CAPÍTULO 1

PRODUCTIVE AND QUALITATIVE ASPECTS OF BUFFALO MEAT

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ABSTRACT: This review explores the productive and qualitative aspects of buffalo meat, focusing on production systems, weight development, and the physicochemical properties of the meat. Buffalo farming in Brazil is predominantly extensive, utilizing native or cultivated pastures with minimal supplementation. Compared to cattle, buffaloes exhibit higher fertility rates, better weight gain on lower-quality pastures, and earlier puberty. The review also highlights the physicochemical quality of buffalo meat, emphasizing its superior water retention capacity, lower saturated fatty acid content, and unique sensory properties such as tenderness and flavor. Despite challenges in commercialization, buffalo meat is increasingly recognized as a nutritious and sustainable alternative to beef. This study explores opportunities for improving buffalo meat production and expanding its market.
KEYWORDS: animal nutrition, quality, meat properties.

ASPECTOS PRODUTIVOS E QUALITATIVOS DA CARNE DE BÚFALO

RESUMO: Esta revisão explora os aspectos produtivos e qualitativos da carne de búfalo, com foco nos sistemas de produção, desenvolvimento de peso e nas propriedades físico-químicas da carne. A produção de búfalos no Brasil é predominantemente extensiva, utilizando pastagens nativas ou cultivadas com mínima suplementação. Comparados aos bovinos, os búfalos apresentam maiores taxas de fertilidade, melhor ganho de peso em pastagens de menor qualidade e puberdade precoce. A revisão também destaca a qualidade físico-química da carne de búfalo, enfatizando sua superior capacidade de retenção de água, menor teor de ácidos graxos saturados e propriedades sensoriais únicas, como maciez e sabor. Apesar dos desafios na comercialização, a carne de búfalo é cada vez mais reconhecida como uma alternativa nutritiva e sustentável à carne bovina. Este estudo visa explorar as oportunidades para melhorar a produção de carne de búfalo e expandir seu mercado.
PALAVRAS-CHAVE: nutrição animal, qualidade, propriedades da carne.

1 | INTRODUCTION

According to United Nations (UN) reports, the world's population will reach nine billion by the year 2050, while food consumption will increase. Given the increase in population and consumption, Bruinsma (2009) found that agricultural production would have to increase by more than 70% by 2050 to keep up with the pace of population growth. This means it would be necessary to produce about one billion tons of grain and 200 million tons of meat annually by 2050.

Food is one of the most important human activities because it has a direct impact on the quality of life. In addition to the growing population, changing eating increases the demand for higher-quality food.

Lambertz et al. (2014) stated that the buffalo (*Bubalus bubalis*) has become an important ally in the livestock production system, providing milk, meat, leather and draught power. These animals are characterized by their high growth rate, rusticity, longevity, and adaptability, as they can occupy and adapt to soils with low fertility, swampy soils, swampy terrain, and regions unsuitable for other ruminant species (OLIVEIRA, 2005; VAZ et al., 2003). Buffalo meat farming is gradually gaining ground and becoming more widespread in the country.

Buffaloes offer several advantages over cattle in terms of adaptation and production. They are more resilient in tropical environments, particularly when water for wallowing is available (Thanh & Chang, 2007; Bertoni et al., 2020). Buffaloes can thrive on low-quality, fibrous forages due to their efficient digestive system (Bertoni et al., 2020). They are well-suited for areas unsuitable for cattle production, demonstrating greater rusticity and adaptability (Pirondi et al., 2019). However, buffaloes are more susceptible to heat stress, exhibiting higher breathing rates and heart rates in warm conditions compared to cattle (Vo Thi Kim Thanh & Chang, 2007). Buffaloes have unique reproductive characteristics, including seasonal polyestrous breeding and longer gestation periods (Pirondi et al., 2019). While they produce less milk than dairy cows, buffalo milk is of high quality, and they have a lower predisposition to mastitis (Bertoni et al., 2020).

Unlike dairy farming, which is already well known for producing milk rich in fat, protein, and minerals, buffalo meat offers excellent sensory and nutritional qualities, making it a valuable alternative to red meat.

