Revista Científica, FCV-LUZ / Vol. XXXIII, Supl. Esp., 105 - 113, 2023, https://doi.org/10.52973/rcfcv-wbc016

# BUFFALO MEAT QUALITY, PROCESSING, AND MARKETING: HARNESSING ITS BENEFITS AND NUTRACEUTICAL POTENTIAL

## Calidad, procesamiento y comercialización de la carne de búfalo: aprovechando sus beneficios y potencial nutracéutico

***Sebastiana Failla***

*Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), Research Centre for Animal Production and Aquaculture, Monterotondo, Rome, Italy.*
*Corresponding e-mail: Failla, Sebastiana (sebastiana.failla@crea.gov.it)*

### ABSTRACT

Buffalo meat production is growing in different countries also because buffalo products exhibit some positive characteristics for human health compared to red meats from other species. However, meat quality is also defined by organoleptic aspects. This review aims to highlight the distinctive characteristics of buffalo meat. The principal problems of buffalo meat production are related to the low yield and an abundant layer of subcutaneous fat deposition when the animal is older than 14 months. This last trait, which may seem negative, allows us to carry out prolonged aging time (PAT) without compromising the shelf life and improving meat tenderness, one of the organoleptic characteristic's consumers desires. Another organoleptic characteristic that guides consumer choice is color. This trait depends mainly on the amount and state of myoglobin, a species-specific sarcoplasmic heme protein, and buffalo presents a different molecule than beef. Furthermore, this bright red molecule in the oxidized state transforms into metmyoglobin or deoxy myoglobin in the absence of oxygen, giving a dark color to the meat, which consumers associate with poor quality from old animals. The presence or absence of oxygen shows advantages and disadvantages by acting on the one hand, on the bright meat color and, on the other, on the oxidation of lipids. The best compromise between the two situations is given by skin packaging, which preserves the meat in an anaerobic environment. Keeping the high nutritional quality over time is imperative to maintain the numerous nutritional properties of buffalo meat. In this regard, buffalo meat presents numerous distinctive characteristics among the different groups of fatty acids. Among the saturated one, the abundance of odd and branched fatty acids compared to the bovine breed should be highlighted; for the unsaturated ones, this meat is characterized by the abundance of biohydrogenation products by rumen bacteria such as trans vaccenic and conjugated linoleic acid (CLA), best known for its anti-carcinogenic properties. In comparison, the endogenous pathway of fatty acid formation through the liver or adipose tissue allows us to enhance the elongation capacity of polyunsaturated n3 fatty acids, vital for human health as precursors of anti-inflammatory prostaglandins. Finally, buffalo meat is an essential source of N-acetylneuraminic sialic acid (Neu5Ac), a nine-carbon molecule located in the terminal ends of glycoproteins and glycolipids, an essential nutrient for brain development and function. This molecule can also counteract the intestinal absorption of N-glycolyl sialic acid (Neu5Gc) exogenous for humans, abundant in red meat, with high inflammatory action. In addition to being marketed as fresh meat, Buffalo meat can also be transformed into semi-processed or cured products with peculiar characteristics. Lean products could be well integrated into the modern diet, with clear advantages to consumers and breeders. The nutritional and technological potential of buffalo meat is considerable, and it is necessary to communicate this to the consumer, creating an efficient and dynamic market for buffalo meat-based products.

**Keywords:** buffalo meat, dry aging, oxymyoglobin, nutraceutical compounds, fatty acids.

### RESUMEN

La producción de carne de búfalo está creciendo en diferentes países también porque los productos de búfalo presentan algunas características positivas para la salud humana en comparación con las carnes rojas de otras especies. Sin embargo, la calidad de la carne también viene definida por aspectos organolépticos. Esta revisión tiene como objetivo resaltar las características distintivas de la carne de búfalo. Los principales problemas de la producción de carne de búfalo están relacionados con el bajo rendimiento y una abundante capa de grasa subcutánea cuando el animal tiene más de 14 meses. Este últi-

mo rasgo, que puede parecer negativo, nos permite realizar un tiempo de envejecimiento prolongado (PAT) sin comprometer la vida útil y mejorando la terneza de la carne, una de las características organolépticas que desea el consumidor. Otra característica organoléptica que orienta la elección del consumidor es el color. Este rasgo depende principalmente de la cantidad y el estado de la mioglobina, una proteína hemo sarcoplásmica específica de cada especie, y el búfalo presenta una molécula diferente a la de la carne de res. Además, esta molécula de color rojo brillante en estado oxidado se transforma en metmioglobina o desoximioglobina en ausencia de oxígeno, dando un color oscuro a la carne, que los consumidores asocian con la mala calidad de los animales viejos. La presencia o ausencia de oxígeno presenta ventajas e inconvenientes al actuar, por un lado, sobre el color brillante de la carne y, por otro, sobre la oxidación de los lípidos. El mejor compromiso entre ambas situaciones lo proporciona el envasado tipo “skin”, que conserva la carne en un ambiente anaeróbico. Mantener la alta calidad nutricional en el tiempo es imperativo para mantener las numerosas propiedades nutricionales de la carne de búfalo. En este sentido, la carne de búfalo presenta numerosas características distintivas entre los distintos grupos de ácidos grasos. Entre los saturados cabe destacar la abundancia de ácidos grasos impares y ramificados respecto a los vacunos; para las insaturadas, esta carne se caracteriza por la abundancia de productos de biohidrogenación por bacterias ruminales como el trans vaccénico y el ácido linoleico conjugado (CLA), más conocido por sus propiedades anticancerígenas. En comparación, la vía endógena de formación de ácidos grasos a través del hígado o el tejido adiposo nos permite potenciar la capacidad de elongación de los ácidos grasos poliinsaturados n3, vitales para la salud humana como precursores de las prostaglandinas antiinflamatorias. Finalmente, la carne de búfalo es una fuente esencial de ácido siálico N-acetilneuramínico (Neu5Ac), una molécula de nueve carbonos ubicada en los extremos terminales de las glicoproteínas y glicolípidos, un nutriente esencial para el desarrollo y la función del cerebro. Esta molécula también puede contrarrestar la absorción intestinal del ácido N-glicolil siálico (Neu5Gc) exógeno al ser humano, abundante en las carnes rojas, con elevada acción inflamatoria. Además de comercializarse como carne fresca, la carne de búfalo también puede transformarse en productos semielaborados o curados con características peculiares. Los productos magros podrían integrarse bien en la dieta moderna, con claras ventajas para los consumidores y los criadores. El potencial nutricional y tecnológico de la carne de búfalo es considerable y es necesario comunicarlo al consumidor, creando un mercado eficiente y dinámico para los productos a base de carne de búfalo.

