Why Ethiopian Meat is Considered Dark Cutting and Unsuitable for the Export Market: Lessons Learnt from the Livestock Chain

Birmaduma Gadisa Muleta (birmaduga@gmail.com)
Bako Agricultural Research Center
Mulisa Faji Dida
Ethiopian Institute of Agricultural Research
Ali Kiani
Lorestan University
Cletos Mapiye
Stellenbosch University
Heather Bruce
University of Alberta
Eric Ponnampalam
Victoria University

Research Article

Keywords: Carcass, Livestock, pre-slaughter stress

Posted Date: November 30th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2096433/v1

Abstract

Dark-cutting (DC), also known as dark, firm, and dry (DFD) meat is one of the major challenges confronting the Ethiopian meat industry. A large percentage of carcasses from Ethiopia animals (cattle and shoats) are rejected in domestic and international markets due to DC. The current review highlights the factors that predispose animals to DC in Ethiopia. Overall, DC in Ethiopia is caused by a combination of on-farm and off-farm factors. The major on-farm factors include disease, animal nutrition, production system, age at slaughter, sex, breed, genetics, and management. Off-farm activities include stress experienced during transport, in lairage, or at slaughter such as unusual noise, mixing with unfamiliar animals, overcrowding, beating, vibration, restraint, deprivation of feed and water, adverse weather conditions, fighting in lairage, and stunning. However, DC meat is a dynamic condition that can be handled by humane animal handling and management, appropriate training of abattoir staff and tradesmen, creating awareness for all stakeholders and appropriate transport and slaughter regulations.

1. Introduction

Ethiopia has immense untapped livestock resources as environmental conditions of the country are conducive to a diversity of livestock production. The total cattle population of the country is estimated at 65.35 million, and that of sheep 39.89 million, goats 50.51 million, poultry 48.96 million, and camels 7.70 million (CSA, 2016/17). However, livestock and livestock products are underutilized compared to their potential as they account for less than 1% of global exports of meat products, mainly mutton and chevon (Eshetu en Abraham, 2016).

In Ethiopia, livestock production for meat purposes is limited to feedlot operations close to urban and peri-urban areas. In the rural areas, the availability of concentrate feed is rare and costly, thus most animals are finished mainly on natural pasture, other forages and/or crop residues without supplementation. Cattle in Ethiopia are marketed at very old age (> 7 years). Female cattle are often marketed as cull cows and steers are marketed after being used for draught purposes under crop-livestock farming systems (Arse, Mohammed & Ameha et al., 2013; Mummed & Webb, 2015). These practices have contributed to a low level of meat production compared to that of other countries in Eastern Africa (Assefa, 2017). In 2016/17 Ethiopia produced 46120 tons of meat and exported only 19105 tons (41.4%) (Birhanu, Mummed, Kurtu & Jiru, 2019). This is a very low rate of exportation when the number of livestock resources as indicated by the CSA is considered (CSA, 2019/20). Recently, Ethiopia has been trying to rise from a status of relatively no meat exportation to that of a meat exporter country through building new markets in many Middle Eastern and African countries such as United Arab Emirates (UAE), Saudi Arabia, Yemen, Jordan, Kuwait, Oman, Qatar, Syria Angola, Bahrain, and Egypt (Anteneh, 2010). About 20% of live animals are exported through official channels, and the remaining 80% are traded informally (FAO, 2019).

Sheep and goats are sent to market without considering their mutton and chevon quality, respectively (Ehui et al., 2000; Zelealem et al., 2012). The inability to produce high-quality carcasses is one of the

major problems facing Ethiopian meat export (Mummed en Webb, 2015). The consumers prefer low-fat, packaged, and labeled meat, focusing on a limited number of specific cuts from specific age and breeds (Yami et al., 2018). Another problem is that the domestic prices for live animals in Ethiopia are higher than those of neighbouring countries (Brasesco, F., Asgedom, D., Sommacal, 2019). As a result, the meat industry of Ethiopia is currently uncompetitive in international markets (Brasesco, F., Asgedom, D., Sommacal, 2019).

2. Meat Imports And Exports In Ethiopia

2.1. Meat imports

Livestock production systems in Ethiopia are largely subsistence oriented, and productivity is very low. The market supply of animals originates from highly dispersed, small farms that supply small numbers of nonhomogeneous animals. The animals supplied to the market fall short of meeting the quality attributes required by HED and export markets (Yami et al., 2018). Hence, Ethiopia remains dependent on meat imports (Table 1) despite some of the products being produced domestically. The country imports various livestock meats and processed products. Total imports grew exponentially at 19% per annum between 2006 and 2016 with import value multiplying by six from 500,000 USD in 2006 to 3 million USD in 2016 (Yami et al., 2018). In recent years, Ethiopia has imported over 19 metric tonnes (MT) of meat each year from Italy, China, the USA, Netherlands, UAE, and South Africa (SPS & LMMP, 2010; LMD, 2013; Mummed and Webb, 2015). The key justification for the meat importation from abroad is the lack of high-quality domestic meat for sale to high-end outlets such as hotels and supermarkets where specific taste requirements and cut demands are largely driven by tourists, diplomats, and international events held in the country. These consumers prefer high quality, low-fat, well-packed, and labelled meat, focusing on a limited number of specific cuts. The most desired cuts include beef topside, sirloin, and tenderloin.

Ethiopian supermarkets mainly sell raw and processed beef (sausages) products directly to consumers (Yami et al., 2018). Sadly, this indicates that even the quality of meat produced in Ethiopia is not acceptable to domestic consumers. Thus, it is not surprising that Ethiopian meat does not compete well in the international market (Birhanu, Mummed, Kurtu & Jiru, 2019). For example, 1 kg of fresh beef imported from South Africa costs about 33 USD while 1 kg of local beef costs 10 USD (Eshetie et al., 2018). According to FAO (2018), Ethiopia spends about 2.64, 2.12, and 3.03 billion USD on bovine, pig, and poultry meat imports, respectively. Unresponsive business communication among livestock value chain actors (Alemayehu, 2011; Gadisa, 2018) and the absence of breed improvement policy (Barry I Shapiro, Getachew Gebru, Solomon Desta, Asfaw Negassa, Kidus Negussie en Mechal, 2015) are some of the contributing factors to the fundamental problems of meat quality in Ethiopia. Designing a proper breeding strategy, improved feeding, health service, product safety, product promotion, excellent relationships among industry actors and conducive management conditions should be a path to market success. Product assurance and integrity are the other two key aspects influencing consumer confidence and retail meat purchasing power in national and international markets (EMDIDI, 2016).

