

Dark cutting in large ruminants: Effect of management and environmental factors

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ABSTRACT

Objective: This review analyzes the scientific findings on the main management and environmental factors that increase the incidence of dark cuts in the carcass of water buffalo and bovine of the *Bos* genus.

Design/methodology/approach: Scientific articles were obtained from CAB Abstracts, Pubmed, Scopus and Google Scholar databases. The primary search was carried out on the following keywords: *Antemortem* stress and handling, dark cut, transport, *antemortem* rest, fasting prior to sacrifice. Detailed searches were subsequently carried out on each species.

Results: There are various stressors in handling and pre-slaughter procedures in ruminants. Stress in animals causes bodily injury and affects the quality of the meat, increasing dark cutting in the carcass.

Findings/conclusions: Management practices must be improved in the pre-slaughter stages, animal welfare must be ensured, and stressors must be avoided or reduced. These benefits will help to increase the level of welfare of the animals and will avoid economic losses, due to the presence of dark cutting in the carcass.

Keywords: *Bubalus bubalis*, ante-mortem handling, river buffalo, dark cutting, transport, lairage, beef.

INTRODUCTION

The water buffalo (*Bubalus bubalis*) and cattle of the genus *Bos* are important food sources for the human population. The end development of these animals can occur through fattening in feedlot or grazing. When the animals reach mature body weight, they are shipped, transported, and taken to the slaughterhouse, during slaughter the animals suffer from stress caused by various external factors thus affecting meat quality (Mota-Rojas *et al.*, 2010a,b).



Water buffaloes are valued for their production, disease resistance, longevity, fertility, and meat quality (Macedo, 1999; Sheikh, 2002; Mora-Medina *et al.*, 2019; Bertoni *et al.*, 2019; Hoogesteijn and Hoogesteijn, 2008; Guerrero-Legarreta *et al.*, 2020). These animals have better rearing advantages than *Bos* cattle, for example, they are adapted to the hot and humid regions of muddy and swampy lands of the tropics (Sheikh, 2002; Bertoni *et al.*, 2019; Guerrero-Legarreta *et al.*, 2019a; Mota-Rojas *et al.*, 2019a, b). Although, the appreciation of buffalo meat varies between countries and regions. In some Asian and European countries, buffaloes are marketed at lower prices than cattle, livestock companies implement sales prices and consequently, the productive interest of farmers is limited (Hoogesteijn and Hoogesteijn, 2008; Guerrero-Legarreta *et al.*, 2019b).

The handling and transport of finished animals for meat production, commonly suffer from stress, detracting from their welfare and inducing causes of shrinkage of the carcass, presence of the dark cut in the meat and damage to the carcass due to injuries or bruises (Chandra and Das, 2001ab; Guerrero-Legarreta *et al.*, 2002; Alarcón-Rojo and Duarte-Atondo, 2006; Guerrero-Legarreta and Totosaus, 2006; Mota-Rojas *et al.*, 2010a, b; Guerrero-Legarreta *et al.*, 2019b). In reference to beef (*Bos*), a pH of 6.0 in 24 h (pH₂₄) after slaughter, causes a poor quality of meat. Therefore, becoming undesirable for consumption creating economic losses (Mach *et al.*, 2008). For example, the meat industry in Spain penalizes the price of carcasses with discounts between 30 and 60%, when the pH of the meat is greater than 5.8 (Mach *et al.*, 2008). Dark firm dry meat (DFD) occurs when the final pH (measured in 12-48 h) post-mortem is ≥ 6 (Apple *et al.*, 2005; Warris, 2000). The term DFD is most commonly used in pork meat, so when it occurs in beef, the term assigned is "dark cutting" (Prince *et al.*, 1994; Southern *et al.*, 2006). Beef with a pH₂₄ greater than 6.0 has a dark red color (Mach *et al.*, 2008; Pérez-Linares *et al.*, 2006), there is deterioration in tenderness, the water holding capacity increases (dry) and lower palatability with firmer texture, increases light absorption, microbial growth, unpleasant odor and less uptake of curing salts (Grandin, 1997; Mach *et al.*, 2008; Prince *et al.*, 1994; Alarcón-Rojo and Janacua-Vidales, 2010).

