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Review Article

Opportunities to Improve the Quality of Beef Produced under Smallholder Mixed Crop and Rangeland Livestock Production Systems

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East African countries contain a substantial proportion of cattle (9.3%, 136.4 million) and small ruminants (12%, 253.4 million) compared to the world's total livestock population. In this region, more than 70% of the land surface is conducive to raise red meat animals. However, the region has limited share (approximately 1%) of meat products to the world market due to the failure to satisfy the minimal quality standard. Most of livestock farmers in this region are smallholders operating pastoral and mixed crop-livestock production systems. This study looked at reports on the quality of beef produced by smallholder production systems using Ethiopia as an example in order to identify potential and determinants in quality beef production under smallholders production system. In order to achieve this, research station beef quality reports were considered as a standard to compare the instrumental quality of beef reported from oxen and bulls raised by smallholders in mixed crop-livestock systems, ranches, and Hararghe cattle fattening systems. According to the analysis, oxen in the smallholders in the mixed crop-livestock systems produced comparatively lower-quality beef than oxen reared by the smallholders in the Hararghe fattening and bulls reared in the ranch systems, which produced good-quality beef. Improved feed resources are used in the Hararghe cattle fattening systems; oxen are used for draft service for a brief period of time (2.85 ± 0.58 years) and then sold for slaughter relatively at a young age. In pastoral settings, ranches offer options for the effective use of scare feed resources. The primary factors that determine the quality of beef produced from oxen raised in the mixed crop-livestock system were poor-quality feed resources, long-term draft service (6.62 ± 1.92 years), and old age at slaughter. To improve the quality of beef produced from the oxen raised in the mixed crop-livestock system, the practice of smallholder farmers in the Hararghe cattle fattening system needs to be adopted. The adoption of the practice also contributes to reduce the greenhouse gas emissions from the system and convert the subsistence mixed crop-livestock into a market-oriented system.

1. Introduction

Beef quality is one of the major factors that affects the competitiveness of East African meat exports on the global market [1–3]. Major determinants of meat quality include eating, nutritional, and microbial attributes. These attributes are affected by factors such as nutrition, health status, age, sex, breed, and preslaughter handling of cattle. Postslaughter carcass handling, such as electric stimulation, suspension methods, chilling conditions, and aging of the carcass, also affects the quality of the product. Among these factors, nutrition plays a major role in affecting beef quality [4]. The nutritional status of beef cattle is dictated by the production system.

Four major livestock production systems that are practiced worldwide are: intensive land use and low-input systems (smallholder mixed farming), extensive land use and low-input agro-/pastoral systems, intensive land use and high-input systems (indoor systems), and extensive land use and high-input ranching [5]. Each of these four systems has its own specific objectives, potential, and limitations. At the same time, these livestock-keeping systems influence the environment and livelihoods in different ways and can be optimized in a sustainable way, taking into account economic, social, and environmental considerations.

Africa accommodates more than a quarter of the world's livestock [3], which plays an important role in the continent's food, nutritional security, and economy. East African countries inhabit 9.3% of the cattle, 12% of the small ruminants, and 60.8% of the camels in the world [6]. The major livestock production systems in the region are pastoral, agropastoral, and mixed crop-livestock (MCL) systems. Pastoral and agropastoral production systems account for 53% of beef, 70% of mutton, and 68% of goat meat, while MCL systems account for 35% of beef, 29% of mutton, and 30% of chevon [7]. The same author reiterated that about 70% of the East African region comprises arid and semiarid lands that are conducive to meat animal production. Despite the large size of livestock in the region, it has a low animal product share (4%) in the global market [1]. The proximity of this region to the big meat market in the Middle East and North Africa (MENA) countries is one of the opportunities that need to be utilized. However, only 10% of the meat products imported by MENA countries came from East African countries, while Latin American countries, Europe, and Australia took the highest market share [1]. One of the major reasons why the MENA region imports small proportion of meat from the East African region is that the meat is of poor quality and, thus, doesn't satisfy the market and consumers.

