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REVIEW ARTICLE

Processing characteristics of buffalo meat- a review

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Abstract

Buffalo meat is superior in terms of its lean content and high nutritional value. The growing nutritional insecurity with regard to the quality food warrants sufficient knowledge on this protein rich meat source to meet out the requirements in a balanced diet. Development of meat products with superior quality is possible only with the sufficient knowledge on the physicochemical and functional parameters of the meat. Buffalo meat has superior meat processing characteristics due to its chemical composition, structural components and functional abilities. The major attractive features of buffalo meat are its dark red colour, good marbling, low connective tissue, desirable texture, high protein, water holding capacity, myofibrillar fragmentation index and emulsifying capacity. Intensively reared young male buffalo meat showed higher moisture, collagen solubility, sarcomere length, myofibrillar fragmentation index and water holding capacity than meat from 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 indicated a marked toughness in spent male and female buffalo meat. The processing characteristics of meat are essential find their suitability for developing products with superior quality attributes.

Keywords: Buffalo, meat, quality, processing, characteristics

Introduction

Buffaloes have unique ability to utilise coarse feeds, straws and crop residues converting them into protein rich lean meat. Hence buffaloes fit well in poor countries having poor feed resources (Arganosa, 1973). Buffalo properly managed and fed as a meat producing animal and slaughtered at 16 to 20 months of age yields a highly satisfactory top quality meat at a much lower cost than the cattle (Ranjan and Pathak, 1979). Since buffaloes have been used as draught animals for centuries, they have evolved with exceptional muscular development. Until recently, little thought was given to use them exclusively for meat production. Buffaloes are lean animals. The sub-cutaneous fat layer of the carcass is usually thinner than that on comparably fed cattle. Fat is low even under feed lot conditions (Desmond Hill, 1990). More lean and less fat compared to cattle, has created a demand for it among health conscious consumers (Kondaiah, 2002). Buffaloes have higher degree of resistance and tolerance than cattle against many diseases (Ross Cockrill, 1975). They are reasonably productive up to 15 years of age. At 18 years and even more may produce calves (Banerjee, 1998). Buffaloes have excellent body weight gain compared to other species. Hence forth, the meat production ability of the buffaloes is excellent and sustainable for a longer period in production systems.

The characteristics of buffalo meat for processing into value added products are also outstanding. Buffalo meat is the healthiest meat among red meats known for human consumption because it is low in calories and cholesterol. It has almost 2-3 folds cost advantage over mutton and goat meat. In India, meat is consumed either in curry form with high spices or as processed meat products. Only 2% of the meat is processed in India (APEDA, 2012), the remaining meat is sold in fresh or frozen form. Buffalo meat has gained importance in the recent years because of its domestic needs and export potential. Buffalo meat is well comparable to beef in many of the physicochemical, nutritional, functional properties and palatability attributes (Anjaneyulu *et al.*, 1990). Furthermore, its utility in meat processing is on increase because of higher content of lean meat and less 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.

Several researchers have made significant findings about the quality parameters of buffalo meat with special reference to the processing characteristics. The carcasses from young and old buffaloes were studied regarding physical and chemical aspects (Syed Ziauddin *et al*., 1994). Buffalo meat from old females was subjected to direct and delayed chilling to improve its textural qualities (Rathina Raj *et al.*, 2000). The influence of chilling and freezing on the physicochemical, microbiological and sensory attributes of buffalo meat was studied in detail by Kandeepan and Biswas (2007). Cucumis, ginger and papain treated *Biceps femoris* muscle of spent female buffalo meat were studied regarding physicochemical, histological and sensory attributes (Naveena *et al.,* 2004). Buffalo meat packaged under modified atmosphere conditions was analyzed for its structural and physical parameters (Sekar *et al.,* 2006). Variations in cooking time and temperature were investigated for collagen solubility of *Semimembranosus* muscle in carabeef (Vasanthi *et al.,* 2007). Tateo *et al.* (2007) found results of both pH and thawing loss confirming meat of buffalo calves was more suitable for preservation by freezing. The a^* index increased with animal age but decreased during the 4 days post-thawing. The fresh cut surface of buffalo meat from calves slaughtered at 4 and 8 months was not darker than beef slaughtered at the same age. On the contrary at 12 months of age, the buffalo meat had a lower redness index than beef and a higher haematin concentration. The effect of age and gender on physicochemical and functional aspects of buffalo meat was studied by Kandeepan *et al.,* (2009). In a study conducted by Naveena *et al.* (2011), it was indicated that ammonium hydroxide in buffalo meat marinade increased ($P < 0.05$) the pH, water holding capacity (WHC), collagen solubility, total and salt soluble protein extractability and cooking yield. Reduction ($P < 0.05$) in Warner–Bratzler shear force values were observed in all ammonium hydroxide treated samples compared to non-treated control. The results suggested that ammonium hydroxide might be used to tenderize tough buffalo meat. In this review, the different physicochemical and functional parameters of buffalo meat that facilitates this meat for processing into value added products will be discussed.