**Palabras clave:** carne de búfalo, maduración en seco, oximioglobina, compuestos nutracéuticos, ácidos grasos.

## INTRODUCTION

In the last decade, Buffalo (*Bubalus bubalis* L.) meat has reported an increase in population head livestock as in tonnes of meat production. According to FAO Stat data1, the world buffalo population in 2021 was 203.940 million buffalo head, about more than 9.860 million head compared to 2010. TABLE I shows the buffalo animals slaughtered in 2021 and the quantity of meat produced. On average, each buffalo head produces 151kg of meat, which is low weight if we consider the slaughter of adults. This data highlights that even in 2021, many male calves are slaughtered very young. Furthermore, only around 14% of the world’s buffalo population is slaughtered, and most of these are spent animals.

These data highlight consumer disaffection for this type of product, even though it is clear that buffalo meat has positive characteristics for human health. However, improving knowledge on meat quality and meat processing of buffaloes is slowly bringing about a consumption positive trend because buffalo meat could represent a considerable economic and nutritional source [2]. The principal problems of buffalo meat production are related to the low yield and an abundant layer of subcutaneous fat deposition when the animal is older than 14 months.

The different breeds, age, breeding, and pre-and post-slaughter technologies result in great variability in carcass and meat characteristics, leading to poor quantitative and qualitative performances [2, 3]. Meat quality is defined by different parameters concerning carcass, organoleptic, and nutritional characteristics of meat. For increasingly health-conscious consumers, the last two aspects cannot be separated to satisfy their needs.

## ORGANOLEPTIC QUALITY OF BUFFALO MEAT

Color and tenderness are the principal organoleptic characteristics because they direct consumers’ choices during buying and eating [4]. Both characteristics depend on pre- and post-mortem processes during slaughtering on meat aging and enzymatic proteolysis [5]. At the same time, color is also linked to oxidation processes that occur during aging but also retail and domestic storage [6]. The color of meat depends mainly on the amount and oxidation state of myoglobin (Mb), a sarcoplasmic protein with an iron molecule in the center surrounded by a tetrapyrrole ring called heme. Meat color for each species is typical because the chemistry of myoglobin is species-specific [7].

The molecular mass of buffalo Mb is 86.20 Da higher than the bovine Mb. This is confirmed by analyzing its primary structure. Comparing the amino acid sequences of both Mbs, we found three amino acid differences out of 153 amino acid residues [7]; only one of these substitutions is made by a threonyl amino acid that is a destabilizing β-branched residue. These observations indicate that the structural architecture

*TABLE I*

**CONSISTENCY OF BUFFALO SLAUGHTERED AND TONNES OF MEAT PRODUCT IN 2021**

| 2021 | Buffalo heads | Buffalo slaughtered heads | Meat production (tonnes per year) | Meat yields pro head slaughtered |
|---|---|---|---|---|
| World | 203,939,158 | 28,601,802 | 4,322,190.48 | 151.1 |
| Asia | 200,182,688 | 27,870,440 | 4,107,873.87 | 147.4 |
| *India* | 11,786,188 | 11,769,252 | 1,635,506.69 | 139.0 |
| *China* | 27,022,807 | 4,526,052 | 658,617.77 | 145.5 |
| Africa | 1,263,128 | 507,634 | 166,744.50 | 328.5 |
| Americas | 2,010,831 | 115,779 | 26,047.91 | 225.0 |
| Europe | 482,334 | 110,949 | 21,277.00 | 191.8 |
| *Italy* | 409,410 | 107,949 | 20,691.24 | 191.6 |

Data: FAO [1]

of the heme pockets in the two Mbs is similar, with the same functional properties, but with different behavior during oxidation, due also to higher myoglobin content in buffalo meat as reported by [8]. Even if the Mb quantity depends on age and muscle type, the range is very high, from 2.70 to 9.40 mg/g [9]. Moreover, buffalo meat is richer in iron (1.83 mg/100g) than other species like beef and sheep (1.53 mg/100g on average). The most immediate way to analyze meat color is given by the CieLab system (TABLE II), which considers lightness (L*), redness (a*), and yellowness (b*).

