Buffalo meat quality, composition, and processing characteristics: Contribution to the global economy and nutritional security

B.M. Naveena* and M. Kiran†

*National Research Centre on Meat, Chengicherla, BodaUppal Post, Hyderabad 500092, India
†Department of Livestock Products Technology, Veterinary College, KVAFSU, Bangalore 560024, India

Introduction

The rapidly growing world population will be consuming two-thirds more animal protein by 2050 than it does today. Numerous studies have shown that an increase in consumer income in fast-growing BRICS (Brazil, Russia, India, China, and South Africa) countries, which account for more than 50% of global population, tends to induce important changes in the amount and composition of food consumption. The livestock sector can positively contribute towards augmenting rural livelihood, poverty alleviation, and food security. Of all domestic animals, Asian buffalo (Bubalus bubalis) holds the greatest promise and potential for meat production (Cockrill, 1994). The performance of this species exceeds that of other bovine species in tropical or sub-tropical regions, where pastures are poor in terms of their quality. These differences have been attributed mainly to the capacity of buffaloes to transform and digest feeds of low quality (Ranjan, 1992). Buffaloes have also been reported for their diet flexibility, high disease resistance, and acceptability to a wide range of housing, feeding, and management conditions (Wanapat and Kang, 2013).

The Food and Agricultural Organization (FAO, 2000) has termed buffalo as an important asset that is “undervalued.” Meat produced from buffaloes has gained increased popularity in several southeastern and middle-eastern Asian countries and Africa because of its reduced fat, reduced cholesterol, and other healthier attributes. In terms of buffalo production and population, India is the most important place in the world. With more than 50% of the buffaloes in the world, India has become the largest bovine meat exporter. Buffalo meat does not possess any religious taboo against its consumption, is emerging as important red meat source, and is gaining popularity in many parts of the world. Considering the similarity of buffalo meat with cattle meat (beef) for several quality attributes and the increasing acceptability of buffalo meat, there are huge opportunities for development of the buffalo meat sector. Increasing global requirements and the ever-changing consumer demand for sustainable, economically viable, high quality, and healthier meat and meat products warrants the livestock sector to look for an alternative meat animal/poultry source to feed the burgeoning population. Therefore, keeping in mind the changing face of the global scenario, the present review was written to provide comprehensive information about buffalo slaughtering, meat quality, composition, nutritional aspects, and value addition relative to other established meat sources, especially beef.

Natural History, Evolution, and Zoological Classification of Buffaloes

Asian domestic buffalo (Figure 1) is known by various names in different countries viz, “bhains” (India), “al-jamoos” (Arab countries), “karabue/kwai” (Thailand), “carabao” (Philippines), and “karbo” (Malaysia; Fahimuddin, 1975). Buffalo, like cattle, belong to even-toed (artiodactyl) hoofed (ungulate) animals of the suborder Ruminantia, subfamily...
Bovinae, and tribe Bovini. There are two major types of wild buffalo, *Bos arnee*, the Asiatic buffalo, and *Syncerus caffer*, the African buffalo. It is generally accepted that the domesticated water buffalo, *Bubalus bubalis*, originated from *Bos arnee*, the wild buffalo whose habitat was the northeastern region of India (Fahimuddin, 1975). Buffalo includes two subspecies: the river type (*Bubalus bubalis bubalis*; 2n = 50) and the swamp type (*Bubalus bubalis carabanensis*; 2n = 48), which were domesticated approximately 5,000 years ago. Importations of water buffaloes to the Americas and the Caribbean have occurred over the past century. The earliest imports to Trinidad and Tobago were of the Jaffarabadi breeds in the 1900s. Guyana imported swamp buffaloes in 1930 and Venezuela in 1922. A large number of buffaloes have been imported into Brazil, Peru, and Columbia. During the beginning of 20th century, a large number of Indian buffaloes, particularly Murrah breeds, were imported into the Philippines, Thailand, and Cambodia for upgrading local swamp buffaloes for greater milk yield and draft qualities. Sixteen of the 18 river buffalo breeds (Murrah, Nili-Ravi, Kundi, Surti, Mehsana, Jafarabadi, Nagpur, Pandharpur, Manda, Jerangi, Kalahandi, Sambalpur, Bhadawari, Tharai, Toda, and South Kanara) in the world are located in the Asian continent. India has 12 registered river buffalo breeds, the majority of which were developed mainly for milk production, with no specific meat breeds available (Central Institute for Research on Buffaloes, 2014). The other breeds, Bufalypso or Trinitarian breeds, were developed for meat production in Trinidad and Tobago islands. About 70,000 Asiatic water buffaloes, mainly from the Mediterranean, Murrah, and Jafarabadi breeds, have been reported in Argentina (Irurueta et al., 2008).