Table 1
Distribution of types of importers of beef into Ethiopia (2006–2017)

Importers	No. of importers	Frequency of imports	Total value of imports			
			Ethiopian Birr	Share %	USD	Share %
Catering companies	2	49	11,832,309.2	33.0	11,832,309.2	31.9
Construction companies	24	98	15,843,148.8	44.2	917,528.3	45.4
Embassies	8	25	456,002.6	1.3	28,494.5	1.4
Hotel and restaurants	3	15	1,296,636.4	3.6	68,504.0	3.4
Trading companies	14	74	5,407,052.6	15.1	290,054.9	14.4
Supermarkets	5	27	876,565.6	2.4	63,128.9	3.1
Other organizations	2	2	165,784.5	0.5	7,961.9	0.4
Source: Yami et al., 2018						

2. 2. Live Animals And/or Carcass Export From Ethiopia

The export of live animals from Ethiopia is periodically interrupted due to the bans imposed by importing countries. The main causes of bans for meat exporters are disease outbreaks and unsatisfactory product quality (Brasesco, F., Asgedom, D., Sommacal, 2019). Dark cutting (DC), contamination, toughness, dryness, fatness, small carcass size, lack of uniformity of the cuts supplied, poor sanitation, inappropriate packing, branding, labelling, and lack of continuous supply have been also reported as contributing factors to the failure to meet acceptable international standards (Rich et al., 2008; Yami et al., 2018). Among these, the prevalence of DC at retail display is one of the leading causes of consumer rejection. To avoid low prices as a result of these factors, Ethiopian meat is sometimes re-packaged as Indian, Pakistani, or Somali meat (Rich, 2009; Yami et al., 2018).

3. Dark Cutting Meat And Its Characteristics

Dark cutting meat, mostly known as dark, firm, and dry (DFD) meat, is described as having a dark color that makes it appear less fresh and undesirable to consumers (Table 2). It is also less tender, has an undesirable flavor, and a short shelf-life. Dark cutting meat has been observed in all species (Table 2).

Dark cutting meat has a dark, purple red to black color which is abnormal (Table 2). Meat color is the most important attribute that influences customers' decisions at the point of purchasing (Udomkun et al.,

2018). Consumers use meat color as an indication of freshness and wholesomeness when purchasing fresh meat at the place of sale (Yami et al., 2018). Dark cutting meat is mainly identified by visual assessment within the visible light spectrum. The color of normal meat which is preferred by most people is bright-red, cherry-red, or pinkish- to bright-red (Ponnampalam et al., 2017). Normal muscle blooms to a bright cherry-red color when exposed to air. Deviations of meat color from the bright cherry-red color are defect indicators (Wicks et al., 2019).

Another characteristic of DC meat is its dryness and firmness which is determined by touching the surface of the meat (Table 2). Meat is called DC when the ultimate pH post-mortem measured after 12–48 hours is greater than 5.9. The ultimate pH of DC ranges from 5.9–6.5, with some meat reaching 6.8. These values are higher than the normal pH range (5.4–5.7) of meat from an unstressed animal (Adzitey & Nurul 2011; Warriss 2000). Dark cutting meat can also be defined based on glycolytic potential or glycogen levels in the muscles of slaughtered animals. Muscle glycogen levels at rest should be 0.8 to 1.0% before slaughter for cattle. Muscle glycogen reserves of an animal subjected to various forms of long-term pre-slaughter stress are significantly low due to depletion (Ponnampalam et al., 2017). Decreasing muscle glycogen levels to less than 0.6% limits the production of lactic acid and associated hydrogen ions that are responsible for decreasing the pH of meat (Ponnampalam et al., 2017). Thus, a glycogen deficiency would prevent the normal decline of meat post-mortem pH (Adzitey & Nurul, 2011; Birhanu et al., 2020)

A variety of severe pre-slaughter stresses can cause the depletion of muscle glycogen (Miller, 2007). Pre-slaughter stresses change the color of the meat to dark by preserving the structure of a protein called myoglobin, which transports oxygen from the blood to the muscle mitochondria (Walsh et al., 2019). If the animal’s glycogen is depleted before slaughter, the pH may not drop quickly enough to denature myoglobin. In this case, the meat will be dark in color and have high water-holding capacity as other muscle proteins remain in their native configuration (Warner, 2017)

Dark cutting meat has a reduced shelf-life, and a greater ability to support microbial growth (Table 2). Increased microbial activity leads to more spoilage and development of an unpleasant flavor. Reduced shelf-life is primarily due to a high pH and capacity to retain water, which is conducive for microbial growth. The problem is related to decreased levels of muscle glycogen, which limits its conversion to lactic acid. Lactic acid bacteria are naturally found on meat and “compete” with spoilage bacteria. The reduction in glycogen results in a significant decrease in lactic acid bacteria. As a result, bacteria that produce hydrogen sulfide, which causes an off-odor and green discoloration, multiply and proliferate (Ponnampalam et al., 2017). It has been reported that dark-cut beef consumed before spoilage has a slightly soapy off-flavor (Birhanu et al., 2020). Consumers tend to avoid DC meat due to the perception of the meat being from old, mistreated, stressed, poorly handled, and unhealthy animals (Ponnampalam et al., 2017).

Table 2
Summary of indicators of dark cutting (DC) meat

Dark cutting meat description	References
Dark in colour	Warriss (2000); Muchenje et al. (2009); Ekiz et al. (2012); Gruber et al. (2010)
Low light scattering ability	Warriss (2000)
Dryness and Firmness	Ponnampalam et al. (2017)
High water holding capacity	Muchenje et al. (2009); Ekiz et al. (2012)
Abnormal tenderness	Swatland (2008)
Smaller extracellular space	Warriss (2000)
High ultimate pH (> 5.8) and lower amino acid due to glycogen depletion pre-slaughter	Kannan et al. (2001); Muchenje et al. (2009); Ekiz et al. (2012)
Spoilage odour is produced at an early age/short microbial shelf life	Gallo et al. (2003); Warriss (2000)
High oxygen (O_2) used up due to cytochrome activity	Warriss (2000); (Chulayo and Muchenje (2013)
Increased the level of creatine kinase (CK) and lactate dehydrogenase (LDH) enzyme	Chulayo and Muchenje (2013); Alam et al. (2018); Birhanu, Mummed, Kurtu & Jiru (2019)

Dark cutting meat may occur due to many on-farm and off-farm factors. The major on-farm factors that have been related to DC meat are the production system, nutritional background, animal management, breed, sex, age at slaughter, and subclinical diseases (Ponnampalam et al., 2017). Off-farm activities include fatigue after transport to market, fear, fighting in lairage, beating, climatic changes, aggressiveness, prolonged withholding of feed before slaughter, mixing of unfamiliar animals, and stunning. These factors can lead to physical, physiological, and psychological changes in the animal body affecting the ultimate quality and profitability of the meat. A recent review covered in detail, the causes, contributing factors, and mechanism of DC meat in sheep and cattle, and suggested some future research directions to minimize its incidences (Ponnampalam et al., 2017).

As a consequence of pre-slaughter stress, an animal may experience fear, dehydration and hunger, increased physical activity and fatigue, and physical injury. This autonomic response results in the secretion of catecholamines and glucocorticoids. Increased secretion of these hormones amplifies the mobilization of energy sources in the body. Catecholamines, clearly invoke significant changes in glucose metabolism resulting in significant depletion of muscle glycogen reserves (Walsh et al., 2019). Any kind of pre-slaughter stress has a profound effect on meat quality attributes such as ultimate pH, tenderness, color, and water-holding capacity (Ferguson en Warner, 2008).