Physicochemical characteristics

pH: The basic and most important parameter in determining the quality of the meat is pH. It is highly related to other meat processing parameters like water holding capacity and emulsifying capacity. Higher the pH more will be the water holding capacity and emulsifying capacity. Stress related aspects in carcasses cause Pale, Soft and Exudative meat with sudden fall in pH after slaughter, while Dark, Firm and Dry meat is observed in carcasses having very high pH due to depleted glycogen level in the carcass.

Although processing characteristics of high pH meat is desirable, it is subjected to early spoilage due to higher microbial growth owing to high moisture and water activity present in the meat. The normal ultimate pH of buffalo meat varies from 5.4 to 5.6 (Kandeepan and Biswas, 2007a; 2007b). As evident from Table 1, the pH of the meat from intensively reared young males was 5.57, which did not differ significantly from spent male buffalo meat (Kandeepan *et al.,* 2009). The significantly ($P<0.05$) lower ultimate pH in spent

Table 1: Physicochemical and functional properties of meat from different groups of buffaloes

Parameter	Groups		
	Young Male	Spent Male	Spent Female
	Physicochemical characteristics		
pH	5.57±0.02[ab]	5.59±0.02[a]	5.52±0.01[b]
Moisture (%)	74.99±0.38[a]	73.42±0.28[b]	72.63±0.46[b]
Protein (%)	21.20±0.26[a]	21.61±0.37[a]	20.70±0.32[a]
Fat (%)	2.67±0.24[b]	2.76±0.25[b]	3.98±0.35[a]
Total meat pigments (ppm)	1107.92±3.15[b]	1148.79±6.43[a]	1146.82±3.58[a]
Salt soluble protein (%)	5.89±0.06[ab]	6.04±0.09[a]	5.79±0.09[b]
Collagen content (%)	0.82±0.02[b]	1.54±0.20[a]	1.85±0.25[a]
Collagen solubility (%)	29.90±1.64[a]	7.40±0.28[b]	9.33±0.77[b]
Muscle fibre diameter (µm)[#]	69.83±0.75[c]	73.47±0.90[b]	78.87±0.90[a]
Sarcomere length (µm)[##]	1.83±0.02[a]	1.51±0.01[c]	1.56±0.01[b]
Shear force value (N)	60.60±2.11[c]	81.90±1.96[b]	93.81±1.35[a]
Myofibrillar fragmentation index (%)	84.77±0.67[a]	79.69±0.30[b]	72.23±1.94[c]
	Functional properties		
Water holding capacity (ml/100g)	13.34±0.99[a]	12.67±1.63[a]	8.67±0.54[b]
Emulsifying capacity (ml oil/2.5g mea	103.60±1.05[b]	116.00±3.03[a]	106.00±3.51[b]

n=10, [#]n=375, [##]n=500; Means with different superscripts in the same row indicate significant difference (P<0.05)

female buffalo meat might be due to the response of female buffaloes to transport stress than males (Jedlicka *et al.,* 1980). The meat obtained from young male buffaloes fed with high protein diet showed a pH of 5.54 (Anjaneyulu *et al.,* 1985). The ultimate pH of the muscle was significantly higher in male than female (Grigor *et al.,* 1999). A pH of 5.69 in meat chunks (Naveena *et al.,* 2004) and 5.64 in ground meat (Sahoo and Anjaneyulu, 2000) were observed in meat obtained from spent female Murrah buffaloes of 10 years age. Neath *et al.* (2007) indicated that postmortem pH decline of buffalo meat was significantly slower than that of beef, which was confirmed by lactic acid concentrations, but was not explained by glycogen content. In addition, there was no significant difference in the ratio of slow to fast type muscle fibers in buffalo and cattle, indicating that myosin heavy chain type was not responsible for the difference in pH decline and tenderness between the buffalo meat and beef. The study demonstrated that the tenderness of water buffalo meat was superior to that of Brahman beef, which may have been due to the difference in pH decline and the subsequent effect on muscle protease activity.