**Global Perspectives**

The world buffalo population is estimated to be 198.88 million, spreading across 42 countries, of which 96.4% are distributed in Asia, 2.9% in Africa, and the rest in Europe and Latin America (FAOSTAT, 2012). Population growth of buffaloes is dynamic, increasing at 12.5% for past 10 years, with most of the growth in Asia, especially in India, which is the largest buffalo-producing country in the world with more than 50% of the buffaloes in the world. In the year 2012–2013, India produced 1.53 million tonnes (MT) of buffalo meat (Table 1) of which 1.1 MT was exported to more than 48 countries around the world (APEDA, 2014). India overtook Brazil as the top bovine meat exporter (boneless frozen meat) in the world, and Indian buffalo meat exports are expected to increase by 20% to 1.7 MT because of competitive pricing and quality. A small proportion of buffalo meat is domestically consumed in India as hot-boned boneless meat without chilling or any further processing. China (including mainland China) produces 0.62 MT of buffalo meat, most of which is sold as fresh meat and only small proportion of which is processed into dried meat, sausages, and ham. The Chinese government has attached great importance and increased input to the exploitation of the buffalo industry in recent years. In the Philippines, a massive Carabao Development Program was started in 1993 to improve native swamp buffalo locally known as carabao to develop their meat, milk, and draught potential. In Thailand, the swamp buffalo population has gradually decreased from 4.8 million in 1992 to 1.54 million in 2012. In Italy, because of the huge demand for buffalo mozzarella cheese, the buffalo population has increased from 0.19 million to 0.34 million in 2012 (Wanapat and Kang, 2013). In South America, although the herd size of buffaloes has been small, increasing interest and development of the buffalo population has been recorded in various countries including Brazil, Venezuela, Argentina, and others to increase the herds and production efficiency in meat and milk, especially for cheese production. Malaysia, Indonesia, and Philippines have registered a reduction in the buffalo population in the last decade.

**Table 1. Buffalo population and buffalo meat production in India and the world in the year 2012 (top 5 countries).**

| Country                        | Buffalo population millions | Percent of world buffaloes % | Ranking in the world | Buffalo meat production million tonnes | Percent of world buffalo meat % | Ranking in the world |
|--------------------------------|-----------------------------|------------------------------|----------------------|----------------------------------------|---------------------------------|----------------------|
| World                          | 198.88                      | —                            | —                    | 3.59                                   | —                               | —                    |
| India                          | 115.40                      | 58.02                        | 1                    | 1.53                                   | 42.61                           | 1                    |
| China (including mainland China)| 46.50                       | 23.38                        | 2                    | 0.62                                   | 17.26                           | 3                    |
| Pakistan                       | 32.70                       | 16.44                        | 3                    | 0.80                                   | 22.28                           | 2                    |
| Nepal                          | 5.10                        | 2.56                         | 4                    | 0.16                                   | 4.45                            | 5                    |
| Egypt                          | 3.90                        | 1.96                         | 5                    | 0.40                                   | 11.14                           | 4                    |

*Source: FAOSTAT (2013).*

Figure 1. Domestic water buffalo (*Bubalus bubalis*) from Murrah breed of India (Source: Central Institute for Research on Buffaloes, India; www.cirb.res.in).
Production Potential and Slaughtering of Buffaloes