The consumer classifies dark cutting as old meat (Pérez-Linares *et al.*, 2008; Guerrero-Legarreta *et al.*, 2020; Cruz-Monterrosa *et al.*, 2020). The increase in pH₂₄ is due to the decrease in glycogen pre-slaughter, caused

by the physical and psychological stress that occurs in the animals before slaughter. The various stressors involved are the long transport times given from the farm to the slaughter plant, the time the animal waits to enter the slaughterhouse, the climatic conditions and the social breakdown (Schaefer *et al.*, 2001; Önenç, 2004; Ferguson and Warner, 2008; Mach *et al.*, 2008). However, glycogen levels also vary widely at slaughter, depending on the amount of feed consumed, body weight, nutritional status, muscle type, fiber type, muscle buffer capacity, gender, breed type and temperament (Ferguson and Warner, 2008; Mach *et al.*, 2008). Additionally, the handling of the buffalo is more difficult than the cattle, it requires more personnel and time for the activities of loading, confinement, herding, movement, unloading and in the waiting pens for slaughter. Management of water buffalo must have an adequate balance in the truck to avoid injuries (Chandra and Das, 2001).

Most meat-producing countries report annual frequencies of dark cutting meat from 3 to 22% (Pérez-Linares *et al.*, 2008). The UK reports a 10% incidence of dark cutting. The United States reports 4% (Warris, 2003, Pérez-Linares *et al.*, 2006). Spain (Mach *et al.*, 2008) and northern Mexico (Pérez-Linares *et al.*, 2006) report incidences of dark cutting of 13 and 9%, respectively. The causes of stress are associated with high ambient temperatures, body efforts and high arousal after slaughter (Prädl *et al.*, 1994).

This review analyzes the environmental and management factors that influence dark cutting in water buffalo and cattle (Figure 1, 2). The fasting period, duration of transport, transport conditions and environmental factors, among others, are described.

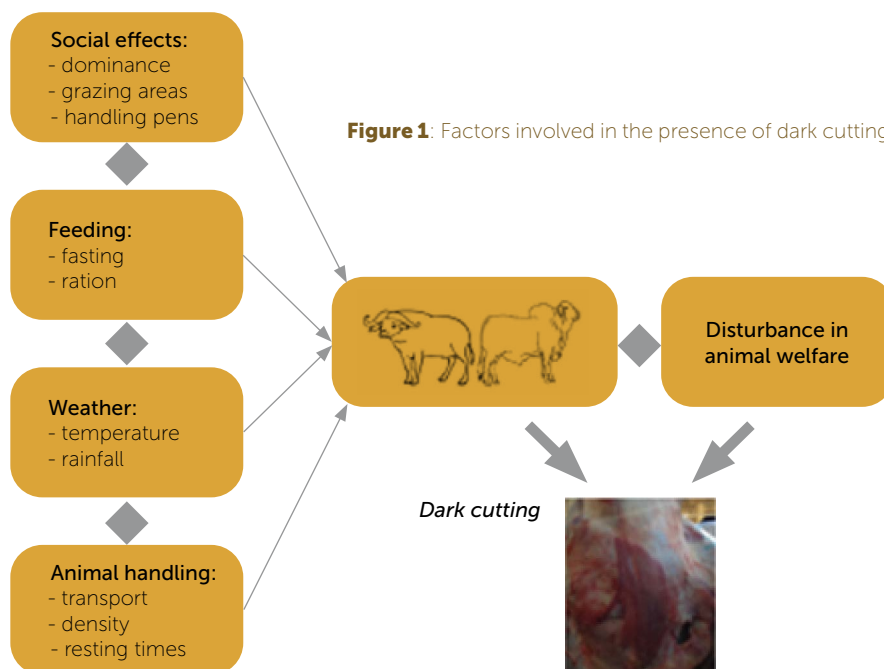
Environmental and management factors that influence the presence of dark cutting