3. 1. Dark Cutting Meat In Ethiopia And Its Major Causes

Dark-cutting meat is one of the major challenges confronting the Ethiopian meat industry. Due to DC meat, most of the carcasses suitable for export from Ethiopia are rejected. This problem also makes the country vulnerable and dependent on meat imports. Different authors like Akililu et al. (2005), Abebe et al. (2010), Legese and Fadiga (2014), Yami et al. (2018) stated sheep carcasses from highland areas of Ethiopia quickly darkened and had a short shelf-life in contrast Merera et al. (2013) reported that DFD case is not related with origin of animals rather than others pre-slaughter handling and genotypes. Except Merera et al. (2013) took meat pH and color other authors were only collected information from stakeholders. Hence, they did not quantify amount of darkness. Because, paucity of research activities focusing on meat and meat products (Assefa, 2017). Even though the claim of meat darkness is high from meat export market and high ended domestic (HED) hotels in Ethiopia. However, few authors like Birhanu, Mummed, Kurtu & Jiru (2019) & Birhanu et al. (2020) reported totally about 30.77% DFD meat for Harar (14.29%), Boran (35.71%) and Arsi (45.45%) cattle breeds. Gadisa (2018) reported about 38.57% DFD; 22.86% PSE in the wet season and 10.42% DFD; 33.33% PSE at dry season for Arsi, Bale and Harar cattle breeds.

Dark meat is often sold at a discounted price and is generally unsuitable for export markets. Even in a developed country, the DC meat causes a significant economic loss to the meat industries because consumers reject it at the point of purchase (Ponnampalam et al., 2017). Severe pre-slaughter stress factors including transport, exhaustion at market, feed restriction, water deprivation, fear, mixing with animals unfamiliar, fighting for space in lairage, beating, and stunning have been reported in Africa and Ethiopia (Mummed, 2015;Birhanu, Mummed, Kurtu & Jiru, 2019). Therefore, this review examines the factors behind DC meat in Ethiopia and provides baseline information for the fate of the meat industry in Ethiopia.

3.2. Production system and DC meat

In Ethiopia, livestock are raised in three different production systems: mixed crop-livestock, agro-pastoral, and intensive production. The environmental conditions, feed quality and quantity that animals receive differ among production systems in Ethiopia. The difference in nutritive value of feeds may in turn have impacts on carcass weight, fatness, muscle glycogen content, and the quality of the meat. Below, the different livestock production systems in Ethiopia and how they cause DC meat are discussed.

i. Mixed crop-livestock production system

The mixed crop-livestock production system in Ethiopia is practiced traditionally (Anteneh, 2010) especially in the areas where there is sufficient rainfall (1,503 mm) and moderate temperature (15.6°C) (Moges en Bhat, 2021). The numerous livestock products that are used for domestic consumption are obtained in the mixed crop-livestock production systems. However, farmers do not sell their products based on demand in a market. About 75% of farmers in this system sell cows after being culled from dairy services (Mummed, 2015). Oxen are sold after the ploughing season. Most of the animals are in poor body condition due to chronic stress and hard work such as draughting in the farm. The poor body

condition results in low carcass yield, chemical and sensory quality (Anteneh, 2010), and these are ideal conditions for the formation of DC meat due to the higher level of physical activity leading to low muscle glycogen reserves at slaughter.

Hararghe's finishing system, a type of mixed crop-livestock production system, is an exception. In Hararghe, ruminants are finished via a long traditional practice (Abebe en Urge, 2014). The system is largely based on cut-and-carry green feeds from maize and sorghum origin including thinning, leaf strip part of maize, and sorghum plants (Alemayehu et al., 2016; Anteneh, 2010; Ayalew et al., 2013; Tolera, 2007). Farmers usually buy young steers from the adjacent lowlands pastoral areas and use them for ploughing and other farm work. In this system, bulls are tethered under shade, finished and sold before they become old (less than 4 years) and emaciated. The Hararge bull finishing system is unique in Ethiopia (Tefera et al., 2019). Tsigereda and Mengistu (2011) reported that Hararge farmers utilized Fenugreek (*Trigonella foenumgraecum*) flour, fermented dough or their blend, and yeast (*Saccharomyces cerevisiae*) for fattening of Harar. This model of finishing cattle minimizes incidences of DC meat. There is no need for long-distance travel to find feed and water. Animals are not heat stressed since they are tethered under the shade. Animals are also young when they are offered to the market. However, Hararghe's cattle finishing system is only practiced in the Hararghe area and transported long distances about 350–500 km which causes stress subsequently affecting meat quality at slaughter.

ii. Pastoral and agro-pastoral livestock production system

Pastoral and agro-pastoral production systems in Ethiopia are mainly found in the lowlands and largely rely on natural or semi-natural vegetation. Production is subsistence-oriented and milk is the main product. In Ethiopia, commercial feedlot operators purchase 3–6 year-old Boran, Kerayu, and Ogaden cattle from the lowlands. The Boran cattle breed, categorized as *Bos indicus* (humped Large East African Shorthorn Zebu type) is one of the local cattle breeds from the Borana rangelands in southern Ethiopia reared by the Borana pastoralists of Oromoo people. Pastoralists and agro-pastoralists sell excess young bulls to highlanders and feedlot operators (FAO, 2019). The young bulls are preferred because they show a good production response to fattening, deliver high-quality beef and qualify for the standards required by the export market niche for Ethiopian cattle breeds (Genet Dadi en Teklebrhan, 2017; Legese et al., 2008; Teklebrhan et al., 2013).

The majority of Ethiopia’s livestock supplied for export originate from the pastoral and agro-pastoral areas of Afar, Somali, and Borena sedentary. Producers rear cattle, young sheep and goats (weaners), camels, and poultry. These producers are often located in rural areas where access to markets and infrastructure is insufficient. Hence non-specialised trucks and improper handling transportation are used to bring animals to the market, which causes stress (Arse, Mohammed & Ameha, 2013; Gadisa, 2018; Mummed, 2015). Prolonged nutritional restriction and overstocking which may happen in agro-pastoral and pastoral systems in Ethiopia are stressful. Chronic stress may also happen in overstocking due to heavy parasite burdens (MoST, 2016). The other problem in the pastoral and agro-pastoral livestock production system is seasonable feed scarcity. The animals are forced to travel long distances in search

of feed and water in warm climate conditions which causes chronic stress. All these stress conditions may lead to the depletion of stored glycogen before slaughter which in turn may result in DC meat (Adzitey en Nurul, 2011).

iii. Intensive livestock production system

The intensive livestock production system is practiced in urban and peri-urban areas in Ethiopia (USAID, 2016). Intensive farming is a prominent business of the meat industry because plentiful cheap by-products are used for this system (Zander, 2011). Finishing animals under intensive system offers an opportunity for the livestock producers to sell their products in the domestic market as well as to export in the region (Ayenew, 2012). However, season-dependent feed availability affects the quality of animals delivered to the market (Genet Dadi en Teklebrhan, 2017; Teklebrhan et al., 2013). In commercial feedlots, a large number of unfamiliar animals, about 1000–1500 heads of cattle, are fed in one barn (Teklebrhan et al., 2013). Usually, there are no individual pens in Ethiopian feedlot farms. The intensively-finished animals are less prone to develop DC carcasses than extensively-finished cattle as natural pasture has lower energy than concentrates (Hughes et al., 2014).

