Effect of age and gender on the processing characteristics of buffalo meat

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A B S T R A C T

Comparison of processing characteristics of meat from young male, spent male and spent female buffaloes was made to find the suitability of the meat for developing ready to eat meat products. Intensively reared young male buffalo meat showed higher moisture, collagen solubility, sarcomere length, myofibrillar fragmentation index and water holding capacity than meat from the other animals. A higher pH, total meat pigments, salt soluble protein, emulsifying capacity and lower collagen solubility were observed in spent male buffalo meat. Spent female buffalo meat had higher fat, total collagen, muscle fibre diameter and shear force value. Sensory evaluation of pressure cooked meat chunks indicated a marked toughness in spent male and female buffalo meat samples. These results suggest that young male buffalo meat is more suitable for processing in chunks and spent male and female buffalo meat is more suitable for processing in smaller particles.

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1. Introduction

Buffalo meat has gained importance in the recent years because of its domestic usage and export potential. Buffalo meat is comparable to beef in many of its physicochemical, nutritional and functional properties and sensory attributes. Furthermore, its use in meat processing is increasing because of its higher content of lean meat and lower fat. This dark meat possesses good binding properties and is useful in product manufacture. Despite the vast population and contribution of buffaloes to total meat production in India, their potential in the processed meat sector is not completely exploited.

The carcasses from young and old buffaloes were studied regarding physical and chemical aspects (Syed Ziauddin, Mahendrakar, Rao, Ramesh, & Amla, 1994). Buffalo meat from old females was subjected to direct and delayed chilling to improve its textural qualities (Rathina Raj, Jagannatha Rao, Narasimha Rao, & Mahendrakar, 2000). Cucumis, ginger and papain treated Biceps femoris muscle of spent female buffalo meat were studied regarding physicochemical, histological and sensory attributes (Naveena, Mendiratta, & Anjaneyulu, 2004). Buffalo meat packaged under modified atmosphere conditions was analyzed for its structural and physical parameters (Sekar, Dushyanthan, Radhakrishnan, & Narendra Babu, 2006). Variations in cooking time and temperature were investigated for collagen solubility of Semimembranosus muscle in carabeef (Vasanthi, Venkataramanujam, & Dushyanthan, 2007). However, no scientific information regarding meat quality for product processing from different groups of buffaloes has been reported. The objective of this study was to compare the physicochemical and functional properties of meat obtained from three different groups of buffaloes, i.e. intensively reared young male, aged/spent male and female buffaloes.

2. Materials and methods

2.1. Buffalo meat sample

Buffalo meat was obtained from young males (about 18 months old) intensively reared at the Division of Animal Nutrition, Indian Veterinary Research Institute, Izatnagar, Bareilly district, Uttar Pradesh state, India. Whereas, the meat from aged/spent male (culled buffalo bullock) and spent female (culled buffalo female) buffaloes (>10 years) were procured from the meat market, Bareilly. A total of thirty buffaloes, ten in each group were used to study the processing characteristics of meat. The samples were collected from the longissimus dorsi muscle of the carcasses, of similar conformation from each group of buffaloes, slaughtered according to the traditional halal method. The meat was obtained within 6 h of slaughter, packed in low density polyethylene (LDPE) bags and transferred to a freezer (Vest Frost, Denmark) maintained at −18 ± 1 °C until processed. The meat was thawed at 4 ± 1 °C for 12 h before evaluation. The
meat samples for quality assessment were ground in a mincer (Santos, France), packed in polyethylene terephthalate (PET) jars and stored in the refrigerator (4 ± 1 °C) until required.

2.2. Physicochemical and functional characteristics

The pH of the tissue homogenate was recorded by the combined glass electrode of a digital pH meter (Model CP 901, Century Instruments Ltd., Chandigarh). The moisture content was determined by oven drying, protein by Kjeldahl nitrogen estimation and fat by Soxhlet extraction with petroleum ether (AOAC, 2002). The salt soluble protein content was determined by a slight modification of the method of Knipe, Olson, and Rust (1985). Optical density of the salt solubilized protein solution was determined (Elico Scanning Mini SL 177) at 540 nm and converted using a bovine serum albumin (BSA) standard curve to (mg) protein per ml solution. SSP was expressed as g per 100 g meat. The fibre diameter of buffalo meat samples were assessed as outlined by Jeremiah and Martin (1982). Muscle fibre diameter was measured as the mean diameter of the middle and the two extremities of 25 randomly selected muscle fibres and expressed in micrometers.