Moisture: The moisture present in meat determines the binding ability of the meat to some of the binders and fillers added in making processed products. It has high correlation with the fat content of the meat. It is also related with the shelf stability of the processed products since it has relationship with the water activity of the meat for the microbial growth. Moisture content of the meat has direct relationship with juiciness of the processed meat products, which is one of the important sensory attribute. Young male Murrah buffaloes showed a moisture percentage of 74.04-77.75 (Kesava Rao *et al.,* 1985; Syed Ziauddin *et al.,* 1994; Kandeepan and Biswas, 2007a; 2007b).The meat obtained from high protein diet fed young male buffaloes showed moisture content of 76.36% (Anjaneyulu *et al.,* 1985). Whereas, spent female Murrah buffaloes showed a moisture percentage of 76.51-79.69 (Syed Ziauddin *et al.,* 1994; Naveena *et al.,* 2004). Some authors did not find any significant difference in the moisture content between young and old animals (Jokismovic and Ognjanovic, 1977). The major changes in the percentage of chemical composition of the body of an undernourished animal were the loss of fat and protein and gain in proportion of water (Syed Ziauddin *et al.,* 1994). 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 (Kandeepan *et al.,* 2009). 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).

Protein: Meat is praised for its high protein content which makes it obligatory in balanced diet. The amount of protein especially the myofibrillar fractions are the basic supportive element through which meat emulsion is formed. The protein source open up their lipophilic and hydrophilic structures to bind with the water and lipid leading to emulsion formation by the addition of other non meat ingredients into them. The sarcoplasmic fractions contribute to the colour of the processed products while the connective tissue proteins contribute to the texture of the meat products. The protein content of the meat is highly related to the water holding capacity, emulsifying capacity and better nutritional quality of the meat. A higher protein content of 20.53% was recorded in meat obtained from young male buffaloes fed with high protein diet (Anjaneyulu *et al.,* 1985). Young male buffaloes showed a protein percentage of 17.33-23.3 (Kesava Rao *et al.,* 1985; Kandeepan and Biswas, 2007a; 2007b). Whereas, spent female Murrah buffaloes showed a protein percentage of 17.81-20.08 (Syed Ziauddin *et al.,* 1994; Naveena *et al.,* 2004). Meat from males had markedly higher protein content than females (El-Kirdassy and Abdel-Galil, 1977; Mohan *et al.,* 1987). 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 (Kandeepan *et al.,* 2009).

Fat: The meat fat is responsible for the species specific flavor present in the meat products. The amount of fat contained in a meat product also determines the juiciness of the meat product. The ruminant fat are saturated and not easily dispersed in meat emulsion resulting in poor appearance of the product with fat droplets visible on the product. This result in a phenomenon called mouth coating while the product is consumed. Intact males contained less fat (Stoikov and Dragoeva, 2002). Palmitic, stearic, oleic and linoleic acids were the four predominant fatty acids in the phospholipids of buffalo meat (Kesava Rao and Kowale, 1991). High protein feeding in young male buffaloes recorded a fat content of 1.50% in the meat (Anjaneyulu *et al.,* 1985). Buffalo meat from 2 years old male calves showed a fat percentage of 1-3.5 (Kesava Rao *et al.,* 1985; Kondaiah *et al.,* 1986; Kandeepan and Biswas, 2007a; 2007b). The intramuscular fat percentage varies between the muscles. The low level of intramuscular fat could be due to poor marbling reported in buffaloes (FAO, 2005). An increased fat content in intensively fed bulls were observed (Sami et al., 2004). Male animals are leaner than females (Warris, 2000). The meat from females and steers contained a higher fat content than from bulls (Zi *et al.,* 2004). Meat from spent female buffaloes had a significantly ($P<0.05$) higher fat content compared to the other groups (Kandeepan *et al.,* 2009). Fat is the last tissue to mature and older animals tend to be fatter (Warris, 2000).