The reports given by Akililu et al. (2005), Abebe et al. (2010), Legese and Fadiga (2014), Yami et al. (2018) stated that goat and sheep carcasses from highland areas of Ethiopia quickly darkened and had a short shelf-life compared with those from lowland areas. In contrast, Merera et al. (2013) reported that darkening of mutton from both highlands and lowlands was not different. The authors concluded feeding energy-rich diets before slaughter to restore glycogen depletion. Legese and Fadiga (2014) also reported that exporting highlands sheep is underway to Bahrain since the country has developed a taste for Ethiopian highlands sheep meat. Needier is, therefore, important to investigate if the meat darkness difference between highland and lowland small ruminants is due to environment or genetics, or their interaction.

3.3. Diet

In Ethiopia, crop residues of cereals and pulses account for about 32% of the total feed utilized and these are ranked second to grazing, which constitutes 37% (CSA, 2019/20). Natural pasture and crop residues are the major animal feed resources in Ethiopia (Amistu et al., 2016; Belachew, 2019; Worku et al., 2016). However, both feed resources are only available seasonally, are low quality, and surprisingly sometimes have nutrient value less than maintenance requirements. Crop residues of cereals contain crude protein (CP) levels below 8% and neutral detergent fiber (NDF) of above 55% with limited intake and lower digestibility (Bediye en Sileshi, 1995). Steers raised on pasture also had a significantly lower glycolytic potential and the pH/temperature decline rate of carcasses was slower than those from feedlot systems (Webb en Erasmus, 2013). Feeding high-energy diets or energy supplements such as grains and by-products during the finishing period of cattle and sheep may be useful to reduce the occurrence of DC meat (Ponnampalam et al., 2017). Therefore, energy source and provision of rest for two-week at or near the abattoir before slaughter is beneficial for minimizing DC meat (Walsh et al., 2019). A finishing diet can improve meat quality, especially appearance and aroma, as well as the fat level and color. Cattle

finished on pasture are more likely to produce DC carcasses, which frequently have high ultimate pH values, due to their lower energy and slower growth rate than animals raised in intensive finishing systems fed quality mixed ration (Ponnampalam et al., 2017). Feeding supplements (hay/silage) in the last 7 days before slaughter has been reported to reduce the relative risk of DC meat by 25% (Loudon et al., 2018).

3.4. Breeds and genotypes

There is variation in meat quality among species and animals within a species. Variation among animals reared in the same environment and slaughtered at the same age, weight, and degree of finish suggests a genetic cause for some variation (Yami et al., 2018). Genetic variation can influence the biochemical and structural characteristic of muscle fibers and intramuscular connective tissue, when selection is used to achieve production efficiency and improve meat/flesh quality (Listrat et al., 2016). Dairy breeds are characterized by higher levels of myoglobin and thus iron in their muscle (Dunne et al., 2004), which can affect the color of meat.

In Ethiopia, there is no specific cattle breed that is exclusively selected for beef production, nor has there been development of the indigenous breeds for production traits (Assefa, 2017). However, the recent report indicated that the Borana cattle breed is targeted for enhanced contribution to the beef industry in Ethiopia (ATO, 2020) as it is already for some African countries like Botswana, Namibia, and South Africa (Yami et al., 2018). According to Legese and Fadiga (2014) standard live weight of animals to be exported alive for a bull is 300–320 kg, and for sheep and goats is 14–27 kg. Ethiopian sheep and goats have low average carcass weights. This might be due to poor genetic performance, poor animal husbandry practices, or their combination (Legese en Fadiga, 2014). In general, comparative research on breed characterization for meat production potential and other production traits for various livestock species in Ethiopia is limited (Worku et al., 2019), and warrant further investigation.

3.5. Farm management

Farm management conditions such as the application of metabolic modifiers, growth promoters, and hormone implants impact meat colours. In Ethiopia, not all livestock species have access to housing. The report of Gadisa (2018), only about 10% of livestock producers provide housing or/shade for their animals. Housing of large animals after weaning is rare in Ethiopia as the housing is prepared from locally available material for calves, small ruminants and poultry mostly to protect them from predators. Even in most feedlots, animal houses are exposed to sun, rain, and wind without overhead cover, because shade is only provided to sick animals (Teklebrhan et al., 2013).

Stocking density at the feedlot, free grazing, and inadequate shelters housing contribute to animal pre-slaughter stress. Commercial feedlots keep large groups of unfamiliar animals (1000–1500 heads of cattle) at one barn because there is no compartment house/barn with a specific dimension for both feeding and watering trough (Teklebrhan et al., 2013). Although the majority of land in Ethiopia is under crop production, the integration of crop production and livestock husbandry is not satisfactory.

Decreasing grazing land, lack of good quality feeds in arable lands results in a consistent increase in the price of industrial by-products continuously constraining livestock production (Duguma et al., 2012).

3.6. Age of animal at slaughter

The age at slaughter significantly affects meat color. As animals become older, meat contains more myoglobin and is therefore more prone to be perceived as DC meat. Age at slaughter is determined by many factors such as production system, nutrition, and growth rate, all of which have positive relationships with the darkness of meat (Girard et al., 2012; Hughes et al., 2014). An older animal has darker meat due to higher muscle pigment content and/or lower muscle glycogen concentration and fiber size increases with animal age in all species (Listrat et al., 2016). In Ethiopia, there is potential for indigenous cattle breeds to produce beef of sufficient quality to satisfy both domestic and export demand if appropriate breeding strategies are designed and supported by proper management (farm to abattoir) and feeding strategy. Dairy-beef as a resource is also underutilized in Ethiopia (David, 2006).Mummed (2015) reported that cattle less than two years of age were not slaughtered in Ethiopian abattoirs. A young animal is demanded by export markets because it is a good source of lean and tender meat. Bull calves at an intensive dairy farm in Ethiopia are early (three days to month) culled to minimize the cost incurred by the farm (Gadisa, 2018). Hence, producers sell calves at an early age; however, marketing dairy calves for meat is not common (Mummed & Webb, 2014). Therefore, these young bulls are given to relatives in the rural areas and unfortunately are unlikely to survive due to inappropriate feed, health, and housing.

3.7. Transportation

Livestock transportation in Ethiopia significantly influences the level of competitiveness in general, and exports in particular. Most animals are transported at least once in their lifespan from farm to auction centers (Chulayo et al., 2012). Since there are no specially built trucks for animal transport in Ethiopia, livestock is often transported via walking from farm to market. The absence of dedicated animal transport contributes to quality deterioration as a result of injury and stress (Yami et al., 2018).