Total collagen contents of the raw meat samples were estimated by determining the hydroxyproline (HP) content of the meat sample as described by Neuman and Logan (1950); with some modifications. The HP content (g/100 g) was multiplied by 100, then the collagen content (g/100 g). Water holding capacity was determined according to the centrifugation method of Wardlaw, Maccaskill, and Acton (1973) with slight modification. The difference between the added and decanted solutions was expressed as a percentage of the initial weight of meat. The method used for determining the EC was slightly modified to that of Swift, Locker, and Fryar (1961). The volume of oil just exceeding the EC of the meat sample was recorded and expressed as ml of oil emulsified per 2.5 g meat.

2.2.1. Total meat pigments

Total meat pigments were determined by a solvent extraction technique modified from Hornsey (1956). About 10 g of the minced meat sample was homogenised to a smooth paste using an Ultra Turrax tissue homogenizer (Model T25, Janke and Kunkel, 1 KA Labor Technik, Germany) with 23 ml of a mixture containing 40 ml of acetone, 2 ml of distilled water and 1 ml of concentrated HCl. The remainder of the solution was then added and kept for 1 h with intermittent mixing. The solution was filtered to give a solution of acid haemin in 80% acetone (including the 7 ml water present in 10 g meat). The optical density of this filtrate was measured at 640 nm, with an 80% acetone/water solution as blank. The absorbance of the filtrate was multiplied by 680 to give the concentration of total pigments present in the meat as ppm of haemin.

2.2.2. Sarcomere length

The samples for sarcomere length measurements were removed after 24 h of ageing, put in 2.5% glutaraldehyde fixative and prepared by modifying the method of Cross, West, and Dutson (1980). One gram of sample was put in 15 ml of first fixative or solution A (0.1 M KCl, 0.039 M boric acid and 5 mM EDTA in 2.5% glutaraldehyde) in a 50 ml beaker and covered for 2 h, then the sample was transferred to 15 ml of solution storage or solution B (0.025 M KCl, 0.039 M boric acid and 5 mM EDTA in 2.5% glutaraldehyde) in a 50 ml beaker and covered for 24 h. The samples were stored at 4 ± 1 °C until analysis. The fixed samples were quantitatively transferred to 50 ml polycarbonate centrifuge tubes with 7 ml of 0.25 M sucrose solution. The sample was homogenised at low speed with an Ultra Turrax tissue homogenizer (Model T25, Janke and Kunkel, 1 KA Labor Technik, Germany). A drop of the homogenate was transferred to a slide and covered with a cover slip. The slide was then examined under a microscope using a 10× eye piece with a calibrated micrometer under an oil immersion objective lens (100×). Sarcomere length was measured as the mean length of 10 sarcomeres in 10 randomly selected myofibrils.

2.2.3. Collagen solubility

Collagen solubility was estimated by measuring the soluble hydroxyproline fraction in the cooked meat sample. The soluble hydroxyproline was determined by modifying the procedure of Okkonko, Obanu, and Ledward (1992). Four gram of minced buffalo meat samples were placed in 50 ml glass centrifuge tubes and 12 ml of one-fourth strength Ringer’s solution (1 × 8.6 g NaCl, 0.3 g KCl & 0.33 g CaCl2 per litre) were added. The samples were heated at 77 °C for 70 min, 10 min being required to achieve the required temperature of the water bath. The samples were stirred occasionally. The samples were quantitatively transferred to 50 ml polycarbonate centrifuge tubes. After centrifugation at 1787 g for 20 min in a REMI research centrifuge, the supernatant was decanted into a 50 ml beaker. The residues were washed with 8 ml of one-fourth ringer’s solution and centrifuged again at 1787 g for 10 min. The supernatants were combined and represented the soluble fraction. The residues represented the insoluble fraction. Each fraction was separately transferred into a narrow mouthed 50 ml conical/ether extraction flask and covered with a watch glass/small petri dish. The supernatants and residues were hydrolyzed with 40 ml of 6 N HCl for 12 h at 105 °C in a hot air oven (Kailash Scientific & Electronics, New Delhi, India). Hydroxyproline in the hydrolysates were determined by the procedure of Neuman and Logan (1950). The percent soluble hydroxyproline was calculated as soluble hydroxyproline divided by total hydroxyproline multiplied by 100. Thus