Buffalo and cattle can be stressed by hunger, thirst, fatigue and injuries (Ferguson and Warner, 2008; Grandin, 1997; Mach *et al.*, 2008; Mota-Rojas *et al.*, 2019a,b,c). The presence of dark cutting implies animal stress and inadequate conditions before and during slaughter (Grandin, 1997; Mota-Rojas *et al.*, 2010a,b). Factors that induce chronic stress include long periods without food consumption (prolonged fasting), fatigue caused by long periods of transport, fights between animals from different herds when boarding the truck (Silva *et al.*, 1999; Grandin, 1997; Warris, 2000; Alarcón-

Rojo and Janacua-Vidales, 2010; Pérez-Linares et al., 2008) and/or poor handling during unloading. All these factors cause physical exhaustion (Kent and Ewbank, 1983; Grandin, 1997; Mounier et al., 2006; Ferguson and Warner, 2008; Jeleniková et al., 2008; Pérez-Linares et al., 2008) and have a negative effect in meat quality (Broom, 2003; Mounier et al., 2006; Alarcón-Rojo and Janacua-Vidales, 2010).

Effect of fasting

Perhaps fasting in ruminants has lower adverse effects than in other species, because the rumen acts as a reservoir of nutrients and the production of volatile fatty acids is a constant source of energy (Gallo and Tadich 2005). However, the loss of energy reserves causes depletion of liver and muscle glycogen, inducing problems of browning of the meat in the postmortem period (Ferguson and Warner, 2008). Hargreaves et al. (2004) mentions an increase in dark cutting, when the steers were transported without rest for 24 h while fasting. Animal transport must be programmed, from the moment they arrive at the truck until they are housed in the pens of the slaughterhouse, considering rest periods during the trip. Rest activities for 16 h and fasting for 24 h in animals induces a decrease in β -HBA (Tadich et al., 2005; Gallo and Tadich, 2005). Food deprivation in animals must be managed properly to prevent adverse effects on meat quality. The cited authors conclude that good quality meat can be achieved when resting times are given, before slaughtering the animals.



Effect of climatic conditions

Adverse seasonal conditions enhance stress in meat-producing animals, cattle are more sensitive to a hotter environment than to cold temperatures, especially when there are sudden changes in temperature (Kadim et al., 2004). Kreikemeier et al. (1998) cite that the dark cutting percentages were more common in the months of October (0.43%) to February (0.69%). Likewise, Grandin (1992 and 1993) reported a higher percentage of dark cutting in animals raised in very cold climates and with high rainfall, due to loss of body heat and shivering.

Effect of transport

Animal stress caused by transport is due to the lack of resting times, lack of food or water, exaggerated noises, fatigue, sudden changes in temperature, accelerated movements of the truck and space restrictions (Ferreira



Figure 2: Water buffalo (*Bubalus bubalis*) and its commercial meat.

et al., 2006; Gallo, 1994; Hargreaves *et al.*, 2004; Gallo and Tadich 2005).

The time of transfer of animals from the place of breeding to the slaughterhouse should be from 1 to 48 h; if the time is longer, the quality of the carcass and the meat is affected. Losses are particularly caused in live weight, carcass yield and quality grade, appearing dark cutting (Schaefer *et al.*, 2001). Gallo and Tadich (2005) report that the muscular pH of the steers was not affected when the transport of the animals was less than 16 h from the corral to the slaughterhouse, and when resting periods before slaughter were less than 16 h. In the case of the water buffalo, Zava (2011) mentions that transport for more than 700 km causes a loss of 7 and 9% of their body weight. Also Pérez-Linares *et al.* (2006) indicate that the arrival of the animals to the truck for more than 35 minutes, with temperatures above 16 °C, caused the damage of dark cutting.

Effect of charge density

Animal load density during transport affects the levels of some hematic variables (Knowles, 1999; Gallo and Tadich 2005). Tadich *et al.* (2003b) evaluated the densities of 400 vs. 500 kg/m² on some blood metabolites, indicating that the higher density increased cortisol, glucose and creatine kinase. Cortisol and CK levels remained high until 12 h of animal rest, while the glucose level did not change.