Bulitta et al. (2012) reported that about 16% of animals die and 10.7% of animals are injured during transport from Gudar to Finfine. This journey force animals to walk long-distances (250–300 km) across wide rivers which have no bridges in a journey without sufficient feed, water, and rest. Long-distance traveling increases the levels of intramuscular creatine kinase and lactate dehydrogenase enzymes, which are enzymes that indicate physiological responses to stress during transportation (Alam et al., 2018; Chulayo & Muchenje, 2013). Vehicular transport often entails deprivation of feed and water for long periods of time, roughly handling before and during transport (e.g., using cattle prods), exposing animals to temperature extremes or severe weather, shipping of stress-susceptible animals such as intact males (bulls), and vibration of the truck, all of which contribute to the stress of livestock during marketing in Ethiopia (Bulitta et al., 2012; Birhanu, Mummed, Kurtu & Jiru, 2019). In particular, sheep and goats have a high mortality rate and rapid loss of live weight during long-distance ground transportation (Teklebrhan et al., 2013). Air transport is less stressful and shows less mortality rate as compared to on foot, trucking,

and sea transportation. However, the cost of air transportation is a major challenge because the cost is not affordable for smaller operations (Legese en Fadiga, 2014).

3.8. Lairage

Lairage is used as a collection place for animals just before slaughter. This place is designed to provide animals with a recovery period from transport alleviating stress (Merten et al., 2011). Mummed (2015) reported bruising, contamination, pneumonia, and poor bleeding are the major causes of meat defects in Ethiopia. This bruising has been occurred during, handling, and is due to excessive use of sticks during transport and lairage, as well as due to an absence of clean, dry bedding and space in lairage (Birhanu, Mummed, Kurtu & Jiru, 2019). Also, in lairage, drinking water and feed must be available. In Ethiopia, most of the abattoirs lack lairage, thus animals fight and injury occurs, and there is not opportunity for sufficient rest at the slaughterhouse before harvesting (less than 4 hours), with lack of water sometimes dehydrating animals before slaughter (Birmaduma et al., 2019; Mummed, 2015). The additional physical demands experienced by animals before slaughter may lead to fatigue if the animals do not have an opportunity to rest and recover in lairage before slaughter.

3.9. Diseases

Disease is a state in which normal functions are disturbed or altered at the cellular, tissue, organ, or whole organism level. Disease occurs due to exposure to pathogenic micro-organisms, poor management especially related to feeding, poor genetic selection, and toxic agents. Exhaustion and exposure of animals to dust during long-distance trekking to search for feed and water in route to markets and abattoirs, lack of shelter, and overcrowding are causes of chronic stress and make for an environment conducive to disease (Mummed, 2015). In Ethiopia, in neither pastoral nor other livestock production systems are there a disease-free zone. In reality, government efforts and policy have moved away from diseases issue leading to different trade bans. Trans-boundary animal diseases (TADs) such as CBPP (Contagious Bovine Pleuropneumonia), CCPP (Contagious Caprine Pleuropneumonia), FMD (Foot and Mouth Disease), LSD (Lumpy Skin Disease), AHS (Africa House sickness), PPR (Pest des Petits Ruminants) and NCD (New castle Disease) are limiting the productivity, market access of livestock and their products to regional and international markets (Seyoum en Teshome, 2018).

3.10. Market infrastructure

Market infrastructure components for meat export in Ethiopia are underdeveloped. Transporting live animals and meat from the abattoir using a non-specialised truck affects the shelf-life of meat (Arse Gebeyehu, 2013). In Ethiopia, most factories do not have sufficient chilling and freezing facilities (EDMIDI, 2016). The packing system of most meat exporter factories in Ethiopia currently uses very poor technology. Ethiopian customers, including Middle Eastern and Angolan importers, often complain about the carelessness and poor quality of meat packaging supplied by Ethiopians. Covering with the stockinette is the only packing technology currently used by most exporters (LMD, 2013; EDMIDI, 2016).

The lack of a specific brand name for Ethiopian meat and live animal is another important issue. The absence of branding is the cause of the country's economic loss as a whole due to the rejection of exported products (Frimpong, 2009). Almost all meat exporting countries like New Zealand, Australia, and Brazil have their brand in the international market. Some reasons for the bad image of Ethiopian products are poor quality, lack of international recognition and limited promotion, unresponsive to business communications, and unreliability in meeting contractual obligations (LMD, 2013).

In general, poor animal handling results in the loss of weight, physical injuries, sickness, reduced meat color, and even death from poor welfare conditions. Hence, as Ethiopia struggles to address its meat quality issues needs a strong and consistent strategy with regard to live animal management/pre-slaughter animal handling and post-slaughter processing additional to improving infrastructure (markets, slaughterhouses, farm installations) and training farmers and stockpersons in general handling of animals and good practices to satisfy domestic and international markets

4. Strategies To Minimize Dc Meat Incidences In Ethiopia

Prior to slaughter, livestock must be monitored during feeding, implanting, penning, processing, transporting, and holding. If proper steps are taken to reduce stress and allow for acclimation and rest following a stress event, the incidence of DC carcasses will be greatly reduced. Nonetheless, identifying animals at a higher risk of stress and preventing stress from occurring remains a challenge for the industry. To minimize DC meat in the Ethiopian meat sector, the development and implantation of the following options are important:

4.1. Production: Reorient subsistence livestock production system to market demands at regional, national and international. Producers should consider breed, market demand, and environment in the plan of production. Stimulate private sector investments to modernize and improve the sector competitiveness through promoting the commitment of commercial fattening and finishing to create models that will enhance group marketing and contract production for farmers to increase yields and quality.

4.2. Nutrition:- From a nutritional standpoint, providing a high-energy diet, particularly during the finishing phase and prior to marketing to increase intramuscular glycogen concentration and, by improving growth rate, reducing slaughter age to increase meat tenderness. To avoid acidosis, a high-energy diet must be properly balanced and prepared, as acidosis impairs feed intake and promotes agitation and aggressive behavior. For two to three weeks before slaughter, supplement a good energy source diet to replace/restore muscle glycogen depleted during travel to the abattoir.

4.3. Breeding: First and foremost, it is crucial to develop stress-resistant breeds. Since many authors have discovered a high incidence of DC in stress-prone animals. This is because animals' responses to stress are governed by a complex interaction of genetic factors and prior experiences. Nonetheless, tropical breeds, in particular, are resistant to stress but grow slowly. Temperate breeds, on the other hand, are more vulnerable to stress but grow at a faster rate. A mix of genotypes from temperate and tropical regions could help reduce the prevalence of DFD meats.

4.4. Diseases: Even though there is no disease-free zone in Ethiopia, cattle illness, infection, and diseases are critical causes of stress among the standard factory of farming conditions. The government should tried to create a disease-free zone and build adequate local agro vets' sales network to improve access to animal health inputs and service.