\[
\text{Collagen solubility (%) = } \frac{\text{Soluble collagen}}{\text{Soluble collagen + Insoluble collagen}} \times 100
\]

2.2.4. Warner–Bratzler shear force

Shear force value were determined by modifying the method of Berry and Stiffler (1981). The meat samples were cut into 6 cm³ and vacuum packed in LDPE bags and then cooked at 80 °C for 1 h by immersing in a water bath. After cooling to room temperature the samples were cut into 1.5 cm cubes and sheared with a Warner–Bratzler blade attached to the texture analyzer. The crosshead speed was 2 mm/s. Maximum force required to cut the samples (shear force) was recorded. The average value for each sample was recorded as the mean of duplicates and expressed in Newtons (N).

2.2.5. Myofibrillar fragmentation index

The myofibrillar fragmentation index (MFI) was determined by modifying the method described by Davis, Dutson, Smith, and Carpenter (1980). This basically measured the proportion of muscle fragments that passed through muslin cloth after the sample had been subjected to high speed homogenisation. Ten grams of minced meat was transferred to a 100 ml polycarbonate centrifuge tube containing 50 ml of cold 0.25 M sucrose and 0.02 M potassium chloride solutions. The samples were allowed to equilibrate for 5 min then were homogenised for 40 s at full speed with an Ultra Turrax tissue homogenizer (Model T25, Janke and Kunkel, 1 KA Labor Technik, Germany). The homogenate was filtered through a preweighed muslin cloth through a funnel placed in a 50 ml test tube. The homogenate was stirred with a glass rod to hasten filtration. A gentle and uniform squeezing was made to all samples in the muslin cloth to drain out excess moisture. The resulting muscle
fragments collected on the screen were blotted with Whatman No. 1 filter paper. The weight of the sample with the screen was taken after 40 min of drying at 37 °C (Bharat Instruments & Chemicals, New Delhi, India). MFI was calculated as a percentage of the weight of muscle fragments passed through (initial weight of muscle sample – weight of residue after drying) to that of the initial weight of the muscle.

2.3. Sensory evaluation

The meat chunks (3 cm cubes) from three different buffalo groups were mixed with 1.75% salt and water (50% of meat taken) in a glass beaker (250 ml) and covered with aluminium foil. Water in a pressure cooker immersed one-fourth of the height of the beaker. The glass beakers containing meat samples were then placed in the pressure cooker. Cooking was done under high flame till the first whistle and then turned to cook under simmering for 30 min. The cooked samples were separated from the meat extract, cooled to room temperature and subjected to sensory evaluation.