Meat pigments: The amount of pigment present in the meat decides the colour of the product. Buffalo meat products are darker in colour owing to their higher myoglobin content compared to other livestock species. The meat obtained from intact males was lighter in colour (Stoikov and Dragoeva, 2002). The myoglobin content varied from 2.7 to 9.4 mg/g depending upon the type of the muscle and age and meat becomes darker with increasing age (Valin *et al.,* 1984). A slight variation in myoglobin was observed in the meat from spent male and female buffaloes (Dransfield *et al.,* 1990). The meat pigment concentration of spent male buffalo meat was significantly higher than young males (Klastrup, 1984), which was attributed to greater content of haeme pigment and myoglobin (Mamino and Horn, 1996). The heme pigment concentration in meat samples of bulls was 3.59 to 3.99 mg/g (Maltin *et al.,* 1998). The total meat pigment obtained from spent female buffalo was 0.25% (Sahoo and Anjaneyulu, 2000). The meat pigment content from younger buffaloes was significantly (P<0.05) lower than spent male and female buffaloes (Kandeepan *et al.,* 2009). A slight variation in myoglobin concentration was observed in the meat from spent male and female buffaloes.

Salt soluble protein (SSP): The myofibrillar proteins can be extracted well in the presence of salts which form the basis for emulsion based and restructured meat products. The binding and emulsifying ability of the protein molecules are greatly improved after their extraction with salt resulting in good emulsion stability. About 35% of meat protein was salt soluble (Swan *et al.,* 1995). The higher amount of SSP or extractable proteins would result in greater emulsifying capacity of the muscle (Turget, 1984). The percent water soluble protein and SSP of buffalo thigh meat, tripe and heart were 4.08, 4.35; 2.87, 6.30 and 4.40 and 4.53 respectively (Kondaiah *et al.,* 1986a).

Sarcoplasmic and myofibrillar protein concentration of 5.12 % and 7.19% were recorded in meat from high energy diet fed male buffalo calves (Anjaneyulu *et al.,* 1985). Spent female buffalo meat showed a SSP of 8.2% (Anjaneyulu *et al.,* 1989). Spent male buffalo meat had significantly (P<0.05) higher salt soluble protein compared to the meat from young male and spent female buffaloes (Kandeepan *et al.,* 2009). 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 and Boles, 2006).

Collagen content: Among the connective tissue protein, collagen content of the meat is highly responsible for the texture of the product due to the connective tissue content. But collagen is heat labile and higher amount of collagen in meat may cause structural deformities in sausage production. The collagen content was 10-13% of total protein (Swan *et al.,* 1995). Connective tissue in the buffalo meat had a bigger contribution to toughness (Robertson *et al.,* 1986). The total concentration of connective tissue components were not closely related to the scores for muscle fibre tenderness. Chronological age was significantly related to the collagen content in the muscle. The collagen content increased significantly with advancing age of the male Murrah buffaloes (Yadav and Singh, 1985). A hydroxyproline content of 0.12% was recorded in high protein diet fed young male buffaloes (Anjaneyulu *et al.,* 1985). The muscles from young buffaloes of 1 to 2 years showed less collagen (0.91 to 1.71 g/100g) than from 12 year old buffaloes (1.16 to 2.23 g/100g) (Syed Ziauddin *et al.,* 1994). Some authors did not find any differences in the amount of connective tissue in young and aged animals (Cross et al., 1973; Reagan et al., 1976). As animals get older the collagen cross links are stabilized. After cooking the collagen cross links weaken but do not break, so contributing to the toughness of meat from old animals (Warriss, 2000). Collagen content of meat from intensively reared young male buffaloes was significantly (P<0.01) lower than other two groups (Kandeepan *et al.,* 2009). 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 influenced by sex contributed to the toughness of meat in spent groups (Bosselmann *et al.,* 1995).

Collagen solubility: The soluble fraction of collagen present in meat is responsible for the extent of tenderness of the product due to connective tissue presence. Higher the soluble fractions, less is its contribution to product toughness. As animals get older the collagen cross links were stabilized and the collagen was much less soluble (Reagan *et al.,* 1976; Warriss, 2000). Soluble collagen percentage was significantly related to the contribution of connective tissue to toughness as assessed by sensory panel. Chronological age was significantly related to percent soluble collagen in muscle. The soluble collagen decreases (13.5 to 3.6) as the age of the animal increases (Cross *et al.,* 1973; Reagan *et al.,* 1976). A collagen solubility of 6.58% was observed in meat chunks from spent female Murrah buffaloes (Naveena *et al.,* 2004). The collagen solubility of meat in young male buffaloes was significantly (P<0.05) higher than that of other two groups (Kandeepan *et al.,* 2009). 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.