Thus, this review will address the productive aspects of buffalo farming, including management systems and weight development, as well as the physicochemical properties of buffalo meat. It will also explore the nutritional value and sensory qualities of buffalo meat, highlighting its potential as a sustainable and healthy alternative to beef

2 | BEEF BUFFALO AND THEIR EXPLOITATION

Farms are usually run under extensive systems based on native or cultivated pastures, most of the time without the use of concentrated feed, and it is even uncommon for them to be supplemented with roughage during periods of poorer food supply (Bernardes, 2010). Under these conditions, the speed of the animals' development usually follows the food supply and the reproductive seasonality of the species. In this particular case, buffaloes usually perform better than cattle, since calving usually takes place in the summer, the final period of the greatest quantitative and qualitative supply of pasture, which allows the dams to give birth in good body condition and, consequently, return to heat earlier, resulting in higher fertility rates than those observed in cattle managed under similar conditions, whose calving is usually concentrated in the spring, after a period of relative scarcity of pasture. It is common to see fertility rates of over 80% in buffalo, often even over 90% (Bernardes, 2010).

Also according to Bernardes (2010), the lactation period for buffaloes in Brazil usually coincides with the lowest supply of pasture which, while on the one hand compromises milk productivity, on the other hand ensures that the calf, which is raised in the country under natural suckling, has a good growth rate until weaning which, occurring in the spring when there is a greater supply of pasture, allows the animal to continue its development continuously until the start of the next unfavorable period when it will be around 12-15 months old on average. Even during this period, they usually show comparatively better weight gain at pasture than cattle, due to their admittedly better ability to convert poorer quality food.

Once the period of food restriction has passed, the return of pastures in better condition allows the animals to reach puberty at around 24 months of age, and to present their first calving at an average age of 36 months, earlier than in the regions from which they originated (India), where the dynamics of food supply are different from those in Brazil (Bernardes, 2010).

The weight development of buffalo in Brazil depends on the management conditions to which they are subjected, the breed, and the fact that whether or not their dams are used for dairy production. In general, males reach slaughter weight (around 430-480 kg) between 18-24 months of age in herds dedicated exclusively to beef, and between 30-36 months of age in dairy herds. According to Assumpção (1996), when finished in confinement, however, buffaloes perform quite satisfactorily with weight gains equivalent to and even slightly higher than those achieved by zebu under the same conditions, 1,144 g/d and 1,026 g/d respectively.

3 | MEAT PRODUCTION

According to the FAO (2006), global production of buffalo meat has grown significantly, especially in the East, with India, Pakistan, and China standing out as the main producing countries. In the West, Brazil is the leading producer of buffalo meat, due to territorial extension, combined with favorable climate and soil conditions, which facilitate buffalo production in the medium and long term, resulting in better quantitative and qualitative performance (Bernardes, 2006).

In Brazil, according to Vale (1999), for many years, buffalo meat came from old animals, slaughtered at the end of a long working life. As a result, a great deal of prejudice was created by associating buffalo meat with the characteristics of low-quality meat. Nowadays, this type of prejudice has diminished a lot and there is a good demand for the meat of these animals which, due to its nutritional value, is considered healthy food.

Lisboa et al. (2020) said that in Brazil there is still little and divergent information on the production and consumption of buffalo meat and the data is often confused with beef statistics.

World production of buffalo meat was estimated at 74.64 million tons in 2016, which corresponded to only 5.44% of the total beef produced in the world, which was around 1.3 billion tons (Oliveira, 2018). 23 Records from the Brazilian Association of Meat Exporting Industries (ABIEC) in 2019 showed that Brazil was responsible for 14.8% of the world's beef and veal production, about 10.5 million tons, and of this total there is no specific data to determine the portion of buffalo meat (ABIEC, 2019).

According to Jorge and Andrighetto (2005), during their experience, they witnessed how difficult it is for beef buffalo farmers to sell their animals ready for slaughter. Many meatpackers claim that there are operational problems on the slaughter line (mainly higher labor costs); that the head, hide and bones are heavier; and that the carcass yield is lower than that of cattle, among other justifications. Also, according to Jorge and Andrighetto (2005), meatpackers, because they have strong bargaining power, prefer to continue with these historical allegations rather than face up to the positive results of scientific research, which could reduce their profit margins to the benefit of the producer. As a result, after boning, buffalo meat ends up being identified and marketed as beef.