Buffalo calves weigh around 22 to 25 kg during birth. Average body weight of the adult male and female buffaloes varies between 480 and 550 kg and 420 and 450 kg, respectively. Buffaloes attain puberty at a later age than cattle. First conception occurs at an average body weight of 250 to 275 kg, which is usually attained at 24 to 36 months of age. Their first calving is at 4 to 5 years of age, and they continue to produce calves up to 18 years age. Feeding practices are based on extensive systems, and buffaloes are freely grazed on natural grassland, forests, canal banks, and rice fields after harvesting. Compared with cow calves, the buffalo calves have greater body weight at birth, show faster growth, and can utilize poor-quality fodder more efficiently. The average gain in body weight per day is 0.85 kg up to 1 year and 0.66 kg up to 2 years of age under ordinary conditions of feeding and management. They were not specifically raised for beef production. If fed on balanced economical rations and properly cared for, a daily gain in body weight of 1 kg in healthy male calves would not be difficult to achieve (Ranjan, 1992). Even by eating poor quality roughage, buffaloes grow faster than cattle because of their better digestibility. The cost of fattening per kilogram of body weight is therefore much less for buffalo than cattle. Intensive feeding of male buffaloes in commercial feedlots for quality meat production started in 1999 (Wanapat and Kang, 2013). Male calves at the age of 8 to 10 months are purchased from farmers and are fed a high-protein/high-energy diet to put on additional body weight of 120 kg in 4 months. Murrah yearling grow by 0.9 to 1.0 kg/day and would have greater dressing percentage (Ranjan, 2004). The study conducted in Brazil on buffalo production systems to increase muscle mass in a short time has shown that buffaloes are able to gain body weight quickly and consequently provide high yield of carcass and retail cuts.

In India, buffaloes are primarily reared for milk production and normally slaughtered when they became uneconomical for milk production or draught purpose (Naveena et al., 2011b). They are not specifically bred or fed for meat. Buffaloes are usually slaughtered according to the traditional halal method without any stunning at designated municipal abattoirs for domestic consumption, and no grading is followed. Hot-boned boneless buffalo meat is domestically sold and consumed without further processing. For export purposes, around 53 state-of-the-art, modern abattoir cum buffalo meat processing plants (Figure 2) are operating in India (APEDA, 2014). All the export-oriented buffalo slaughter units have mandatory requirements of accreditation with Hazard Analysis and Critical Control Points (HACCP) and ISO standards to ensure the quality and safety of buffalo meat. The Bureau of Indian Standards and National Standard Authority of India on food hygiene have developed HACCP and their guidelines for application. Most of the buffalo meat–exporting plants have ISO:9001–2008 certification. All of the animals are slaughtered by the halal system under the strict vigilance of Jamait-e-Ulema-e-Hind as per the principles of Islamic Sharia. Standard cuts from Indian buffaloes (Figure 3) for export market includes: chuck, chuck tender, brisket, blade, shin and shank from fore quarter and top side, silver...
Buffalo Meat Composition, Quality, and Sensory Attributes

Composition

Buffalo meat is known to be a part of the human diet with a favorable effect on vitality and incidence of diseases as demonstrated by some comparative trials between buffaloes and cattle or other species (de Mendoza et al., 2005). Composition, physicochemical, nutritional and functional properties, and sensory attributes of buffalo meat are comparable with beef (Anjaneyulu et al., 2007). Composition of buffalo meat relative to beef is presented in Table 2. Moisture percentage of 74.04 to 77.75% has been reported for fresh buffalo meat (Anjaneyulu et al., 1985; Syed Ziauddin et al., 1994; Naveena et al., 2004). Buffalo meat showed a protein percentage of 17.33 to 23.3% (Syed Ziauddin et al., 1994; Naveena et al., 2004). Among all of the red meats, buffalo meat has been reported to have the lowest concentration of total lipids (1.37 g/100 g). Buffalo meat from 2-year-old male calves showed a fat percentage of 1.0 to 3.5 (Kesava Rao and Kowale, 1991). The relatively low fat content in buffalo meat is attributed to poor marbling. Buffalo meat has less fat and saturated fat than beef. The energy value for buffalo meat was found to be 57.22% less than beef. Low cholesterol content and energy value (6.8 Kcal/g dry matter) of buffalo meat was also reported by Anjaneyulu et al. (1985). Palmitic, stearic, oleic, and linoleic acids were reported to be predominant fatty acids in the phospholipids of buffalo meat (Kesava Rao and Kowale, 1991). Buffalo calves have shown to produce meat with the most favorable (n-6)/(n-3) ratio (7.00) compared with the bovine calves and the buffalo cows (Dimov et al., 2012). Buffalo meat has an advantage of having low fat and cholesterol compared with beef and is rated superior to beef by a few researchers (Valin et al., 1984; Kesava Rao and Kowale, 1991). Water buffalo meat was also reported to contain a greater concentration of conjugated linoleic acid (1.83 mg/g fatty acid methyl esters) compared with meat from zebu-type cattle (1.47 mg/g fatty acid methyl esters; de Mendoza et al., 2005).