To satisfy domestic meat demand and obtain a higher share of global markets, the East African major meat animal production system needs to supply quality meat. To identify the major determinants of meat quality and suggest possible improvements, the case of beef production in Ethiopia is analyzed in the current review. Ethiopia has the largest livestock population in Africa, with 65 million cattle, 40 million sheep, 51 million goats, and 8 million camels [8]. Beef cattle production systems in Ethiopia are categorized as pastoral/agropastoral, MCL, Hararghe cattle fattening (HCF) system, ranch, and intensive feedlot system. The pastoral system is practiced in the lowland part, which accounts for 50%–60% of the land in the country [9]. In this system, the primary purpose of keeping cattle is milk, with beef being a by-product. Ranches account for about 2% of cattle production [1], while MCL accounts for 77% of the cattle population in Ethiopia [9]. The latter system is characterized by a subsistence-oriented traditional system with poor cattle feed resources and draft service by the oxen. The Hararghe fattening system is a component of the MCL system, which is characterized as a traditional market-oriented system. A product-based fattening system is practiced in urban and periurban areas in Ethiopia, with a relatively higher number of agroindustry plants [2].

Studies have shown that production systems influenced the quality of beef. For example, extensively produced cattle have a higher muscle fiber area and Warner–Bratzler shear force (WBSF) value, darker meat color, and higher moisture content than beef produced from intensively produced cattle [10, 11]. However, the effects of Ethiopian production systems on the quality of beef are not well documented. The existing cattle production systems in Ethiopia differ in terms of feed resource, purpose of cattle, and husbandry management, which necessitate the need to understand influence of production system on quality of beef and come up with possible improvement strategies. This review analyzes the influence of smallholder cattle production systems on beef

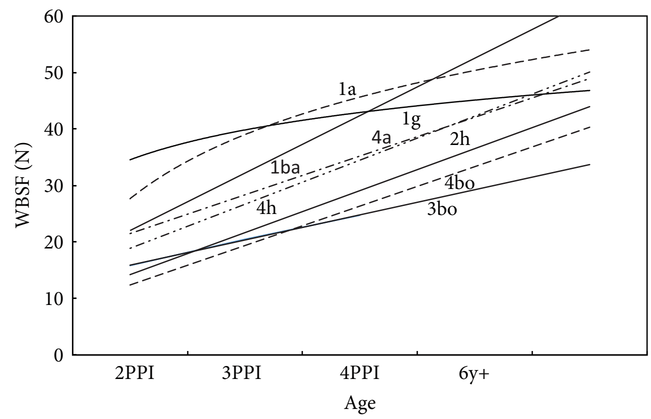

Figure 1: Trends of WBSF of beef from oxen/bulls reared under (1) MCL system, (2) HP system, (3) ranch, and (4) research station. a, Arsi; ba, Bale; bo, Boran; g, Gofa; h, Harar breeds; PPI, pair of permanent incisor; WBSF, Warner–Bratzler shear force.

quality and identifies determinants and opportunities to improve the quality of the beef.

2. Methodology

The research reports on the instrumental quality of beef from bulls and oxen raised under MCL, Hararghe fattening, and ranch beef production systems that served as the foundation for the evaluation and analysis. Since the research station is thought to meet all of the fundamental husbandry requirements for animal farming, beef quality reports from bulls and oxen finished under research stations were used as a standard for comparing the performance under smallholders production systems. Furthermore, research station reports clearly helped to determine the effect of cattle breeds on the quality of beef, which is, otherwise, confined to the production system. The review is based on the reports on the quality of the beef that were evaluated using instrumental methods such as WBSF, color, water-holding capacity (WHC), chemical composition, and fatty acid profile were used as sensory panel testing are subject to bias.