Buffalo meat increases in lightness during aging, while it decreases during oxidation. The old animals show different colors, particularly for major concentrations in Mb (+ an index) and intramuscular fat (+ b indexes), as found for grazing animals, which have meat richer in pigments [10]. However, the buffalo cannot accumulate large percentages of carotenoids in the adipose tissue; in fact, this tends to be white even in the carcass of adult animals [11].

In the function of heme oxidation, the myoglobin changes in color; the bright red molecule in the oxidized state (oxymyoglobin) transforms into metmyoglobin due to the oxidation of iron from ferrous to ferric state or into deoxy myoglobin in the absence of oxygen as in vacuum packaged meat, giving a dark color to the meat and consumers associate it with poor quality from old animals [16]. Different packaging technologies try to solve this very pronounced problem in buffalo meat due to the excessive presence of iron [17]. Among the technologies that improve the marketing and shelf life of buffalo meat, the following are highlighted: modified or protective atmosphere packaging (MAP), whose atmosphere blown inside consists mainly of 80% oxygen ($O_2$) and 20% carbon dioxide ($CO_2$); vacuum packaging and skin packaging, storage in the absence of oxygen and edible film. These types of packaging can be supported by using absorbent pads and films activated with antimicrobial and antioxidant substances [18, 5]. The presence or absence of oxygen shows advantages and disadvantages by acting on the one hand on oxymyoglobin formation and the bright meat color

*TABLE II*

**COLOR (CIELAB PARAMETERS) OF MEAT BUFFALO IN DIFFERENT CONDITIONS**

| Type | Lightness L* | Redness a* | Yellowness b* |
|---|---|---|---|
| Musles [12] | | | |
| LD | 44.33$^b$ | 16.35$^b$ | 13.01$^b$ |
| GB | 49.45$^a$ | 17.32$^{ab}$ | 15.82$^a$ |
| CLOTB | 46.04$^b$ | 18.11$^a$ | 15.02$^a$ |
| Aging period* [13] | | | |
| 24 hours | 36.5$^c$ | 17.12$^a$ | 13.27 |
| 48 hours | 39.0$^b$ | 16.54$^{ab}$ | 13.34 |
| 168 hours | 42.9$^a$ | 16.10$^b$ | 13.91 |
| Aging period*[14] | | | |
| 7 days | 44.65 | 20.22$^a$ | 8.21$^b$ |
| 21 days | 44.13 | 19.74$^b$ | 8.04$^b$ |
| 35 days | 44.61 | 19.43$^b$ | 10.53$^a$ |
| Storage time*[12] | | | |
| 15 days | 45.53$^a$ | 18.98$^b$ | 13.98$^a$ |
| 90 days | 42.99$^{ab}$ | 17.36$^c$ | 10.03$^c$ |
| 180 days | 41.12$^b$ | 20.03$^a$ | 11.69$^b$ |
| Age at slaughter*[15] | | | |
| 10 months | 43.95$^a$ | 19.24$^b$ | 15.72 |
| 14 months | 41.69$^b$ | 20.22$^b$ | 15.79 |
| 18 months | 39.79$^c$ | 21.41$^a$ | 16.22 |
| Feeding system*[10] | | | |
| Mais silage | 46.81$^a$ | 18.10$^b$ | 14.53$^a$ |
| Hay | 42.46$^b$ | 19.65$^a$ | 12.60$^{ab}$ |
| Pasture | 41.10$^b$ | 19.92$^a$ | 10.93$^b$ |

LD=Longissimus dorsi; GB=Gluteos biceps; CLOTB=Caput longuum tricipite brachii; *=LD. Different letters on column indicate significant differences per $p$<0.05

on the other on the oxidation of lipids. The best compromise between the two situations is given by skin packaging, which preserves the meat in an anaerobic environment, producing all the positive effects of the vacuum. However, it does not allow the dripping liquids from the meat, significantly improving and extending the shelf life [19].

Nonetheless, this technology is still costly and is used for small portions of raw meat, grounded meat, or meat preparations, which could be purchased in retail. The main problem of meat packaging, besides the need to enhance efficiency in terms of shelf life, is to lower the production cost and limit plastic pollution. An answer to these problems could be given by edible film and coat using hydrocolloid and lipid components.

The buffalo slaughter produces many residues, such as skin, blood, bones, meat trimmings, and fatty tissues, which represent a risk to the environment because they are often discarded as waste without being used. These biowastes contain biopolymers and other compounds such as proteins, polysaccharides, and fat with good biological properties capable of producing sustainable food packaging (both active film or coating), which could be edible, biodegradable, and act as carriers of biobased active agents such as antimicrobials, antioxidants, and health-promoting compounds. The difference between films and coatings consists in their manufacture and application. Edible films are dried, preformed thin sheets, while edible coatings are applied as a liquid of varying viscosity onto the surface of muscle by spraying or dipping [20].

In addition to active and edible packaging, intelligent systems were tested on buffalo meat based on sensors with bromophenol blue sensitive to total volatile basic nitrogen released from buffalo meat during prolonged refrigerated storage [21].

However, preserving time for the high nutritional quality of buffalo meat is imperative in order not to lose the numerous nutritional properties like antioxidant compounds such as Q10, glutathione, vitamins, minerals such as iron, zinc, and selenium, essential amino acids in particular branch amino acids and polyunsaturated fatty acids.