Meat Quality

The major attractive features of buffalo meat are red color, reduced fat and cholesterol with poor marbling, low connective tissue, desirable texture, high protein, water-holding capacity, myofibrillar fragmentation index, and emulsifying capacity (Kandeepan et al., 2013). It is to be noted that buffalo meat is similar in tenderness to beef and has the added advantage of reduced cholesterol content (Paleari et al., 1997). Buffalo meat quality was often studied in comparison with cattle meat (beef), and lots of similarities were reported for various meat quality characteristics and sensory attributes between these two meats (Neath et al., 2007; Tateo et al., 2007). Palatability characteristics, shear force values, and taste panel scores of buffalo meat and beef obtained from identical age groups have been reported as almost similar (Ognjanovic, 1974). Buffalo meat is stated to have physicochemical, biochemical, and technological properties comparable to those of beef. Post-mortem muscle pH ranging from 5.50 to 5.70 has been reported in fresh buffalo meat cubes (Naveena et al., 2004; Kandeepan et al., 2009) and ground buffalo meat patties (Naveena et al., 2011b). Myoglobin content of fresh buffalo meat varied from 2.7 to 9.4 mg/g depending on the type of the muscle and animal age, and meat becomes darker with increasing age (Valin et al., 1984). Different authors have reported the redness scores (a* value) ranging from 12.0 to 20.0 for fresh and frozen buffalo meat of different age groups (Tateo et al., 2007; Irurueta et al., 2008; Naveena et al., 2011b). Dry-aged buffalo meat was