A trained panel was used to study the perceived differences between the different groups of cooked buffalo meat chunks by descriptive profile scoring of sensory attributes. The trained panelists (n = 10) consisted of scientists and post-graduate students of the Division of Livestock Products Technology, IVRI, Izatnagar. Panelists were trained according to guidelines for cookery and sensory analysis of meat as suggested by the American Meat Science Association, 1995 and were well acquainted with the different sensory attributes. They were briefly told about the nature of the experiment without disclosing the identity of samples. Samples were warmed (40–45 °C) using a microwave oven (LG electronics India (P) Ltd., Mumbai) for 1 min and served to the panelists. Each panelist received two cubes from each sample of cooked buffalo meat chunks in a randomized order. Each session included samples from all groups of buffalo meat. Panelists were provided with filtered water to clean their pallets between samples. Panelists evaluated samples for appearance, flavour, juiciness, tenderness and connective tissue residue using eight-point scales. The scale used for appearance was: 1 = extremely poor, 2 = very poor, 3 = moderately poor, 4 = slightly poor, 5 = fair, 6 = good, 7 = very good, and 8 = excellent. The scale used for flavour was: 1 = extremely bland, 2 = moderately bland, 3 = moderately abundant, 4 = slightly abundant, 5 = slightly intense, 6 = moderately intense, 7 = very intense, and 8 = extremely intense. The scale used for juiciness was: 1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, and 8 = extremely juicy. The scale used for tenderness was: 1 = extremely tough, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tender, 6 = moderately tender, 7 = very tender, and 8 = extremely tender. The scale used for connective tissue was: 1 = abundant, 2 = moderately abundant, 3 = slightly abundant, 4 = moderate, 5 = slight, 6 = traces, 7 = practically none and 8 = none. Panelists reported scores to the nearest half-point. Panelists’ scores were averaged for statistical analysis. Tests were conducted under white fluorescent lights in partitioned booths.

2.4. Statistical analysis

The data were analyzed using SPSS (version 10.0 for Windows; SPSS, Chicago, III., USA) with randomized block design. The data were subjected to analysis of variance, least significant difference and Duncan’s multiple range tests to compare the means to find the difference between groups. The smallest difference (D25) for two means to be significantly different was P < 0.05.

3. Results and discussion

3.1. Physicochemical and functional characteristics

3.1.1. pH

The normal ultimate pH of buffalo meat varies from 5.4 to 5.6 (Kandeepan & Biswas, 2007). The pH of the meat from intensively reared young males was 5.57, which did not differ significantly from spent male buffalo meat (Table 1). The significantly (P < 0.05) lower ultimate pH in spent female buffalo meat might be due to the response of female buffaloes to transport stress (Jedlicka, Mojto, Vancisin, Kenetova, & Palwik, 1980). The meat from intensively reared young male buffaloes showed a significantly (P < 0.05) higher moisture content than the meat from spent male and female buffaloes (Table 1). The moisture content of buffalo meat decreases as the age of the animal increases which is probably associated with an increase in fat content (Lawrie, 1998). Intensive feeding of young male buffaloes with a high protein diet did not result in a significant difference in protein content of the meat compared to semi extensively reared spent male and female buffaloes (Table 1). Meat from spent female buffaloes had a significantly (P < 0.05) higher fat content compared to the other groups (Table 1). Fat is the last tissue to mature and older animals tending to be fatter (Warriss, 2000).

3.1.2. Proximate composition

The meat from intensively reared young male buffaloes was significantly (P < 0.05) lower than that of spent male and female buffaloes (Table 1). A slight variation in myoglobin concentration was observed in the meat from spent male and female buffaloes. Meat becomes darker in colour with increasing age (Valin, Pinkas, Dragner, Boikovski, & Polikronov, 1984) as the meat pigment concentration increases with greater content of myoglobin (Mamino & Horn, 1996).

3.1.3. Total meat pigment

The meat pigment content from younger buffaloes was significantly (P < 0.05) lower than that of spent male and female buffaloes (Table 1). A slight variation in myoglobin concentration was observed in the meat from spent male and female buffaloes. Meat becomes darker in colour with increasing age (Valin, Pinkas, Dragner, Boikovski, & Polikronov, 1984) as the meat pigment concentration increases with greater content of myoglobin (Mamino & Horn, 1996).

3.1.4. Salt soluble protein

Spent male buffalo meat had significantly (P < 0.05) higher salt soluble protein compared to the meat from young male and spent male buffaloes.

Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Groups</th>
<th>Young male</th>
<th>Spent male</th>
<th>Spent female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphochemical characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>5.57 ± 0.02bc</td>
<td>5.59 ± 0.02ab</td>
<td>5.52 ± 0.01a</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td></td>
<td>74.99 ± 0.38a</td>
<td>73.42 ± 0.28bc</td>
<td>72.63 ± 0.40bc</td>
</tr>
<tr>
<td>Protein (%)</td>
<td></td>
<td>21.20 ± 0.26a</td>
<td>21.61 ± 0.37ab</td>
<td>20.70 ± 0.32bc</td>
</tr>
<tr>
<td>Fat (%)</td>
<td></td>
<td>2.67 ± 0.24a</td>
<td>2.76 ± 0.25ab</td>
<td>3.98 ± 0.35bc</td>
</tr>
<tr>
<td>Total meat pigments (ppm)</td>
<td></td>
<td>1107.92 ± 3.14ab</td>
<td>1148.79 ± 6.43a</td>
<td>1146.82 ± 3.58ab</td>
</tr>
<tr>
<td>Salt soluble protein (%)</td>
<td></td>
<td>5.89 ± 0.06a</td>
<td>6.04 ± 0.09ab</td>
<td>5.79 ± 0.09bc</td>
</tr>
<tr>
<td>Collagen content (%)</td>
<td></td>
<td>0.82 ± 0.02bc</td>
<td>1.54 ± 0.20bc</td>
<td>1.85 ± 0.25ac</td>
</tr>
<tr>
<td>Collagen solubility (%)</td>
<td></td>
<td>29.90 ± 1.64a</td>
<td>7.40 ± 0.28b</td>
<td>9.33 ± 0.77bc</td>
</tr>
<tr>
<td>Muscle fibre diameter (μm)</td>
<td></td>
<td>69.83 ± 0.75a</td>
<td>73.47 ± 0.40ab</td>
<td>78.87 ± 0.90bc</td>
</tr>
<tr>
<td>Sarcomere length (μm)**</td>
<td></td>
<td>1.83 ± 0.02a</td>
<td>1.51 ± 0.01a</td>
<td>1.56 ± 0.01bc</td>
</tr>
<tr>
<td>Shear force value (N)</td>
<td></td>
<td>60.60 ± 2.11a</td>
<td>81.90 ± 1.96bc</td>
<td>93.81 ± 1.35ac</td>
</tr>
<tr>
<td>Myofibrillar fragmentation index (%)</td>
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<td>84.77 ± 0.67a</td>
<td>79.69 ± 0.30b</td>
<td>72.23 ± 1.94bc</td>
</tr>
<tr>
<td>Functional properties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water holding capacity (ml/100 g)</td>
<td></td>
<td>13.34 ± 0.99a</td>
<td>12.67 ± 1.63ab</td>
<td>8.67 ± 0.54bc</td>
</tr>
<tr>
<td>Emulsifying capacity (ml oil/2.5 g meat)</td>
<td></td>
<td>103.60 ± 1.05a</td>
<td>116.00 ± 3.03a</td>
<td>106.00 ± 3.51a</td>
</tr>
</tbody>
</table>

n = 10, *n = 375, **n = 500.

Means with different superscripts in the same row indicate significant difference (P < 0.05).
female buffaloes (Table 1). Salt soluble protein was related to the water holding capacity and moisture content of the meat in each group. Meat with higher salt soluble protein can retain more water to improve the cohesiveness and binding strength of the product during processing (Swan & Boles, 2006).

3.1.5. Collagen content

Collagen content of meat from intensively reared young male buffaloes was significantly ($P < 0.01$) lower than the other two groups (Table 1). Collagen content of meat from spent female buffalo was markedly higher compared to spent male buffalo meat. The result suggests that the meat from spent male and female buffaloes could be tougher. An age related increase in pyridinoline content of intramuscular collagen and cross link formation induced by sex contributed to the toughness of meat in spent groups (Bosselmann, Moeller, Steinhart, Kirchgesnsser, & Schwarz, 1995).

3.1.6. Collagen solubility

The collagen solubility of meat in young male buffaloes was significantly ($P < 0.05$) higher than that of other two groups (Table 1). As animals get older the collagen cross links become stabilized and the collagen is much less soluble (Maltin et al., 1998). The collagen of spent male buffalo meat was slightly less soluble than the collagen of spent female buffalo meat. This was attributed to the highly stabilized cross links induced by the work (draught) done by spent/old male buffaloes.