Despite this, even though there are no Brazilian statistics on buffalo meat production, due to several factors, Jorge and Andrighetto (2005) were able to estimate meat production by estimating the buffalo herd according to the ABCB, the national average slaughter rate for cattle and the average weight of buffalo carcass in Brazil. And following their same reasoning, it was possible to estimate.

According to ABCB estimates, the Brazilian buffalo herd has around 3.5 million animals (Bernardes, 2010); Average national bovine slaughter rate in 2021 according to IBGE data (2021): Cattle slaughtered/ Cattle herd in the year 2021 x 100 = 27.54 million/ 224.6 million = 0.1226 x 100 = 12.26%; and the average carcass weight of buffalo in Brazil, according to Jorge (2001), is 240 kg/cwt. Therefore, the estimated slaughter in 2021 was approximately 429,100 head (3,500,000 x 12.26%) producing around 102,984 tons of meat (429,100 x 240).

4 | MEAT ASPECTS (PHYSICOCHEMICAL)

Monte et al. (2012) stated that among the most important properties of meat, chemical quality stands out, based on the levels of protein, lipids, cholesterol and fatty acids; physical quality through parameters such as pH, color, weight loss due to cooking, water retention capacity and sensory quality that evaluates flavor, tenderness, aroma, juiciness and others.

4.1 Fatty acids in buffalo meat

Lipids are important macronutrients present in different concentrations in meat, depending on different factors such as species, breed, sex, age at slaughter, sexual condition and the animal's diet. Lipids are made up of simpler substances, fatty acids, and buffalo meat has a different fatty acid profile to that found in other red meats, as evidenced by the lower content of saturated fatty acids and the presence of polyunsaturated fatty acids (Leach, 2001; Oliveira, 2005).

4.2 Water retention capacity of meat

According to Vieira (2007), water is the main constituent of meat (lean meat: 70-75%) and its ability to retain this moisture is very important for maintaining its functional properties. The amount of water present at the intramuscular level has a direct influence on texture, as the higher the water content fixed in the muscle, the more tender the meat will be (Gaya and Ferraz, 2006). Water retention capacity refers to the meat's ability to retain water during the application of external forces, such as cutting, heating, grinding or pressure. A lower water retention capacity implies losses in nutritional value through the exudate released, resulting in drier and less textured meat after cooking (Zeola et al., 2002).

The water retention capacity can be influenced by the drop in pH; the higher the pH, the greater the water retention capacity (Huff- Lonergan And Lonergan, 2005). Pearson (1994) also states that the water retention capacity is related to the color of the meat, as the amount of light absorbed or reflected depends on the surface structure, which varies with the isoelectric point of the myofibrillar proteins and the location of water within the cells.

In terms of capacity, water comes in the form of bound water (5%), immobilized water (10%) and free water (85%), and the total water content of meat is important for the processing it will undergo, such as cooling, freezing, salting, curing, canning, etc. The higher the bound water content, the greater the water retention capacity of the muscle tissue (Dabés, 2001; Pardi et al., 2006). All the factors that influence the water retention capacity of fresh meat also affect the water retention capacity of frozen and thawed meat.

4.3 Meat pH

According to Pinheiro et al. (2009), in circumstances where the animal's ante-mortem welfare conditions are respected, the pH of the muscle after the animal's death decreases from approximately 7 to 5.5. This is due to the use of glycogen, which, in the absence of oxygen, is transformed into lactic acid, resulting in post-mortem biochemical reactions and the transformation of muscle into meat. According to Woltersdorf and Troeger (1990), pH is the most important parameter for predicting the final quality of meat and is considered the main indicator of its quality at a commercial level, since it can affect important characteristics such as color, tenderness, flavor, water retention capacity, weight loss due to cooking and conservation (OURIQUE and NICOLAIEWSKY, 1990).