![Table 2. General description, composition, and meat quality of cattle and buffalo meat.](https://academic.oup.com/af/article-abstract/4/4/18/4638806/4638806)
medium chloride and food grade polyphosphates are reported to improve pH, chemicals (Naveena et al., 2011a). Use of different concentrations of so-
from old/spent buffaloes using plant proteases (Naveena et al., 2004) and
Researchers have attempted to improve the tenderness of meat produced
fibers, connective tissue layers, and z-disk (Figure 4, unpublished data).
mission electron microscopy has been performed depicting the muscle
meat. Myofibrillar fragmentation index (MFI) was reported to be 87.5
and 41.72 mm (Naveena et al., 2011a) was reported for fresh buffalo
35.32 mm (Anjaneyulu et al., 1985), 60.76 mm (Naveena et al., 2004),
). Muscle fiber diameter ranging from
meat chunks (Naveena et al., 2011)
al., 1994). Collagen solubility of 45.5% was observed in spent buffalo
old buffaloes of 12 years of age (1.16 to 2.23 g/100 g; Syed Ziauddin et
years showed less collagen content (0.91 to 1.71 g/100 g) compared with
old buffaloes of 12 years of age (1.16 to 2.23 g/100 g; Syed Ziauddin et
recording periods on quality traits of buffalo meat, found that flavor and odor
to beef and has the added advantage of reduced cholesterol content
(Paleari et al., 1997). Irurueta et al. (2008), describing the effect of three
aging periods on quality traits of buffalo meat, found that flavor and odor
corresponded to slightly intense while the amount of connective tissue
corresponded to practically nothing, for the all aging periods studied.
Slaughter age (20 to 34 months) or feeding regimes were reported not to
fluence the flavor and tenderness of buffalo meat (Charles, 1982). Buffalo meat organoleptic characteristics were reported to
be similar to beef. It is to be noted that buffalo meat is similar in tender-
ness to beef and has the added advantage of reduced cholesterol content
water-holding capacity ranging from 23.73 to 39.76% (Irurueta et al.,
back fat. Low-sodium, calcium-fortified restructured buffalo meat rolls
developed using a combination of 80% meat components with 20% pork
were developed by replacing sodium tripolyphosphate with calcium phos-
production of biogenic amines similar to other dry fermented sausages. Low-
on dry fermented buffalo meat sausage with sage oil extract revealed pro-
binders with acceptable quality have been developed. Quality and shelf
acceptability for at least 20 days at 4 ± 1°C under aerobic conditions in
reported to become darker faster than bovine meat, discouraging consum-
Buffalo meat cubes and ground buffalo meat was reported to have a
water-holding capacity ranging from 23.73 to 39.76% (Irurueta et al.,
25.3 to 40.20% (Naveena et al., 2011b), respectively. Sarco-
plasmic and myofibrillar protein concentration of 5.12 and 8.2% were
recorded in buffalo meat (Anjaneyulu et al., 1985; Kandeepan et al.,
Hydroxyproline content of 0.12% was recorded in young buffa-
loes (Anjaneyulu et al., 1985). Muscles from young buffaloes of 1 to 2
years showed less collagen content (0.91 to 1.71 g/100 g) compared with
old buffaloes of 12 years of age (1.16 to 2.23 g/100 g; Syed Ziauddin et
Collagen solubility of 45.5% was observed in spent buffalo
meat chunks (Naveena et al., 2011a). Muscle fiber diameter ranging from
35.32 mm (Anjaneyulu et al., 1985), 60.76 mm (Naveena et al., 2004),
and 41.72 mm (Naveena et al., 2011a) was reported for fresh buffalo
meat. Myofibrillar fragmentation index (MFI) was reported to be 87.5
in 6-year-old male Murrah buffaloes (Kulkarni et al., 1993). To under-
stand the toughness of buffalo meat from old animals, scanning and trans-
mision electron microscopy has been performed depicting the muscle
fibers, connective tissue layers, and z disk (Figure 4, unpublished data).
Researchers have attempted to improve the tenderness of meat produced
from old/spent buffaloes using plant proteases (Naveena et al., 2004) and
chemicals (Naveena et al., 2011a). Use of different concentrations of so-
dium chloride and food grade polyphosphates are reported to improve pH,
water-holding capacity, emulsion stability (ES), and emulsifying capacity
(EC) in ground buffalo meat (Kondaiah et al., 1985). Quality of ground
buffalo meat was also reported to be improved by pre-blending with sodi-
um ascorbate (Sahoo and Anjaneyulu, 1997). Although buffalo meat from
older animals is considered darker in color, tough in texture, and poor in
flavor, this is not true with respect to meat from young buffaloes that are
reared and fed for early slaughter (Ognjanovic, 1974). Researchers have
reported Warner–Bratzler shear force values ranging from 22.95 to 44.08
N (Irurueta et al., 2008) and 20.0 to 45.0 N (Naveena et al., 2004) for
different muscles of buffaloes. Very often, adulteration of sheep and goat
meat with buffalo meat or beef has been reported in India. Researchers
have developed highly accurate and efficient molecular techniques us-
ing polymerase chain reaction-restriction fragment length polymorphism
(PCR-RFLP) of mitochondrial 12S rRNA gene (Girish et al., 2005) be-
sides several other immunological methods.