If color is the first parameter consumers use for buying meat, tenderness is the first attribute that consumers use to evaluate the organoleptic quality during eating. Generally, the buffalo meat obtained from young animals is tender compared to beef at the same age and breeding system. Meat tenderization depends on various factors that occur mainly in the period around slaughter and are linked both to the animal and to technological tenderization systems like variation in temperature/time of aging, electrical stimulation, different suspension methods, and use of exogenous enzymes. These factors affect the glycolytic and proteolytic enzymatic activity, acting on pH, ability to retain liquids, and myofibrillar degradation processes. Therefore, meat tenderization is a delicate multifactorial process during aging [22].

The effect of aging is time-dependent; some first-quality cuts, in particular loin, usually receive a prolonged aging time (PAT), but in order to avoid rancidity and microbial proliferation, various preservation techniques have been implemented. The most common ones are classified into: “dry aging” and “wet aging” [23].

Dry aging includes maturation in a controlled environment (+2°C of temperature and 78% of relative humidity) or protected maturation with films that ensure oxygen penetration and the losses of liquids and allow an antimicrobial barrier [24]. This process can last for weeks or even months. The anatomical cuts for prolonged aging time must generally be significant and have an abundant subcutaneous fat layer to prevent liquid loss and excessive oxygen penetration, blocking lipid oxidation. At the same time, proteolysis continues due to the enzymatic activity. Usually, buffalo loin has an abundant adipose panniculus that is well suited to this process [25], ensuring tenderness, flavor, and formation of bioactive peptides. The chunk of meat dries outside, making the “crust,” after a few weeks, starts the fiber contraction, preventing the deterioration of meat.

The crust will be removed before consumption, with considerable product losses [26].

Among the wet aging processes, we have vacuum-packed meat maturation, or meat maturation with marinate, improving overall acceptability (TABLE III). The vacuum-packed meat remains in contact with liquids, giving blood and metal taste, but using calcium chloride marination (FIG. 1), the tenderness

*TABLE III*

**SENSORY EVALUATION OF LONGISSIMUS THORACIS ET LUMBORUM OF BUFFALO DURING WET AGING [14]**

| Aging (Days) | Odor | Flavor Intensity | Overall Tenderness | Juiciness | Overall Acceptability |
|---|---|---|---|---|---|
| 0 | 6.12 ± 0.45 | 5.78 ± 0.60 | $6.25 \pm 0.73^{f}$ | 5.48 ± 0.61 | $5.42 \pm 0.62^{c}$ |
| 7 | 6.08 ± 0.50 | 5.75 ± 0.53 | $6.66 \pm 0.57^{e}$ | 5.54 ± 0.59 | $5.44 \pm 0.59^{c}$ |
| 14 | 6.05 ± 0.19 | 6.69 ± 0.56 | $6.97 \pm 0.65^{d}$ | 5.59 ± 0.81 | $5.50 \pm 0.81^{c}$ |
| 21 | 6.00 ± 0.26 | 5.72 ± 0.72 | $7.32 \pm 0.69^{c}$ | 5.65 ± 0.73 | $5.67 \pm 0.56^{b}$ |
| 28 | 5.97 ± 0.35 | 5.76 ± 0.51 | $7.47 \pm 0.67^{b}$ | 5.64 ± 0.83 | $5.69 \pm 0.28^{b}$ |
| 35 | 5.99 ± 0.31 | 6.82 ± 0.42 | $7.86 \pm 0.40^{a}$ | 5.66 ± 0.52 | $5.79 \pm 0.57^{a}$ |

Hedonic scale on 8-point, where 8 = excellent, while 1 = extremely bad. Different letters on column indicate significant differences per $p<0.05$.

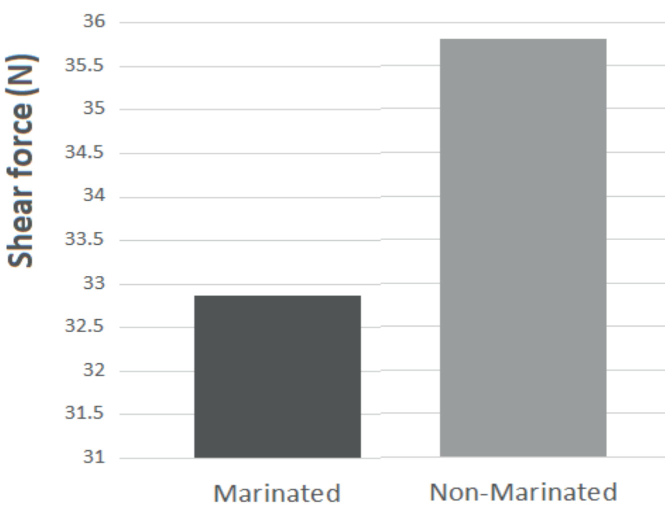


**FIGURE 1. SHEAR FORCE OF *LONGISSIMUS THORACIS ET LUMBORUM* OF BUFFALO MARINATED WITH $CaCl_2$ [27]**

improves during aging time [27]. The flavor can be improved with the addition of brines and spices, which also show an antibacterial and antioxidant function, catching iron and improving color [23, 14].