4.5. Marketing: The livestock supply base to the export and the HED markets is narrow and largely limited to animals of lowland origin due to special tastes and preferences (flavor, meat color, etc.) is develop for lowland animals. Land allocated for livestock auction center is small due to competition within residences house hence none can accommodate separation of animal types. Therefore, whilst livestock marketing is held two days per week highly, overcrowding, novelty, and lack of sanitation are major causes of stress due to almost no auction center facilities having available even fencing. Established feed and water at auction places is necessary and development of a price policy through premium payment for the young and well-finished animal for meat purposes will incentivize producers.

4.6. Transportation: Animals are transported to markets for sale or directly from farms to abattoirs. In either case, stress should be kept to a minimum. Keep transportation and marketing times to a minimum. This implies that farms, markets, and abattoirs should be located close to one another. Vehicles used to transport animals must provide adequate ventilation and be well maintained, and driven on smooth, well-maintained roads. Animals should be provided with access to shade, water, and food (especially if the animals will keep long in the market). Keep animals together in their rearing group because mixing unfamiliar animals will result in fighting. Overcrowding should be avoided because it increases the occurrence of DC meat as a result of stress.

4.7. Slaughtering Process: Before slaughter animals should be rested at the abattoir to allow for sufficient recovery from the stress of travel or transport. Lairage time should also be kept to a minimum. If the animals will be spending more time in the lairage, provide them with food and water. If the animals will be kept in lairage for a longer time than expected, place bedding on the floor and feed sugar or molasses to replenish muscle glycogen. Mist water can be sprayed on animals to keep them cool, especially when the weather is hot. Abattoirs must be well-designed to ensure that the animals are subjected to as little stress as possible prior to slaughter. Mechanical stunning (captive bolt pistol, percussion stunner, or free bullet), electrical stunning, and anesthetic gas (CO_2) all render animals unconscious prior to sticking rather than using hammer and knife which are currently used in most municipality abattoirs. If done correctly, this has the potential to reduce pain, distress, and struggling after sticking and, as a result, can help reduce the incidence of DC meat. To reduce distress, animals must be well restrained before stunning and/or sticking. Promoting uptake of food standards by slaughterhouses via accesses facilities, use of modern instruments, and periodically training and health treatment for abattoir workers will also likely contribute to improved meat quality.

4.8. Post-slaughter: After dressing, the carcasses should be chilled. Different cooling rates can influence the rate of pH drop via hydrogen ion production as well as the onset of rigor mortis. This has the potential to harm the carcass and meat quality. The modern chilling practice focuses on speeding up the chilling

process by using refrigerated air to reduce microbial growth and evaporative weight loss. The carcass classification system should be demonstrated at all levels.

4.9. Appropriate Policy/strategies: Developing a consistent strategy to improve technical and economic results of primary meat production, carcass quality, commercial cuts, and meat products made from fresh meat rather than confusing stakeholders with multiple strategies should be used to drastically reduce DFD issues. To benefit meat suppliers and meet demand, government policy should consider developing a price policy and implementing quality-based payment for meat and live animals. It should also include development of adequate animal health services and establishment of an internationally accredited certification system for meat exports, as well as efficient and transparent livestock marketing systems. A strong animal welfare policy, scientific research design, maximum media coverage, and continuous monitoring also should all be developed.

5. Conclusions

Ethiopian livestock production chain is long and fully challenged which causes for chronic stress. These chronic stresses are fundamental causes for meat darkness. Hence in Ethiopia, DC meat is the major challenge inhibiting meat consumption at high ended domestic hotel and export market. This review indicated that DC meat arises from current production and handling practices and poor quality feeds supplied to indigenous breeds. Therefore, reorienting livestock production is critically important in Ethiopia to respond the meat quality requirements of high-end domestic and export markets. Government policy changes are important with regard to animal handling, production and slaughter if Ethiopia is to become able to supply sufficient acceptable product domestically and become an export of meat.

Declarations

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Abebe, B., & Urge, M. (2014). Small Scale Beef Cattle Fattening Practices on farm Performance Evaluation and Opportunities for Market Orientation in Western Hararghe Zone Chiro District. Haramaya University.
2. Abebe, G., Kannan, G.,& Goetsch, A.L. (2010). Effects of small ruminant species and origin (highland and lowland) and length of rest and feeding period on harvest measurements in Ethiopia. African J. Agric. Res. 5, 834–847.
3. Adzitey, F.,& Nurul, H. (2011). Pale soft exudative (PSE) and dark firm dry (DFD) meats: Causes and measures to reduce these incidences - a mini review. Int. Food Res. J. 18, 11–20.

4. Akililu, Y., Haweks, P., King, A., & Sullivan, G., (2005). Sanitary and Phytosanitary standards (SPS) and Livestock-meat marketing assessment for Ethiopia: Consultancy Report for a project funded under the RAISE IQC for sanitary and phytosanitary standards (SPS) of USAID in Washington. DC USA, ETH \& EGAT Off. Usaid/washingt.
5. Alam, M., Hasanuzzaman, M., Hassan, M.M., Rakib, T.M., Hossain, M.E., Rashid, M.H., Sayeed, M.A., Philips, L.B., & Hoque, M.A. (2018). Assessment of transport stress on cattle travelling a long distance (648 km), from Jessore (Indian border) to Chittagong, Bangladesh. Vet. Rec. Open 5, e000248.
6. Alemayehu, K. (2011). Value chain assessment of beef cattle production and marketing in Ethiopia: Challenges and opportunities of linking smallholder farmers to the markets. Livest. Res. Rural Dev. 23, 255–265.
7. Alemayehu, Y., Adicha, A., Mengistu, M., &Eshetu, B. (2016). Assessments of Market Oriented Beef Cattle Fattening System Under Farmer Management Condition in South Omo Zone of Snnpr. Curr. Res. Agric. Sci. 3, 31–45. https://doi.org/10.18488/journal.68/2016.3.3/68.3.31.45
8. Amistu, K., Temesgen, M., Alemu, A., &Tarekegn, W. (2016). Assessment of beef cattle fattening and marketing system and contribution to household food security in case of Lemmo Woreda, Hadiya Zone, Southern Ethiopia. J. Mark. Consum. Res. 29, 1–10.
9. Anteneh, B. (2010). Cattle milk and meat production and marketing systems and opportunities for market-orientation in Fogera woreda, Amhara region, Ethiopia. ILRI (aka ILCA and ILRAD).
10. Arse, G., Mohammed, Y., & Ameha, S. (2013). Evaluation of proximate composition of beef of Arsi cattle in Adama Town, Oromia, Ethiopia. Int. J. Agric. Innov. Res. 1, 183–187.
11. Assefa, G. (2017). Livestock Research Strategies: Dairy, Beef, Sheep, Goats and Camels (2016--2030).
12. Ayalew, T., Duguma, B., & Tolemariam, T. (2013). Traditional cattle fattening and live animal marketing system in different agro-ecologies of Ilu Aba Bora Zone, Oromia, Ethiopia. Glob. Vet. 10, 620–625. https://doi.org/10.5829/idosi.gv.2013.10.5.6688
13. Ayenew, H. (2012). Risk analysis in cattle fattening in North West Ethiopia: Empirical evidence form two limit Tobit model. Int. J. Dev. Sustain. 1, 240–254.
14. Barry I Shapiro, Getachew Gebru, Solomon Desta2, Asfaw Negassa, Kidus Negussie, G.A.,& Mechal, H. (2015). Ethiopia livestock master plan Roadmaps for growth and transformation. ILRI Proj. Report. Nairobi, Kenya Int. Livest. Res. Inst. (ILRI).
15. Bediye, S.& Sileshi, Z. (1995). Chemical composition, in vitro digestibility and energy values of Ethiopian feedstuffs, in: 3. National Conference of the Ethiopian Society of Animal Production, Addis Abeba (Ethiopia), 27-29 Apr 1995.
16. Belachew, M.M. (2019). Beef cattle fattening practices, constraints and future potentials in Ethiopia: a review. Anim. Res. Int. 16, 3401–3411.
17. Birhanu, A.F, Mummed, Y.Y, Kurtu,M.Y, O'.Quinn,T., & Jiru, Y.T. (2019). Level of Pre-slaughter stress and quality of beef from Arsi, Boran and Harar cattle breeds in Ethiopia. Cogent Food Agric. 5.