Muscle fibre diameter: The size of muscle fibers in meat determines the texture of the processed products with increasing toughness and coarse texture with increasing thickness of myofibrils. Measurement of muscle fibre diameter could be useful for selection of animals with tender meat (Renand *et al.,* 2001). A significant relationship was observed between muscle fibre diameter and tenderness. Large muscle fibres are generally indicative of less tender beef (Seideman *et al.,* 1987). The meat obtained from high protein diet fed young male buffaloes showed a muscle fibre diameter of 35.32µm (Anjaneyulu *et al.,* 1985). A much less diameter of muscle fibres were observed in young animals (Warriss, 2000; Stoikov and Dragoeva, 2002). A muscle fibre diameter of 49.2 to 49.7 µm was observed in raw beef from 18 month old bulls (Palka *et al.,* 2003). In concentrate fed male Murrah buffaloes muscle fibre diameter of 80 µm was observed. As the age and slaughter weight increased there was an increase in muscle fibre diameter (Reddy *et al.,* 1990; Warris, 2000). A muscle fibre diameter of 60.76 µm was recorded in meat chunks from spent female Murrah buffaloes (Naveena *et al.,* 2004). Fibre diameter was positively correlated to shear values but negatively correlated to tenderness and sarcomere length of the muscle (Biswas *et al.,* 1989). 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 (Kandeepan *et al.,* 2009). An increase in age of river buffaloes was associated with increasing muscle fibre diameter (Ragab *et al.,* 1966). Fibre diameter was positively correlated to shear values but negatively correlated to tenderness and sarcomere length of the muscle.

Sarcomere length: Sarcomere length has some important effect on meat quality. Shorter the sarcomere length, the meat is tough and has low WHC. The sarcomere length was positively correlated to lean texture (Seideman *et al.,* 1987). A sarcomere length of 2.3 µm was observed in raw beef from 18 month old bulls (Palka *et al.,* 2003). Young buffalo bulls showed a sarcomere length of 1.73 to 1.88 µm. The longer the sarcomeres more tender the meat (Reddy *et al.,* 1990; Devine *et al.,* 1999). Males had significantly shorter sarcomere length than females in turkeys (Varadarajulu and Cunningham, 1971). However, the variation in sarcomere length had no impact on tenderness of beef from Charolais sires (Maher *et al.,* 2004). The sarcomere length of buffalo meat was significantly (P<0.05) higher in young males compared to spent male and females (Kandeepan *et al.,* 2009). 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 the tenderness variation due to sarcomere length in spent male and female buffaloes.

Shear force value: Shear force values provide basic information on tenderness, WHC and texture of the meat. Neath *et al.* (2007) determined the difference in tenderness and some characteristics of water buffalo meat and beef during postmortem aging. It was observed that the buffalo meat had significantly lower shear force values compared to beef for *Longissimus thoracis* (LT) and *semimembranosus* (SM) muscles, which was supported by a difference in troponin T degradation. The Warner-Bratzler shear force values differed between the muscles in young male buffaloes (Kesava Rao *et al.,* 1985; Reddy et al., 1990). The meat obtained from young male buffaloes fed with high protein diet showed a shear force value of 4.03 kg/1.25 cm core (Anjaneyulu *et al.*, 1985). Shear force values for low fat ground buffalo meat patties prepared from spent female Murrah buffalo meat was found to be 0.37 kg/cm^2 (Suman and Sharma, 2003). Shear force value was reported to have positive and higher correlation with fibre diameter, hydroxyproline content and toughness of the meat and negatively correlated with the sarcomere length of the meat (Biswas *et al.*, 1989). The buffalo meat obtained from young males showed a significantly (P<0.05) lower shear force value than the other groups (Kandeepan *et al.*, 2009). Intensive feeding decreased the shear force value of the meat (Shiba *et al.*, 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 and Swan, 1995). The shear force value was highly related to the muscle fibre diameter and collagen content of the buffalo meat.

Functional characteristics

Water holding capacity (WHC): Among the functional parameters, the inherent ability of the meat to hold its own water and its ability to bind with water added to it separately or as a constituent present in non meat additives in a product formulation is the most important factor in deciding suitability of the meat for processing into products. It is directly related to emulsion stability and juiciness of the meat products. A water holding capacity of 20.61 ml/100g was recorded in meat obtained from young male buffaloes fed with high protein diet (Anjaneyulu *et al.*, 1985). The meat from young buffalo males of 2 years age showed WHC 13.50 ml/100g (Kondaiah *et al.*, 1986). The meat from entire males had higher water holding capacity than castrates (Bedeir *et al.*, 1981; Dessouki *et al.*, 1981). Whereas, the meat samples from spent female Murrah buffaloes showed a WHC of 16.67 ml/100g in ground meat (Sahoo and Anjaneyulu, 2000). As indicated in Table 1, the water holding capacity of young male buffalo meat did not differ significantly from the spent male buffalo meat (Kandeepan *et al.*, 2009). 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 *et al.*, 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 and Swan, 1995).