## NUTRITIONAL QUALITY

The proximate composition of buffalo meat is not different from little marbled bovine meat if we consider both species have the same muscle, just as the percentage of collagen is not different to beef at the same age and breeding conditions. Buffalo meat has a lower percentage of cholesterol than beef, but this difference is related to the bovine breed used in comparison; in fact, Di Stasio and Brugiapaglia [3] consider only eight bibliographic sources report cholesterol values that range from 32.20 to 123.79 mg/100g of buffalo meat.

Fatty acids are most important to define the nutritional quality of meat because the quantity and the structure of fatty acids impact human health. In this regard, buffalo meat presents numerous distinctive characteristics in the different groups of fatty acids (TABLE IV) if compared with other species fed and bred similarly. Among the saturated ones, the abundance of branched fatty acids compared to the bovine breed should be highlighted because these fatty acids have a nutraceutical function in the human diet [28]. For the monounsaturated ones, this meat enhances its characteristics thanks to the abundance of oleic acid and products of the biohydrogenation of rumen bacteria such as trans vaccenic (18:1 trans 11), trans palmitoleic (16:1 trans 9), and so on. Also, some polyunsaturated fatty acids come from the rumen activity as conjugated linoleic acids (CLA), best known for their anti-carcinogenic properties [29], are significantly more abundant in buffalo than beef and yak [30].

The endogenous pathway of fatty acid formation through the liver or adipose tissue allows us to enhance the elongation capacity of polyunsaturated n3 fatty acids, vital for human health as precursors of anti-inflammatory prostaglandins. Also, if the composition of n6 and n3 fatty acids is principally diet-dependent, the elongation capacity of PUFA is partly due to genetic effects [31]. The inability of humans to produce linoleic acid (C18:2n6) and linolenic acid (C18:3n3) means that their presence in the diet is vital. Although many vegetables help us overcome this deficiency, we need animal products to get long-chain n3 PUFAs such as eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and Docosapentaenoic acid (DPA). These are precursors of lipoxins, prostaglandins, and leukotrienes with anti-inflammatory action and are abundantly present in fish. If we consider DPA instead, with its numerous

*TABLE IV*

**FATTY ACID (% OF TOTAL FAME) ON *LONGISSIMUS THORACIS* OF DIFFERENT SPECIES**

| | Buffalo | Beef | Yak | RMSE |
|---|---|---|---|---|
| ∑ SFA | $45.28^{a}$ | $45.50^{a}$ | $42.15^{b}$ | 3.27 |
| ∑MUFA | 40.23 | 41.64 | 40.12 | 3.58 |
| ∑PUFA | $14.49^{b}$ | $12.87^{c}$ | $17.73^{a}$ | 1.42 |
| ∑CLA | $0.71^{a}$ | $0.53^{b}$ | $0.64^{ab}$ | 0.11 |
| BCFA | $1.25^{a}$ | $1.04^{b}$ | $1.17^{ab}$ | 0.18 |
| MUFA trans | $1.35^{a}$ | $1.37^{a}$ | $0.85^{b}$ | 0.36 |
| ∑ PUFA n6 | $12.10^{b}$ | $11.07^{c}$ | $13.91^{a}$ | 0.99 |
| ∑ PUFA n3 | $2.39^{b}$ | $1.80^{c}$ | $3.82^{a}$ | 0.57 |
| ∑ UFA/∑SFA | 1.21 | 1.20 | 1.37 | 0.32 |
| ∑n6/∑n3 | $5.06^{ab}$ | $6.14^{a}$ | $3.64^{b}$ | 1.50 |

FAME = fatty acid methyl ester; SFA=saturated fatty acids; MUFA=monounsaturated fatty acids; PUFA=polyunsaturated fatty acids; UFA= unsaturated fatty acids. Different letters on row indicate significant differences per $p<0.05$

Data: CREA not published

metabolic functions that influence the decrease in serum adiponectin and hepatic lipogenesis [32], this is highly present in meat (TABLE V).

Buffalo meat DPA showed an intermediate content if compared with beef and yak. Recently, numerous studies have highlighted the capability of DPA to be converted into EPA and DHA as needed and, therefore, can be considered a source of long-chain n3 storage thanks to its remarkable ability to resist oxidation. Furthermore, if we feed the buffaloes with a diet based on grass or added flaxseeds and algae, we can enrich the products of animal origin with DPA and functional elements for humans.

Finally, buffalo meat is an essential source of N-acetylneuraminic sialic acid (Neu5Ac), a nine-carbon molecule located in the terminal ends of glycoproteins and glycolipids, an essential nutrient for brain development and function [33]. This molecule can counteract the intestinal absorption of N-glicolilneuramic acid (Neu5Gc) exogenous sialic acid for humans, which is abundant in red meat, and it has high inflammatory action, also considered one of the leading causes of colon cancer. As reported in Kawanishi [34], a dietary intake of Neu5Ac five times higher than Neu5Gc was sufficient to eliminate the incorporation of Sialic acids (Sia) foreign forms in human cell membranes.

In this case, to reduce the inflammation caused by exogenous Sias, reducing red meat consumption would not be necessary, but increasing consumption of animal products with a higher quantity of Neu5Ac, as buffalo meat showed Neu5Ac 6.2 times greater than Neu5Gc. The sialic acid in buffalo meat can provide functional molecules and block the absorption of exogenous sialic acid that harms humans.

To avoid inflammation potentially caused by meat, switching to a vegetarian diet is inconsistent because it lacks iron, vitamin B12, essential amino acids, and long-chain essential fatty acids. A promising alternative is an increase in the weekly consumption of meat with higher amounts of Neu5Ac, which can prevent the accumulation of exogenous sialic acid in human cells.

