo cuts indicate that cooked bovine NY (6.30) differed significantly from all cooked buffalo cuts ($p<0.05$), and the same was true for the a^* value of cooked bovine PI. However, the a^* values of cooked bovine NY and RE from the same species were statistically similar ($p>0.05$).

For b^* , raw buffalo NY was similar to PI (7.58 vs 7.13, $p>0.05$). However, RE showed a significant decrease of 1.67 units compared to NY ($p<0.05$) and 1.22 units compared to PI ($p<0.05$). Andrade et al. (2022) reported a b^*

value 7.32 for the buffalo *L. lumbarum* muscle. In contrast, Joele et al. (2016) found higher b^* values of 12.62 and 12.50 in buffalo meat raised under traditional and silvopastoral systems with supplementation, respectively. In raw bovine cuts, significant differences ($p < 0.05$) were observed in b^* values across all cuts, ranging from 5.97 to 8.43. Kim et al. (2019) reported b^* values between 6.77 and 10.14 for different bovine cuts. Similar b^* values were revealed for the cooked buffalo cuts for PI and RE, with a minimal increase of 0.12 units in PI ($p > 0.05$). However, b^* decreased from PI to NY by 1.99 units ($p < 0.05$) and from RE to NY by 1.87 units ($p < 0.05$). PI had a significantly higher b^* value than NY in cooked bovine cuts, with a difference of 1.23 units ($p < 0.05$). In contrast, the b^* value for cooked RE was similar to that of both NY (12.33 vs 11.89, $p > 0.05$) and PI (12.33 vs 13.12, $p > 0.05$). After cooking, the b^* value increased significantly ($p < 0.05$) in all three cuts of both species. Oz et al. (2016) observed a similar trend in bovine meat exposed to seven cooking methods, including boiling. Finally, for raw cuts in both bovine and buffalo, the b^* values for NY and RE were similar within both species ($p > 0.05$). Similarly, the b^* value for PI was consistent between the two species ($p > 0.05$). Differences in b^* values between cooked bovine and buffalo cuts were observed only in the bovine NY cut, which had a higher value (1.37 units) than buffalo-cooked NY ($p < 0.05$). The b^* value for PI in bovine was similar to that in buffalo (13.12 vs 12.51, $p > 0.05$). A similar pattern was observed for RE, where the b^* value for buffalo was slightly higher (0.06 units), but this difference was not statistically significant ($p > 0.05$).

Hedonic analysis

Tenderness, juiciness, and flavor are key attributes of meat's overall palatability (O'Quinn et al., 2018). In the hedonic evaluation, 500 responses were collected, as shown in Table 3, for tenderness, juiciness, flavor, aroma, and overall acceptance of buffalo meat versus beef. Figure 1 presents the sensory acceptance results for the five evaluated characteristics.

The acceptance test (degree of liking, DL) indicated that, for tenderness, the highest frequency of DL was “moderately like” for both species. For juiciness, most panelists rated buffalo meat in the neutral category, “neither like nor dislike,” while bovine was most frequently rated as “dislike moderately.” Regarding flavor, the majority of panelists gave buffalo meat a higher DL score (“moderately like”) compared to bovine (“slightly like”). Andrade et al. (2022), in a sensory analysis with 100 panelists (51 women and 49 men) aged 18 to 29 years, reported that buffalo meat was less tender and juicy than beef ($p < 0.05$). However, buffalo meat did not differ in flavor from beef ($p > 0.05$). In contrast, a consumer panel rated buffalo meat higher for tenderness and juiciness than Angus beef raised under the same conditions (Canozzi et al., 2016).

Regarding aroma, for water buffalo meat, the highest frequency of general acceptance (GA) responses was recorded in the “slightly like” category, while for beef, the scores ranged from 4 to 6, indicating responses from “slightly like” to “like very much”. According to Bleicher et al. (2022), volatile composition and meat odor depend on precursors present in raw meat, such as amino acids, peptides, glycogen, reducing sugars, nucleotides, and thiamine. Various pre-slaughter factors, including species, breed, sex, age, diet, and muscle type, influence these components. Furthermore, post-mortem conditions also determine the development of volatile organic meat compounds. Regarding overall acceptance, the highest frequency of GA responses for water buffalo meat was in the “moderately like” category. In contrast, for beef, it was in the “slightly like” category. These findings are significant, as panelists showed no sensory rejection of water buffalo meat after tasting, suggesting it could be a viable option for consumers, supported by its physicochemical characteristics, which were also evaluated in this study. (O'Quinn et al. 2018).

Conclusion

The results indicate that water buffalo meat is a significant alternative for meeting the growing demand for high-quality food because of its remarkable physicochemical and organoleptic properties, similar to those of beef. These characteristics make it a viable option for developing high-quality, value-added meat products. This is particularly relevant given the considerable growth in the water buffalo population in Mexico in recent years.

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