3. Quality of Beef Produced from Oxen Raised under the Mixed Crop-Livestock System

Figure 1 shows the trends in WBSF of beef from oxen and bulls raised on ranches, research stations, MCL, and HCF systems. The WBSF values for beef from bulls and oxen from Ethiopian cattle breeds reported by Dagne et al. [12], Merera [13], and Musa [14] were used to generate the trendlines. As trendlines 1a, 1ba, and 1g demonstrate, the tenderness of meat from oxen raised in the MCL system had a comparatively higher WBSF value. The tenderness value of beef was classified by Calkins and Sullivan [15] as follows: tender (<37.63 N/8.46 lb), intermediate (37.63–48.82 N), and tough (>48.82 N/10.3 lb). Based on this criterion, the tenderness of beef from the MCL system (1a, 1g) can be considered tender for oxen slaughtered to the age of replacing 2PPI and then intermediate and tough. The tenderness of beef shown by 1ba was tender for oxen slaughtered to the age of replacing 3PPI and then intermediate and tough beef. Gadisa [16]

Table 1: Lifetime draft service provided by oxen in MCL and HP systems in eastern part of Ethiopia (Adapted from [26]).

Draft service of oxen		MCLS*		HCFS**	
	N	Mean	SD	Mean	SD
Per day (hr, min)	15	5 : 19	0 : 12	3 : 20	0 : 24
Morning	15	2 : 53	0 : 14	0 : 44	0 : 10
Afternoon	15	2 : 26	0 : 15	2 : 36	0 : 21
Days per year (days)	120	99	13.9	27	5.3
Lifetime service (year)	120	6.62	1.92	2.85	0.58

*MCLS, mixed crop-livestock system; **HCFS, Hararghe cattle fattening system.

reported that out of the total beef samples collected from MCL, 39.43% were tender, while the rest were intermediate (26.76%) and tough (34%).

The availability of nutrition to cattle, which varies according on the production system, is one of the most important variables influencing quality of beef. It influences growth rates, age at slaughter, muscle energy, and subsequent meat quality [17]. The WBSF trend of beef from oxen raised under the MCL system was generally of lesser quality. The feed resource that is available in the system may be one of the reasons for the low quality. Crop residues (67%) are a primary source of feed for most cattle in this system [18]. According to Makkar [19], crop residue is low in digestibility (<55%) and contains low crude protein (<7%). Some other studies revealed that the livestock feed balance is negative in this system and cannot even meet the maintenance requirement of cattle [20, 21]. Wondatir and Mekasha [22] have also reported that feed supply in this system satisfies only 64% of DM, 81% of the ME, and 66% of DCP required for maintenance of cattle. In such circumstances, low growth rate and poor body condition of cattle are anticipated in this system. Animal with slow growth rate has a higher intramuscular collagen composition [23]. The presence of more connective tissue in the muscles of cattle raised on diets that contain low energy content was reported by Brewer and Calkins [24]. An average body condition score (BCS) of 4.1 was reported for cattle in the MCL system [21]. To achieve the marbling equivalent of a quality category called standard (USDA beef carcass grading system), cattle need to have an average BCS of 5. Based on this criterion, the relatively lower quality of beef from MCL system might also be attributed to lower BCS, which couldn't able to achieve marbling and quality equivalent of standard. Mummed and Webb [25] reported the presence of a higher proportion of inferior fat grades for castrated mature bulls slaughtered in municipal abattoirs in MCL systems. The poor quality of feed might possibly contribute to a slow growth rate, lower BCS, more connective tissue, and a higher proportion of inferior fat grade, which may explain the higher value of WBSF for beef from cattle reared in the MCL system. In the MCL system, oxen are used for beef purposes after a long period of draft service. A study by Adem [26], as shown in Table 1, showed that oxen work for an average of 6.6 years before they are slaughtered for beef purposes. Similarly, Kechero and Janssens [21] reported that oxen served draft service for an average of 6 years before slaughter in the MCL system in Ethiopia. Hume [27] reported that on average, working oxen need 1.2–1.7 times more energy than the energy required for maintenance. The inability of the feed to satisfy requirements for maintenance, growth, and work might negatively influence the body condition of cattle reared in the MCL system.