*TABLE V*

**LONG CHAIN PUFA N3 FATTY ACIDS (% OF TOTAL FAME) ON *LONGISSIMUS THORACIS* OF DIFFERENT SPECIES**

| | Buffalo | Beef | Yak | RMSE |
|---|---|---|---|---|
| C20:5n3 EPA | 0.347$^{b}$ | 0.304$^{b}$ | 0.814$^{a}$ | 0.301 |
| C22:5n3 DPA | 0.942$^{b}$ | 0.557$^{c}$ | 1.425$^{a}$ | 0.323 |
| C22:6n3 DHA | 0.097 | 0.087 | 0.117 | 0.081 |

Different letters on row indicate significant differences per $p<0.05$. Data: CREA not published

*TABLE VI*

**CONTENT IN NEU5GC AND NEU5AC ON *LONGISSIMUS THORACIS* OF DIFFERENT SPECIES [33]**

| Species | Neu5Gc µg/g protein | Neu5Ac µg/g protein | Neu5Ac/ Neu5Gc |
|---|---|---|---|
| Beef | 228.3$^{a}$ | 432.5$^{b}$ | 1.8$^{b}$ |
| Buffalo | 82.7$^{c}$ | 512.6$^{a}$ | 6.2$^{a}$ |
| Yak | 145.7$^{b}$ | 508.5$^{a}$ | 3.5$^{b}$ |
| RMSE | 51.4 | 103.5 | 2.3 |

Different letters on column indicate significant differences per $p<0.05$

## SEMI-PROCESSED AND CURED PRODUCTS: A BRIEF REVIEW

In addition to being marketed as fresh meat suitably packaged to extend its shelf life, Buffalo meat can also be transformed into semi-processed products or various cured products [35, 36].

An exciting review was published by Maheswarappa [37] where grounded or emulsion buffalo meat products were listed: patties, sausages, burgers, restructured meat differently [38] also using sodium alginate and carrageenan [39], enrobed meat. Natural emulsifiers, conservatives, and polyphenols were used in these products to extend the shelf life and consumer acceptability [40]. Shelf-stable, ready-to-eat, spiced pickle-type buffalo meat was also produced [41].

The addition of fat to these products brings an improvement in juiciness and palatability. Of all the fats, pork appears to respond better to the technological transformations of buffalo meat.

Buffalo meat can also be used for numerous preparations involved in the drying and salting processes. These cured products can be obtained with whole cuts of meat and derived from ground meat supplemented with pork fat. By way of example, we report some processed products obtained in Italy with buffalo meat:

### Bresaola

*Bresaola* of buffalo meat, like beef meat GPI product (EEC 1263/96), a typical product of Valtellina (north Italy), is produced by salting and curing different cuts of hindquarters. A strict trimming process is essential to give a unique flavor.

Legs of beef are defatted and seasoned with a dry rub of salt and spices, such as juniper berries, cinnamon, and nutmeg. They are then left to cure for a few days. The drying period is between one and three months. The meat loses up to 40% of its original weight during aging.

### Carne salada

*Carne salada* is obtained with the topside of adult animals. The cuts, cleaned of all fat and tendinous parts, are sprinkled with a mixture of salt and other ingredients and placed in a container where they will remain from 2 to 5 weeks, depending on the size of the individual pieces. During the entire maturation period, the carne salada must be kept in a dark room at a maximum temperature of +12 °C and massaged at least every 2/3 days.

### Sfilacci

*Sfilacci* is a typical product of the Veneto region, usually obtained with horse meat, but buffalo meat also has excellent qualitative performances. The strips of flaccid meat are prepared with very lean meat cut into thin slices along the fiber. It is put in brine for about 15 days, seasoned for about one month, and finally beaten. The meat fibers separate, forming dry filaments of a deep red color.

## CONCLUSION

Buffalo meat has valuable organoleptic and nutritional characteristics. Scientific information must be disseminated, informing consumers that this product is lean and could be integrated into the modern diet, with obvious health advantages.

The nutritional and technological potentiality of buffalo meat is considerable; it is necessary to create an efficient and dynamic market for both fresh and cured products, bringing advantages to breeders who are in this way encouraged to support and spread a meat production chain just as the production of mozzarella and dairy products has spread in many countries.

## REFERENCES

[1] FAOSTAT. Available online: http://www.fao.org/faost4at/en/#home (accessed on 8 October 2023).

[2] Naveena BM, Kiran M. Buffalo meat quality, composition, and processing characteristics: Contribution to the global economy and nutritional security. Anim Front. 2014; 4:18-24. Doi:10.2527/af.2014-0029

[3] Di Stasio L. Brugiapaglia A. Current Knowledge on River Buffalo Meat: A Critical Analysis. Animals. 2021; 11:2111. Doi:/10.3390/ani11072111

[4] Santos D, Monteiro MJ, Voss HP, Komora N, Teixeira P, Pintado M. The most important attributes of beef sensory quality and production variables that can affect it: A review. Liv. Sci. 2021; 250:104573. Doi:10.1016/j.livsci.2021.104573

[5] Jaspal MH, Badar IH, Usman Ghani M, Ijaz M, Yar MK, Manzoor A, Nasir J, Nauman K, Junaid Akhtar M, Rahman A, Hussnain F, Ahmad A. Effect of Packaging Type and Aging on the Meat Quality Characteristics of Water Buffalo Bulls. Animals. 2022; 12:130. Doi: 10.3390/ani12020130.