**Sensory attributes**

The study comparing recent consumers of buffalo meat, consumers
who had never consumed buffalo meat, and long-standing consumers of
water buffalo meat demonstrated that water buffalo meat consumption
could be associated with several beneficial effects on cardiovascular risk
profile, including less carotid atherosclerotic burden and susceptibility to
oxidative stress (Giordano et al., 2010). Palatability characteristics of buf-
falo meat and beef obtained from identical age groups were found to be ei-
ther almost similar or the buffalo meat had better scores on many occasions
(Charles, 1982). Buffalo meat organoleptic characteristics were reported to
be similar to beef. It is to be noted that buffalo meat is similar in tender-
ness to beef and has the added advantage of reduced cholesterol content
(Paleari et al., 1997). Irurueta et al. (2008), describing the effect of three

**Value-Added Buffalo Meat Products**

Buffalo meat has been used in the production of various value-added
meat products (Figure 5), namely sausages, meat loaves, burger patties,
corned buffalo meat, and cured and smoked products (Anjaneyulu et al.,
2007). Emulsion-type buffalo meat sausages with good acceptability were
developed using a combination of 80% meat components with 20% pork
back fat. Low-sodium, calcium-fortified restructured buffalo meat rolls
were developed by replacing sodium tripolyphosphate with calcium phos-
phate, which improves tenderness and binding without affecting prox-
imate composition and microbial quality (Mendiratta et al., 2002). Effect
of different binders on the quality of enrobed buffalo meat cutlets and their
shelf life at refrigeration storage (4 ± 1°C) have been studied. The study
on dry fermented buffalo meat sausage with sage oil extract revealed pro-
duction of biogenic amines similar to other dry fermented sausages. Low-
fat comminuted buffalo meat burger containing different legume flours as
binders with acceptable quality have been developed. Quality and shelf
life of buffalo meat emulsion and restructured buffalo meat nuggets was
acceptable for at least 20 days at 4 ± 1°C under aerobic conditions in

---

**Figure 4.** Ultrastructure of buffalo meat under (top) scanning electron microscopy and (bottom) transmission electron microscopy.
Figure 5. Value-added products from buffalo meat: (top) smoked buffalo meat and (bottom) restructured buffalo meat rolls.

polypropylene bags (Thomas et al., 2006). The investigation to explore the possibilities of commercial utilization of buffalo liver in comminuted meat products indicated that buffalo liver could be commercially utilized for the preparation of acceptable comminuted meat products. Market research and consumer panels have suggested that corned beef produced from buffalo meat and cows is indistinguishable in terms of its sensory attributes. Corned beef made from buffalo meat also proved better in appearance due to the white color of the fat in buffaloes. Combination of hydrocolloid fat substitutes, 0.1% sodium alginate, and 0.75% carrageenan significantly increased the sensory attributes of low-fat ground buffalo meat patties (Suman and Sharma, 2003). Smoked buffalo meat chunks with acceptable color and flavor were produced using 150 ppm of sodium nitrite. Shelf-stable and extruded buffalo meat products were also produced by different researchers.

Bottlenecks for the Buffalo Meat Industry

Some important problems in buffalo production include declining population, problems in breeding and reproduction, poor nutrition, and inadequate animal health services and management practices. Female buffaloes are usually reared for milk production, and the majority of buffalo farmers neglect the male calves, allowing them to die without proper health care. The absence of specific meat breeds and the need for rearing of male buffalo calves exclusively for meat production must be addressed. The majority of female buffaloes are mainly slaughtered after completion of their milk production age, resulting in less acceptability of buffalo meat. Buffalo meat is also considered as more fibrous, darker, coarse, and less tender. In spite of domestication of buffaloes in several countries across the world and widespread consumption of buffalo meat, buffaloes are still considered as wild and their meat categorized under game meat in many developed nations. Sporadic disease outbreaks, especially foot and mouth (FMD) disease, and absence of disease-free zones is limiting the expansion of buffalo meat exports from India. Despite the important role played by buffaloes, there have been relatively limited efforts by various governments and agencies across countries regarding research and development, especially on the development of new breeds, nutrition and feeding, production and management technology, disease prevention, and control compared with other ruminant species. Furthermore, human resource development, curriculum development, and networking through buffalo forums have been at low profile and are moving at a slow pace.