Emulsifying capacity (EC): The amount of myofibrillar proteins present in meat and their ability to emulsify added fat is an important criterion for emulsion stability and better product characteristics in terms of binding and texture. Emulsifying capacity at pH 7.0 was significantly greater than at normal pH and pH 5.0, although the amount of salt soluble protein was not always greater. pH was more important in emulsifying capacity than was percent of salt soluble protein extracted from meat tissues (McCready and Cunningham, 1971). Emulsifying capacity of 99 ml oil/2.5 g meat was recorded in chilled meat from 2 year old buffalo male calves (Kondaiah *et al.*, 1986). Spent female buffalo meat showed an emulsifying capacity of 130.8 ml oil/2.5g meat (Anjaneyulu *et al.*, 1989). 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 (Kandeepan *et al.*, 2009). 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.

Myofibrillar fragmentation index: The amount of myofibrils in meat that gets fragmented by application of mechanical forces determines the texture of the meat product. More the fragmentation of myofibrils, tender will be product texture. The Myofibrillar Fragmentation Index (MFI) is a measure of myofibrillar protein degradation (Seideman *et al.*, 1987). This was highly related to shear force and sensory tenderness ratings (Calkins and Davis, 1980; Huff and Parrish, 1993) and negatively correlated to lean colour (Seideman *et al.*, 1987). Longissimus tenderness was highly and positively correlated

Table 2: Sensory evaluation of cooked meat chunks from different groups of buffaloes

	Group		
Sensory Attributes	Young Male	Spent Male	Spent Female
Appearance	6.64±0.09	6.64±0.09	6.79±0.01
Flavour	6.88±0.08	6.83±0.05	6.83±0.05
Juiciness	6.69±0.08	6.60±0.07	6.50±0.09
Tenderness	7.02±0.06[a]	6.43±0.04[b]	6.17±0.05[c]
Connective tissue residue	7.02±0.06[a]	6.43±0.04[b]	6.17±0.05[c]

n=10; *Based on 8 point descriptive scale; Means with different superscripts in the same row indicate significant difference (P<0.05)

with MFI and indicates the amount of myofibrillar proteolysis that has occurred (Morgan *et al.,* 1993). The MFI was observed to be 87.5 in six year old male Murrah buffaloes (Kulkarni *et al.,* 1993). The buffalo meat from young males had a significantly (P<0.05) higher myofibrillar fragmentation index compared to the meat from spent male and female buffaloes (Kandeepan *et al.,* 2009). Animal age has been shown to have more influence on tenderness attributes than sex of the animal (Huff and 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.

Sensory attributes

The physical, chemical and functional quality of meat is highly related to its sensory characteristics. The sensory attributes of meat products vary with characteristic change in their constitution in meat. Appearance, flavour and juiciness scores did not differ significantly between groups (Table 2) as above. 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 (Kandeepan *et al.,* 2009). Beef from more mature animals repeatedly had 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 *et al.,* 1993). Martín Irurueta (2008) observed that tenderness increased significantly ($p < 0.05$) with postmortem aging of buffalo meat.

The connective tissue residue scores were highly related to the tenderness of the meat (Kandeepan and Biswas, 2005; Kandeepan *et al.,* 2006). The higher amount of connective tissue in older animals resulted in decreased tenderness of meat (Huff and Parrish, 1993).

Conclusions

The knowledge on physicochemical and functional characteristics of meat is highly essential to prepare meat products with superior product characteristics with excellent sensory attributes. These parameters are inter related, the change in one parameter significantly affecting the other. The meat from intensively reared young male buffaloes are suitable for processing in chunk form because of its desirable chemical composition, muscle fibre, collagen characteristics and sensory attributes related to tenderness. Whereas, the meat from spent male and female buffaloes are suitable for processing in smaller particles due to its chemical composition, muscle fibre, collagen characteristics and sensory attributes related to toughness. Therefore, sufficient attention has to be paid in selecting the meat with good physicochemical and functional properties for processing into products. By doing so the success of the product with good product attributes can surely be assured.

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