https://doi.org/10.1080/23311932.2019.1694233

18. Birhanu, A.F, Mummed, Y.Y., & Kurtu, M.Y. (2020). Level of Bruising and DFD Carcasses from Bulls of Arsi, Boran and Harar Cattle Breeds in Ethiopia. Open J. Anim. Sci. 10, 203–218. https://doi.org/10.4236/ojas.2020.101011
19. Birmaduma, G., Yesihak, Y., & Mohammad Y, K. (2019). Evaluation of physical Facilities, Operation and Management Practice in Selective Public Abattoirs in Eastern Oromia, Ethiopia. Int. J. Agric. Sci. Food Technol. 5, 043–049. https://doi.org/10.17352/2455-815x.000040
20. Brasesco, F., Asgedom, D., & Sommacal, V. (2019). Strategic analysis and intervention plan for live animals and red meat in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central- Eastern Oromia, Ethiopia. Addis Ababa.
21. Bulitta, F.S., Gebresenbet, G., & Bosona, T. (2012). Animal Handling during Supply for Marketing and Operations at an Abattoir in Developing Country: The Case of Gudar Market and Ambo Abattoir, Ethiopia. J. Serv. Sci. Manag. 05, 59–68. https://doi.org/10.4236/jssm.2012.51008
22. Chulayo, A.,& Muchenje, V. (2013). Activities of creatine kinase and lactate dehydrogenase as welfare indicators in slaughter cattle, in: 59th International Congress of Meat Science and Technology.
23. Chulayo, A.Y., Tada, O., & Muchenje, V. (2012). Research on pre-slaughter stress and meat quality: A review of challenges faced under practical conditions. Appl. Anim. Husb. Rural Dev. Appl. Anim. Husb. Rural Dev. 5, 1–6.
24. David, H. (2006). Ethiopia sanitary \& phytosanitary standards and livestock \& meat marketing program (spslmm). Feed. to Prod. Export Qual. Ethiop. beef Requir. Recomm.
25. Duguma, B., Tegegne, A., & Hegde, B. (2012). Smallholder livestock production system in Dandi district, Oromia Regional State, central Ethiopia. Read write 20, 25–26.
26. Dunne, P.G., Keane, M.G., O'Mara, F.P., Monahan, F.J., &Moloney, A.P. (2004). Colour of subcutaneous adipose tissue and M. longissimus dorsi of high index dairy and beef$\times$ dairy cattle slaughtered at two liveweights as bulls and steers. Meat Sci. 68, 97–106.
27. Ehui, S., Benin, S., & Gebreselassie, N. (2000). Factors affecting urban demand for live sheep: the case of Addis Ababa, Ethiopia. ILRI (aka ILCA and ILRAD).
28. Ekiz, B., Ekiz, E.E., Kocak, O., Yalcintan, H.,& Yilmaz, A. (2012). Effect of pre-slaughter management regarding transportation and time in lairage on certain stress parameters, carcass and meat quality characteristics in Kivircik lambs. Meat Sci. 90, 967–976.
29. Eshetie, T., Hussien, K., Teshome, T., & Mekonnen, A. (2018). Meat production, consumption and marketing tradeoffs and potentials in Ethiopia and its effect on GDP growth: a review. J Nutr Heal. Food Eng 8, 228–233.
30. Eshetu, E., & Abraham, Z. (2016). Review on live animal and meat export marketing system in Ethiopia : challenges and opportunities 5, 59–64.
31. Ferguson, D.M.,& Warner, R.D. (2008). Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants? Meat Sci. 80, 12–19.

32. Frimpong, S. (2009). Effect of Pre-Slaughter Handling and Transport on Welfare and Meat Quality of Cattle: A Case Study of Kumasi Abattoir. Master's Thesis, Kwame Nkrumah Univ. Sci. Technol. Kumasi.
33. future-livestock-ethiopia-opportunities-and-challenges-face-uncertainty @ www.preventionweb.net, n.d.
34. Gadisa, B. (2018). Analysis of Eating Qualities, Perception of Stakeholders on Beef Qualities Determinants and Commercial Value of Meat Cuts in Eastern Oromia, Ethiopia. Haramaya Univ. Msc Thesis.
35. Gallo, C., Lizondo, G., & Knowles, T.G. (2003). Effects of journey and lairage time on steers transported to slaughter in Chile. Vet. Rec. 152, 361–364.
36. Genet Dadi, M.U., &Teklebrhan, T. (2017). Assessment of Commercial Beef Cattle Fattening Practices and performance in East Shoa Zone. Int. J. Agric. Sci. Food Technol. 3, 067–076. https://doi.org/10.17352/2455-815x.000025
37. Girard, I., Aalhus, J.L., Basarab, J.A., Larsen, I.L.,& Bruce, H.L. (2012). Modification of beef quality through steer age at slaughter, breed cross and growth promotants. Can. J. Anim. Sci. 92, 175–188.
38. Gruber, S.L., Tatum, J.D., Engle, T.E., Chapman, P.L., Belk, K.E., & Smith, G.C. (2010). Relationships of behavioral and physiological symptoms of preslaughter stress to beef longissimus muscle tenderness. J. Anim. Sci. 88, 1148–1159.
39. Hughes, J.M., Kearney, G., & Warner, R.D. (2014). Improving beef meat colour scores at carcass grading. Anim. Prod. Sci. 54, 422–429.
40. Kannan, G., Kouakou, B., Terrill, T.H., Gelaye, S., & Amoah, E.A. (2001). Preslaughter stress effects on physiological responses and meat quality characteristics in goats. J. Anim. Sci. 79, 447.
41. Legese, G., &Fadiga, M.L. (2014). Small ruminant value chain development in Ethiopia: Situation analysis and trends.
42. Legese, G., Teklewold, H., Alemu, D., & Negassa, A. (2008). Live animal and meat export value chains for selected areas in Ethiopia: Constraints and opportunities for enhancing meat exports.
43. Listrat, A., Lebret, B., Louveau, I., Astruc, T., Bonnet, M., Lefaucheur, L., Picard, B.,& Bugeon, J. (2016). How muscle structure and composition influence meat and flesh quality. Sci. World J. 2016.
44. Loudon, K.M.W., Lean, I.J., Pethick, D.W., Gardner, G.E., Grubb, L.J., Evans, A.C.,& McGilchrist, P. (2018). On farm factors increasing dark cutting in pasture finished beef cattle. Meat Sci. 144. https://doi.org/10.1016/j.meatsci.2018.06.011
45. Merera, C., Sebsibe, A., Abebe, G., & Goetsch, A.L. (2013). Length of Feeding Periods on Mutton pH and Color of Highland (Arsi-Bale) and Lowland (Black Head Ogaden) Male Sheep of Ethiopia. J. Sci. Sustain. Dev. 1, 51–61.
46. Merten, C., Ferrari, P., Bakker, M., Boss, A., Hearty, A., Leclercq, C., Lindtner, O., Tlustos, C., Verger, P., & Volatier, J.L. (2011). Methodological characteristics of the national dietary surveys carried out in the European Union as included in the European Food Safety Authority (EFSA) Comprehensive European Food Consumption Database. Food Addit. \& Contam. Part A 28, 975–995.