Conclusion

Sustainable buffalo production through organized farming, scientific rearing, and feeding under natural or organic conditions needs to be practiced. Developing specific meat breeds and rearing male buffalo calves would augment the sustainable meat production. Buffalo-producing countries must consider having state-of-the-art abattoirs for production of clean and safe meat with proper chilling, packaging, and storage facilities. Unlike beef or pork, buffalo meat is free from religious constraints and has the added advantage of low fat and cholesterol. Modern reproductive technologies such as artificial insemination (AI), in vitro fertilization (IVF), and embryo transfer (ET), which are routinely applied in the dairy cattle industry, have to be improved for and adapted to the buffalo industry. Creation of disease-free zones, addressing the issues related to efficient identification of species and sex of the animals as well as traceability, will boost the export meat sector. More research efforts are required to characterize the buffalo meat and develop science-based literature. There is a need to increase the awareness and popularization of buffalo meat to reach out to a larger population. Buffalo meat can be transformed into various value-added products that would be of increased value, with clear advantages to the breeder, and a series of typical products with their own niche in the market place could be created.

Literature Cited

Anjaneyulu, A.S.R., S.S. Sengar, V. Lakshmanan, and B.C. Joshi. 1985. Meat quality of male buffalo calves maintained in different levels of protein. Buff. Bull. 4:44-47.
Anjaneyulu, A.S.R., R. Thomas, and N. Kondaiah. 2007. Technologies for value added buffalo meat products—a review. Am. J. Food Technol. 2:104–114.
APEDA. 2014. Agricultural and Processed Food Products Export Development Authority, New Delhi, India.
Central Institute for Research on Buffaloes. 2014. Buffaloopedia. Central Institute for Research on Buffaloes, Indian Council of Agricultural Research, Hisar, India. www.buffaloopedia.cirb.res.in/ (Verified 12 Aug. 2014.)
Charles, D.D. 1982. Meat tenderness and palatability of swamp buffalo and four breeds of cattle. Anim. Prod. 34:79–84.
de Mendoza, G.M., L.A. de Moreno, N. Huerta-Leidenz, S. Uzcátegui-Bracho, M.J. Beriaín, and G.C. Smith. 2005. Occurrence of conjugated linoleic acid...
in longissimus dorsi muscle of water buffalo (Bubalus bubalis) and zebu-type cattle raised under savannah conditions. Meat Sci. 69:93–100.

Dimov, K., R. Kalev, M. Tzankova, and P. Penchev. 2012. Fatty-acid composition of the lipids in m. longissimus dorsi of bovine and buffalo calves and buffalo cows. Bulg. J. Agric. Sci. 18:778–783.

Dosi, R., A. Di Maro, A. Chambery, G. Colonna, S. Costantini, G. Geraci, and A. Parente. 2006. Characterization and kinetics studies of water buffalo (Bubalus bubalis) myoglobin. Comp. Biochem. Physiol. 145:230–238.

Fahimuddin, M. 1975. Domestic water buffalo. Oxford and IBH Publishing company, New Delhi, India.

FAO. 2000. Water buffalo: An asset undervalued. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. http://empaeg.com/UserFiles/File53242.pdf. (Verified 12 Aug. 2014.)

FAOSTAT. 2012. FAO statistical yearbook. http://faostat.fao.org/site/291/default.aspx. (Verified 12 Aug. 2014.)

Faustman, C., S. Yin, N. Tatijavorworndtham, and B.M. Naveena. 2010. Oxidation and protection of red meat. Part 1. In: E. Decker, R. Elias, and D.J. McClements, editors, Oxidation in foods and beverages and antioxidant applications: Management in different industry sectors. Volume 2. Woodhead Publishers, Cambridge, UK. p. 3–49.

Giordano, G., P. Guarini, P. Ferrari, G. Biondi-Zoccai, B. Schiavone, and A. Giordano. 2010. Beneficial impact on cardiovascular risk profile of water buffalo meat consumption. Eur. J. Clin. Nutr. 64:1000–1006.