The effect of prolonged transport stress and fasting in sheep also increased blood cortisol content, unlike animals with shorter transportation times (Gallo and Tadich 2005). Similar results in cattle report high glucose and CK

when they were transported in the truck without offering feed on arrival (Tadich *et al.*, 2003b). In Chile, the main risk factors that induce dark cutting is the relationship between fasting and transportation times (Amtmann *et al.*, 2004, Gallo and Tadich 2005). Consequently, the animals should avoid prolonged transportation and long waits until slaughter.

Behavior of the water buffalo during transport

Chandra and Das (2001a) cite previous routines that should be considered before transporting water buffalo to the slaughterhouse. In Asia, non-productive animals are transferred to the place-sale, then butchers buy the animals and transport them by trucks to the slaughterhouse (Bertoni *et al.*, 2019). On the other hand, a study carried out with 100 buffalos, divided into ten different transport routes with distances of 20 and 40 km for 30 minutes. The researchers recorded the activities of the animals on the moving truck. The results of clinical signs that buffaloes presented during the trip were: Ocular congestion, tearing, nasal discharge, signs of stress and fear in buffalo. During the transport route, some animals changed their orientation and placed themselves in a parallel, perpendicular or diagonal position inside the truck. Subsequently, 14 buffaloes changed their initial orientation from parallel to perpendicular or diagonal, there was loss of balance in 80 animals, the curves of the road and speed of the truck caused stress in the animals. The same authors reported ocular congestion lesions (52 animals), nasal discharge (13 animals) and salivation (4 animals). During the trip, urination of the animals was observed in 55 animals, only 20 animals urinated twice, 6 animals three times and 21 buffalo defecated. The high frequency of urination and defecation recorded in animals is an indicative sign of fear (Chandra and Das, 2001a).

Presence of injuries and well-being of the buffalo during transport

Chandra and Das (2001b) reported injuries to water buffalo during short movements in India. Bruises were considered injuries of interest in the body, sometimes there is blood secretion in the surrounding areas, due to the rupture of blood vessels. During slaughter, the authors used the Australian scoring system to classify animal carcass bruises. They reported 244 bruises of different categories in the 100 buffalo. Small-deep bruises were the most common (59.0%), then medium bruises (19.3%), small (9.8%), medium-deep (6.1%) and intense (5.7%). Many bruises were observed in the hind limbs (43.4%), the abdomen and upper region (21.3%), the shoulder, neck and back (16.0%) and the perianal region (11.1%). The skin was opened in 10% of traumatic injuries, while the muscle tissues were affected in 90%. Consequently, the economic losses were considerable due to trauma, with the removal of the damaged tissue in the post-mortem canal. Most of the damaged tissues were attributed to improper handling of the animals during loading and unloading and the fall of the animals, caused by mishandling the sudden braking of the truck.

Rest times in the animals

The resting places should be the least stressful for the animals. The stress factors cause physiological disorders in the animals and the carcass with high pH limits vacuum packaging, there is rapid deterioration, the carcass yields and the price of meat decreases (Almonacid, 2003; Gallo and Tadich

2005). Pipek *et al.* (2003) mentioned that the incidence of DFD can be reduced when the animals are housed in individual pens, improving the quality of the meat (pH₂₄ and reflectance), contrary to when several animals are put in a pen. Pérez-Linares *et al.* (2008) observed that resting the animals inside the pen for 12 and 18 h was not enough to reduce stress. On the other hand, Hargreaves *et al.* (2004) mentioned benefits with the increase of resting time, reducing stress and the pH of the meat. The cited authors suggest resting times should be greater than 24 h in the pen. This condition improves glycogen reserve, there is less muscle glycolytic activity, decreases post-mortem lactic acid formation (Hargreaves *et al.*, 2004), and undesirable characteristics in meat are prevented (Prince *et al.*, 1994).

CONCLUSION

The appearance of dark cutting is directly related to the amount of muscle and liver glycogen thus decreasing the quality of the meat. Animals cannot remain for a long time without eating food and must be handled properly during the antemortem period. Stress periods in buffaloes and cattle must be kept to a minimum, avoiding the use of energy reserves and the increase in pH of the meat. Good practices of handling training on ruminant welfare must be applied to avoid suffering prior and during to slaughter.

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