47. Miller, M. (2007). Dark, firm and dry beef. Beef facts Prod. Enhanc. Texas Tech Univ.
48. Moges, D.M.,& Bhat, H.G. (2021). Climate change and its implications for rainfed agriculture in Ethiopia. J. Water Clim. Chang. 12, 1229–1244.
49. Muchenje, V., Dzama, K., Chimonyo, M., Strydom, P.E.,& Raats, J.G. (2009). Relationship between pre-slaughter stress responsiveness and beef quality in three cattle breeds. Meat Sci. 81, 653–657.
50. Mummed, Y. (2015). Beef carcass quality , yield and causes of condemnations in Ethiopia. Thesis Submitt. Partial fulfillment Requir. degree PhD (Anim. Sci.) Fac. Nat. Agric. Sci. Univ. Pretoria Pretoria. 201.
51. Mummed, Y.Y., & Webb, E.C.(2015). Carcass quality audit-A strategy to improve beef sector in Ethiopia.
52. Mummed, Y.Y., & Webb, E.C. (2014). Ethiopian beef carcass characteristics. African J. Agric. Res. 9, 3766–3775.
53. Ponnampalam, E.N., Hopkins, D.L., Bruce, H., Li, D., Baldi, G.,& Bekhit, A.E. (2017). Causes and contributing factors to 'dark cutting' meat: Current trends and future directions: A review. Compr. Rev. Food Sci. Food Saf. 16, 400–430.
54. Rich, K.M. (2009). What can Africa contribute to global meat demand? Opportunities and constraints. Outlook Agric. 38, 223–233.
55. Rich, K.M., Perry, B.D., Kaitibie, S., Gobana, M., & Tewolde, N. (2008). Enabling livestock product exports from Ethiopia: understanding the costs, sustainability and poverty reduction implications of sanitary and phytosanitary compliance. Final Rep. Texas A\&M Univ. Sanit. Phytosanitary Livest. Meat Mark. Program, Addis Ababa, Ethiop. 72.
56. Seyoum, B., &Teshome, E. (2018). Major transboundary disease of ruminants and their economic effect in Ethiopia. Glob. J Med Res.
57. Swatland, H.J. (2008). How pH causes paleness or darkness in chicken breast meat. Meat Sci. 80, 396–400.
58. Tefera, T.D., Mummed, Y.Y., Kurtu, M.Y., Letta, M.U., O'Quine, T.G., & Vipham, J.L. (2019). Effect of Age and Breeds of Cattle on Carcass and Meat Characteristics of Arsi, Boran, and Harar Cattle in Ethiopia. Open J. Anim. Sci. 9, 367–383.
59. Teklebrhan, T.,& Urge, M. (2013). Assessment of commercial feedlot finishing practices at eastern Shoa, Ethiopia. Open J. Anim. Sci. 3, 273.
60. Tolera, A. (2007). Feed Resources for Producing Export Quality Meat and Livestock in Ethiopia Examples from Selected Woredas in Oromia and SNNP Regional States.
61. Tsigereda, F., & Mengistu, U. (2011). Assessment of traditional cattle fattening practices and feedlot performance of Hararghe highland Bulls. Rev. Proc. 28th Annu. Res. Extension, Ethiop. 179–189.
62. Udomkun, P., Ilukor, J., Mockshell, J., Mujawamariya, G., Okafor, C., Bullock, R., Nabahungu, N.L., & Vanlauwe, B. (2018). What are the key factors influencing consumers' preference and willingness to pay for meat products in Eastern DRC? Food Sci. \& Nutr. 6, 2321–2336.

63. USAID. (2016). Nepal : Animal Source Foods Production and Marketing Brief.
64. Walsh, K., McCormack, C.A., Webster, R., Pinto, A., Lee, S., Feng, T., Krakovsky, H.S., O'Grady, S.M., Tycko, B.& Champagne, F.A. (2019). Maternal prenatal stress phenotypes associate with fetal neurodevelopment and birth outcomes. Proc. Natl. Acad. Sci. 116, 23996–24005.
65. Warner, R.D. (2017). The eating quality of meat'IV Water-holding capacity and juiciness, in: Lawrie{\'{}} s meat science. Elsevier, bll 419–459.
66. Warriss, P.D. (2000). Meat Science: An Introductory Text; CABI.
67. Webb, E.C., Erasmus, L.J. (2013). The effect of production system and management practices on the quality of meat products from ruminant livestock. S. Afr. J. Anim. Sci. 43, 413–423.
68. Wicks, J., Beline, M., Gomez, J.F.M., Luzardo, S., Silva, S.L.,& Gerrard, D. (2019). Muscle energy metabolism, growth, and meat quality in beef cattle. Agriculture 9, 195.
69. Worku, A., Urge, M., Animut, G., & Asefa, G.(2019). Comparative Slaughter Performance and Meat Quality of Rutana, Gumuz and Washera Sheep of Ethiopia Supplemented with Different Levels of Concentrate. Open J. Anim. Sci. 10, 48–63.
70. Worku, Z., Tilahun, S., & Tolemariam, T.(2016). Assessment of the prevailing cattle fattening practices in Jimma Zone, South-Western Ethiopia. Glob. Vet. 17, 105–113.
71. Yami, A., Gelaw, F., Koster, H., & Siraw, B. (2018). Reorienting Livestock Production to Respond to the Meat Quality Requirements of High-End Domestic and Export Markets 132.
72. Zander, K.K., 2011. Attitudes of livestock keepers to breeding strategies-threats and opportunities for on-farm conservation of the Borana cattle breed. J. Agric. Sci. 3, 3–12.
73. Zelealem, T., Anal, A.K., Gebrezgiher, G., 2012. Assessment of the sheep production system of northern Ethiopia in relation to sustainable productivity and sheep meat quality.