Girish, P.S., A.S.R. Anjaneyulu, K.N. Viswas, B.M. Shivakumar, M. Anand, M. Patel, and B. Sharma. 2005. Meat species identification by polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) of mitochondrial 12S rRNA gene. Meat Sci. 70:107–112.

Irrueta, M., A. Cadoppi, L. Langman, G. Grigioni, and F. Carduza. 2008. Effect of aging on meat characteristics from water buffalo grown in delta del Paraná in Argentina. Meat Sci. 79:529–533.

Kandeepan, G., A.S.R. Anjaneyulu, N. Kondaiah, S.K. Mendiratta, and V. Lakhmanan. 2009. Effect of age and gender on the processing characteristics of buffalo meat. Meat Sci. 83:10–14.

Kandeepan, G., S. K. Mendiratta, V. Shukla, and M. R. Vishnuraj. 2013. Processing characteristics of buffalo meat—a review. J. Meat Sci. Technol. 1:01–11.

Kesava Rao, V., and B.N. Kowale. 1991. Changes in phospholipids of buffalo meat during processing and storage. Meat Sci. 30:115–129.

Kim, C.J., and E.S. Lee. 2003. Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. Meat Sci. 63:397–405.

Kondaiah, N., A.S.R. Anjaneyulu, V. Kesava Rao, N. Sharma, and H. Joshi. 1985. Effect of salt and phosphate on the quality of buffalo and goat meats. Meat Sci. 15:183–192.

Kulkarni, V.R., B.N. Kowale, V. Kesava Rao, and T.R.K. Murthy. 1993. Storage stability and sensory quality of washed ground buffalo meat and meat patties during refrigerated storage. J. Food Sci. Technol. 30:169–171.

Lapitan, R.M., A.N. Del Barrio, O. Katsube, T. Ban-Tokuda, E.A. Orden, A.Y. Kulkarni, V.V. Bhat, V. Kesava Rao, and T.R.K. Murthy. 1993. Storage stability and sensory quality of washed ground buffalo meat patties. Meat Sci. 37:103–113.

Tateo, A., P. De Palo, N.C. Quaglia, and P. Centoducati. 2007. Some qualitative and chromatic aspects of thawed buffalo (Bubalus bubalis) meat. Meat Sci. 76:338–352.

Thomas, R., A.S.R. Anjaneyulu, and N. Kondaiah. 2006. Quality and shelf life evaluation of emulsion and restructured buffalo meat nuggets at cold storage (4 ± 1 °C). Meat Sci. 72:373–379.

Valin, C., A. Pinkas, H. Drahnev, S. Boikovsky, and D. Polikronov. 1984. Comparative study of buffalo meat and beef. Meat Sci. 10:69–84.

Wanapat, M., and S.C. Kang. 2013. World buffalo production: Challenges in meat and milk production, and mitigation of methane emission. Buff. Bullet. 32:1–21.

About the Authors

Dr. B.M. Naveena is a meat scientist working at National Research Centre on Meat in India. He obtained his Ph.D. in livestock products technology (meat technology) and post-doc in proteomics and meat quality from the University of Connecticut, USA. His research interests include use of proteomic tools for understanding buffalo meat color and texture, identification of peptide biomarkers, and detection of meat adulteration. He has worked on natural ingredient, antioxidant, and packaging mediated strategies for improving color and lipid stability of different meats. He has published more than 50 peer-reviewed research articles, 4 patents, 3 books, and a book chapter. He regularly provides training to entrepreneurs in the area of meat processing and value addition and undertakes consultancy and contract research projects.

Correspondence: naveenpl@rediffmail.com

Dr. M. Kiran obtained his Ph.D. in meat science from Sri Venkateswara Veterinary University, Tirupati, India. He currently works as Assistant Professor at Veterinary College, Bangalore, India. His research interests include understanding and improvement of meat quality, especially tenderness using biochemical, ultrastructural, and proteomic characterization. He has published more than 10 papers in peer-reviewed journals and has presented his work in various national and international seminars and won five best poster/oral presentation awards.

Animal Frontiers

Downloaded from https://academic.oup.com/af/article-abstract/4/4/18/4638806 on 28 July 2018