4.4 Meat color

Zeola et al. (2004) said that the color of meat is a basic criterion in the choice of product, which the consumer can appreciate at the time of purchase, unless other factors, such as odor, are strongly undesirable. Many factors can influence the color stability of meat products, from the animals' diet to the meat packaging procedures. According to José et al. (2009), color stability can be optimized by controlling these factors to keep the amount of oxidation to a minimum.

If the surface appears discolored and brown, the consumer will probably choose not to buy that cut, causing losses for the meat industry. The color of the surface of the meat is due to the chemical state of the myoglobin pigment present in the muscle (Fox, 1966). Hunt (1980) states that the red pigment, oxymyoglobin, can be oxidized to form brown metmyoglobin, leaving the surface of the meat with this color, when the ratio between oxymyoglobin and metmyoglobin becomes very low.

4.5 Shear force

Consumer demand has increased for standardized products with guaranteed tenderness (Koohmaraie, Shackelford and Wheeler, 1995), so meat producers and industries are mobilizing to adapt their production systems to offer their customers a better quality product. Meat texture is the first characteristic evaluated by consumers when qualitative aspects are mentioned (Luchiari Filho and Moura, 1997).

According to Ishihara and Madruga (2013), some indicators can and should be used in meat tenderness studies, such as shear force measurement, myofibrillar fragmentation index, sarcomere length and collagen quantification, considering their ease of application and high correlation with meat tenderness.

4.6 Weight loss due to cooking

According to Bressan et al. (2001), cooking losses are an essential measure of meat quality, since during cooking the heat causes changes in the appearance and physical properties of the meat, such as tenderness and yield at the time of consumption.

Cooking is a process that includes all the chemical, physicochemical and structural changes to food components that are intentionally caused by heat. This process breaks down food structures, improving palatability and digestibility (TSCHEUSCHNER, 2001). In cooking, heating is the result of energy being added to the system as a result of heat transfer (GIRARD, 1991). In the different cooking methods, the forms of heat transfer, the temperature, the duration of the process and the cooking medium are some of the factors responsible for the chemical and physical changes that can modify the nutritional value of food (GARCIA-ARIAS et al., 2003; POTTER and HOTCHKISS, 1995.

5 I SENSORY QUALITIES

There are numerous factors involved in the variation of tenderness, such as post-mortem proteolysis, connective tissue, state of contraction of the muscle, marbling fat, among others, where it must be considered that the marbling fat of the buffalo species has a low concentration (BELEW et al., 2003). The tenderness of buffalo meat is directly associated with physiological maturity, whereas the animal gets older, there is a reduction in the tenderness of the meat of these animals (Vaz et al., 2003).

According to Warriss (2000), the compounds that contribute to the flavor and aroma of meat depend on how much is produced, when the odor starts and what is the minimum concentration detected by the nose. Meat aroma and flavor can be considered complex sensations involving the combination of odor, flavor, texture, temperature and pH. According to Roça (1997), they are determined by factors that affect sensory attributes, related to ante-mortem such as species, age, sex, breed, feeding and handling; and post-mortem such as final muscle pH, carcass cooling conditions, storage and cooking procedures also affect this sensory parameter. When the texture is acceptable, the taste determines consumer satisfaction and appreciation of the meat (Rodas-González et al., 2009).

Acebrón and Dopico (2000) said that in addition to attributes related to color, visible fat and the appearance of freshness of the meat are characteristics that influence the moment of purchase, while flavor and tenderness become more relevant than juiciness when it comes to consumption alone.

6 | CONCLUSION

Buffalo meat production presents a sustainable and efficient alternative to livestock farming, particularly in regions with less fertile soils where buffaloes thrive due to their adaptability, high fertility, and efficient weight gain. Its physicochemical and nutritional qualities, including lower saturated fat content, superior water retention, and tenderness, make it an attractive option for health-conscious consumers. Despite historical prejudices and challenges in commercialization, buffalo meat is gaining recognition as a nutritious and flavorful product. Addressing barriers such as market acceptance and processing limitations through research, innovation, and education will be essential for expanding its production and fully realizing its potential to contribute to global food security and sustainable livestock systems.

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