[6] Tateo A, De Palo P, Quaglia NC, Centoducati P. Some qualitative and chromatic aspects of thawed buffalo (*Bubalus bubalis*) meat. Meat Sci. 2007; 76:352–358. Doi:10.1016/j.meatsci.2006.12.003

[7] Dosi R, Di Maro A, Chambery A, Colonna G, Costantini S, Geraci G, Parente A. Characterization and kinetics studies of water buffalo (Bubalus bubalis) myoglobin, Comp Biochem Physiol B Biochem. 2006; 145:230-238. Doi:10.1016/j.cbpb.2006.07.006

[8] Swartidyana FR, Yuliana ND, Adnyane IKM, Hermanianto J, Jaswir I. Differentiation of Beef, Buffalo, Pork, and Wild Boar Meats Using Colorimetric and Digital Image Analysis Coupled with Multivariate Data Analysis. J. Teknol. dan Industri Pangan 2022; 33:87-99. Doi: 10.6066/jtip.2022.33.1.87 J

[9] Valin C, Pinkas A, Dragnev H, Boikovski S, Polikronov D. Comparative study of buffalo meat and beef. Meat Sci. 1984; 10:69-84. Doi: 10.1016/0309-1740(84)90032-9

[10] Contò M, Cifuni GF, Iacurto M, Failla S. Effect of pasture and intensive feeding systems on the carcass and meat quality of buffalo. Anim Biosci. 2022; 35:105-114. Doi: 10.5713/ab.21.0141

[11] Huang J, Liu X, Feng X, Zhang M, Qu K, Liu J, Wei, X., Huang B, Ma Y. Characterization of different adipose depots in fattened buffalo: histological features and expression profiling of adipocyte markers. Arch Anim Breed. 2020; 63: 61–67. Doi:10.5194/aab-63-61-2020

[12] Settineri D, Failla S, Bisegna V, Di Giacomo A. Effect of different storage conditions on lipid oxidation in buffalo meat. Proc. “Meat consumption and culture”,44th ICoMST , Barcellona (Spagna). 1998; 666-667.

[13] Failla S, Vincenti F, Saltarelli E, Contò M, Ballico S, Ficco A. Aging time effect on quality meat from buffaloes fed on two different diets. Proceedings of the 8th World Buffalo Congress, Caserta, It J Anim Sci. 2007; 6:2S 1195-1198

[14] Jaspal MH, Badar IH, Amjad OB, Yar MK, Ijaz M, Manzoor A, Nasir J, Asghar B, Ali S, Nauman K, Effect of Wet Aging on Color Stability, Tenderness, and Sensory Attributes of Longissimus lumborum and Gluteus medius Muscles from Water Buffalo Bulls. Animals. 2021; 11:2248. Doi:10.3390/ani11082248

[15] Failla S, Gigli S, Iacurto M, Di Giacomo A, Fioretti M. Meat quality in male buffaloes reared with two nutritive levels and slaughtered at 4 different ages. Proceeding of International Symposium on Buffalo Products, Paestum (SA), 1-4/12 1996 EAAP Publication

[16] Ramanathan R, Suman SP, Faustman C. Biomolecular Interactions Governing Fresh 403 Meat Color in Post-Mortem Skeletal Muscle: A Review. J Agric Food Chem. 2020; 404 Doi:10.1021/acs.jafc.9b08098

[17] Tamburrano A, Tavazzi B, Callà CAM, Amorini AM, Lazzarino G, Zottola T, Campagna MC, Moscato U, Lauretti P. Biochemical and nutritional characteristics of buffalo meat and potential implications on human health for a personalized nutrition. It J Food Saf. 2019; 8:8317. Doi:10.4081/ijfs.2019.8317

[18] Sekar A, Dushyanthan K, Radhakrishnan KT, Narendra Babu R. Effect of modified atmosphere packaging on structural and physical changes in buffalo meat. Meat Sci. 2006; 72:211–215. Doi:10.1016/j.meatsci.2005.07.003

[19] Stella S, Bernardi C, Tirloni E. Influence of Skin Packaging on Raw Beef Quality: A Review. J of Food Qual. 2018; 1–9. Doi:10.1155/2018/7464578.

[20] Hamed I, Jakobsen AN, Lerfall J. Sustainable edible packaging systems based on active compounds from food processing by-products: A review. Compr Rev Food Sci Food Saf. 2022; 21:198–226. Doi:10.1111/1541-4337.12870

[21] Shukla V, Kandeepan G, Vishnuraj MR. Development of On-Package Indicator Sensor for Real-Time Monitoring of Buffalo Meat Quality During Refrigeration Storage. Food Anal Meth. 2015; 8:1591–1597. Doi:10.1007/s12161-014-0066-6

[22] Bhat ZF, Morton JD, Mason SL, Bekhit A, El-Din A. Applied and emerging methods for meat tenderization: a comparative perspective. Compr. Rev Food Sci Food Saf. 2018; 17:841-859. Doi:10.1111/1541-4337.12356

[23] Terjung N, Witte F, Heinz V. The dry aged beef paradox: Why dry aging is sometimes not better than wet aging. Meat Sci. 2021; 172:108355. Doi:10.1016/j.meatsci.2020.108355