3.1.7. Muscle fibre diameter

The fibre diameter of spent male buffalo meat was significantly ($P < 0.05$) larger than that of the young males but significantly ($P < 0.05$) lower in comparison to spent female buffalo meat (Table 1). An increase in age of river buffaloes was associated with increasing muscle fibre diameter (Ragab, Darwish, & Malek, 1966). Fibre diameter was positively correlated to shear values but negatively correlated to tenderness and sarcomere length of the muscle.

3.1.8. Sarcomere length

The sarcomere length of buffalo meat was significantly ($P < 0.05$) higher in young males compared to spent male and females (Table 1). Sarcomere length decreases with advancing age and increases the toughness of meat (Ffoulkes, 1992). Spent male buffalo meat had lower sarcomere lengths than that of spent female buffalo meat. This might give rise to tenderness variation due to sarcomere length in spent male and female buffaloes.

3.1.9. Warner–Batzler shear force value

The buffalo meat obtained from young males showed a significantly ($P < 0.05$) lower shear force value than the other groups (Table 1). Intensive feeding decreased the shear force value of the meat (Shiba, Matsuzaki, & Isuneishi, 2004). The meat from spent female buffaloes showed significantly ($P < 0.05$) higher shear force values compared to the spent male buffaloes. Tenderness was also higher in young bulls followed by steers and then cows (Reid & Swan, 1995). The shear force value was highly related to muscle fibre diameter and collagen content of the buffalo meat.

3.1.10. Myofibrillar fragmentation index (MFI)

The buffalo meat from young males had a significantly ($P < 0.05$) higher MFI compared to the meat from spent male and female buffaloes (Table 1). Animal age has been shown to have more influence on tenderness attributes than sex of the animal (Huff & Parrish, 1993). MFI was negatively correlated with the shear force value of the buffalo meat. The MFI of spent female buffalo meat was significantly ($P < 0.05$) lower than the other two groups, which indicates more toughness.

3.1.11. Water holding capacity (WHC)

The water holding capacity of young male buffalo meat did not differ significantly from the spent male buffalo meat (Table 1). A slightly lower water holding capacity in castrates compared to entire males has been shown to be due to higher protein denaturation in castrates (Dessouki, Saied, Abo-Selim, & El-Kholi, 1981). Meat from intensively reared young male buffaloes had significantly ($P < 0.05$) higher water holding capacity than the meat from spent female buffaloes. The WHC and salt soluble protein contents have been reported to be not significantly related (Reid & Swan, 1995).

3.1.12. Emulsifying capacity

The emulsifying capacity of the meat from young male buffaloes was significantly ($P < 0.01$) lower than spent male buffaloes but not spent female buffaloes (Table 1). The significantly ($P < 0.01$) greater emulsifying capacity of the meat from spent males compared to the other two groups was attributed to the highly significant ($P < 0.01$) increased salt soluble protein content.

3.2. Sensory attributes

Appearance, flavour and juiciness scores did not differ significantly between groups (Table 2). The tenderness and connective tissue residue scores of cooked meat chunks differed significantly ($P < 0.01$) among young male, spent male and spent female buffalo groups. Beef from more mature animals has repeatedly been found less tender than beef from younger animals (Smith et al., 1982). The decrease in tenderness score was attributed to decreased activation of the μ-calpain in older animals (Morgan, Wheeler, Koolmaire, Savell, & Crouse, 1993). The connective tissue residue scores were highly related to the tenderness of the meat. The higher amount of connective tissue in older animals resulted in decreased tenderness of meat (Huff et al., 1993).

4. Conclusions

The desirable muscle fibre, collagen characteristics and sensory attributes related to tenderness and chemical composition of the meat from intensively reared young male buffaloes suggest suitability for processing in chunk form such as in a curry. Whereas, the muscle fibre, collagen characteristics and sensory attributes related to toughness and chemical composition of the meat from spent male and female buffaloes suggest suitability for processing in smaller particles i.e. minced in keema or emulsion type patties.

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