[24] Barragán-Hernández W, Leighton PLA, López-Campos O, Segura J, Aalhus JL, Prieto N. Effect of in-the-bag dry-ageing on meat palatability and volatile compounds of cull cows and youthful steers. Meat Sci. 2022; 188:108800. Doi:10.1016/j.meatsci.2022.108800

[25] Salzano A, Cotticelli A, Marrone RJ, D'Occhio M, D'Onofrio N, Neglia G, Ambrosio RL, Balestrieri ML, Campanile G. Effect of Breeding Techniques and Prolonged Post Dry Aging Maturation Process on Biomolecule Levels in Raw Buffalo Meat. Vet Sci. 2021; 8:66. Doi:10.3390/vetsci8040066

[26] Dashdorj D, Tripathi VK, Cho S, Kim YS, Inho H. Dry aging of beef; Review. J Anim Sci Technol. 2016; 58:20. Doi:10.1186/s40781-016-0101-9

[27] Ijaz, M, Jaspal MH, Akram MU, Badar IH, Yar MK, Suleman R, Manzoor A, Farooq M, Ali S, Hussain Z. Effect of Animal Age, Postmortem Calcium Chloride Marination, and Storage Time on Meat Quality Characteristics of M. longissimus thoracis et lumborum of Buffalo Bulls. Foods. 2022; 11:3193. Doi:10.3390/foods11203193

[28] Dąbrowski GI, Konopka I. Update on food sources and biological activity of odd-chain, branched and cyclic fatty acids. A review. Trends Food Sci Technol. 2022; 119:514-529. Doi: 10.1016/j.tifs.2021.12.019

[29] National Research Council (NRC): Carcinogens and anticarcinogens in the human diet. 1996; National Academy Press, Washington DC.

[30] Juárez ., López-Campos O, Prieto N, Galbraith JR, Failla S, Aalhus JL. Chapter 5- Carcass Characteristics and Meat Quality of Bison, Buffalo, and Yak. 2019. In: More than Beef, Pork and Chicken – The Production, Processing, and Quality Traits of Other Sources of Meat for Human Diet. Lorenzo J, Munekata P, Barba F, Toldrá F (eds) pp.95-117 ed. Springer, Cham. Doi:10.1007/978-3-030-05484-7_5, ISBN 978-3-030-05484-7

[31] De Smet S, Raes K, Demeyer D. Meat fatty acid composition as affected by fatness and genetic factors: a review. Anim. Res. 2004; 53:81–98. Doi:10.1051/animres:2004003

[32] Drouin G, Rioux V, Legrand P. The n-3 docosapentaenoic acid (DPA): A new player in the n-3 long chain polyunsaturated fatty acid family. Biochimie. 2019; 159:36-48. Doi:10.1016/j.biochi.2019.01.022

[33] Failla S, Contò M, Miarelli M. Variability of sialic acids in meat from alternative species to beef and pork. Anim Front. 2003; (in press).

[34] Kawanishi K, Coker JK, Grunddal KV, Dhar C, Hsiao J, Zengler K, Varki N, Varki A, Gordts PLSM. Dietary Neu5Ac Intervention Protects Against Atherosclerosis Associated With Human-Like Neu5Gc Loss-Brief Report. Arterioscler Thromb Vasc Biol. 2021; 41(11):2730-2739. doi: 10.1161/ATVBAHA.120.315280.

[35] Paleari MA, Beretta G, Colombo F, Foschini S, Bertolo G, Camisasca S. Buffalo meat as a salted and cured product. 2000; 54:365–367. Doi:10.1016/s0309-1740(99)00111-4

[36] Anjaneyulu ASR, Thomas R, Kondaiah N. Technologies for Value Added Buffalo meat products-a review. Am J Food Technol. 2007; 2:104–114 DOI:10.3923/ajft.2007.104.114

[37] Maheswarappa NB, Muthupalani M, Mohan K, Banerjee R, Sen AR, Barbuddhe SB. Buffalo Meat Processing and Value Addition. 2022. In: Asiatic Water Buffalo. Springer, Singapore. Doi:10.1007/978-981-19-2619-8_8

[38] Ahmad SR, Sharma BD, Irshad A, Ranjan RK, Malav OP, Suman T. Effect of aerobic storage conditions on the quality of functional restructured buffalo meat fillets enriched with natural sources of dietary fibers and antioxidant components. J Food Proc Pres. 2020; 45(3):1–8. Doi:10.1111/jfpp.15072

[39] Suman SP, Sharma BD. Effect of grind size and fat levels on the physico-chemical and sensory characteristics of low-fat ground buffalo meat patties. Meat Sci. 2003; 65:973–976. Doi:10.1016/S0309-1740(02)00313-3

[40] Ahamed ME, Anjaneyulu ASR, Sathu T, Thomas R. Effect of different binders on the quality of enrobed buffalo meat cutlets and their shelf-life at refrigeration storage (4±1°C). Meat Sci. (2007); 75(3):451–459. Doi: 10.1016/j.meatsci.2006.08.008

[41] Malik AH, Sharma BD. Shelf life study of hurdle treated ready-to-eat spiced buffalo meat product stored at 30 ± 3 °C for 7 weeks under vacuum and aerobic packaging. J Food Sci Technol 2014; 51:832–844. Doi:10.1007/s13197-011-0592-9