The study by Mume [26], as shown in Table 2, indicated that on average, oxen lose 10%–12% of their liveweight due to draft service during crop cultivation season in the MCL system. One of the reasons for the weight loss was that the feed resources were not able to meet the nutrient requirements for work, maintenance, and other physiological activities. This is well manifested by the higher WBSF value reported in wet season compared to the dry season in MCL system. Gadisa et al. [28] reported the WBSF values of beef at 42.94 and 23.3 N in wet and dry seasons, respectively, from oxen reared in the eastern MCL system of Ethiopia. Similarly, Nega [29] reported the WBSF values of beef at 36.31 and 26.62 N in wet and dry seasons, respectively, from oxen reared in the southern MCL system of Ethiopia. Supplemental feed given to the oxen during draft service may assist them to maintain their weight and body condition. If it is scare during this period, oxen should be supplemented before selling or slaughter, so that they compensate the weight loss during draft season. However, the practice of supplementing with appropriate feed for proper fattening before marketing is practiced only by 50% of farmers in the MCL system [26].

The quality of beef from oxen raised in the MCL system might also be affected by stress induced by the draft service provided by the oxen. The possibility of draft service inflicting chronic stress on the oxen was reported by Chimonyo et al. [30]. A number of studies have reported the role of physical exercise in imposing stress on cattle, thereby affecting the quality of beef [31–33]. This shows the possibility of oxen being exposed to additional physiological stress in addition to the already existing nutritional stress. The role of physical activity in increasing the insoluble collagen content of beef was reported by Petersen et al. [34]. Oxen exposed to physical activities due to draught power in the MCL system might contain a higher proportion of connective tissue in muscle due to a higher proportion of insoluble collagen. Furthermore, the exposure of oxen to physical activities might also increase the proportion of type I fiber, as physical exercise was reported to transform fast twitch (type II) fiber into slow twitch (type I) fiber. A high proportion of type I fiber in muscular tissue is one of the causes of tough beef [35]. These reports justify the possible contribution of physical exercise to a greater proportion of connective tissue, insoluble collagen, and type I fiber, which might also contribute to the relatively higher value of WBSF observed in the beef sample produced in the MCL system. The possibility of an association between draft utilization of oxen and beef quality was also suggested by Gadisa et al. [28] and Tefera et al. [36]. Animals exposed to long-term preslaughter stress can reduce glycogen stores at slaughter [37]. The loss of glycogen, which, otherwise, would have been converted to fat stored in the body, might be the cause of an increase in the

Table 2: Liveweight loss (%) of oxen during draft service period in MCL and HP systems [26].

Age (years)	MCL systems			HP systems		
	LWBP (kg)	LWEP (kg)	LW loss (%)	LWBP (kg)	LWEP (kg)	LW loss (%)
>8	255.79 ± 4.95	228.55 ± 4.76	10.6	–	–	–
4–6	234.31 ± 13.32	205.2 ± 11.21	12.4	267 ± 12.28	254.96 ± 12.25	4.51
6–8	253.63 ± 8.4	228.2 ± 8.67	10	289.16 ± 11.03	277.92 ± 11.26	3.89
Total	251.92 ± 10.19	225.27 ± 10.76	10.6	275.86 ± 16	264.14 ± 16.33	4.25

LW, liveweight; LWBP, liveweight before plowing season; LWEP, liveweight at the end of plowing season.

proportion of connective tissue that might affect the quality of beef. Birhanu [38] reported high levels of stress (CK and LDH) before loading for transport in beef from bulls reared in the MCL system. Higher level of stress enzymes might be due to the exposure of oxen to multiple stressors such as nutrition, draft service, transport, and heat stimuli during marketing cattle reared in the MCL system. The amount of glycogen present in the muscle, which determines the rate and extent of postmortem glycolysis at the time of slaughter, is one of the key factors controlling the postmortem course and the subsequent quality development [39]. Beef from cattle in the MCL system might contain less glycogen due to lack of sufficient nutrient in the feed and work stress that doesn't permit the meat to acidify enough by producing more lactic acid. Mume [26] reported a high level of ultimate pH in beef from cattle reared in the MCL system. Similarly, Gadisa et al. [28] reported a relatively higher ultimate pH for beef from oxen raised in the MCL system. Birhanu [38] reported high levels of DFD in beef from bulls reared in the MCL system. The level of DFD in beef from oxen reared under the MCL system was higher in the wet season compared to the dry season [28, 29]. This could be related to oxen being stressed during the wet season due to drafts or the feed resources may not provide surplus energy beyond what is required for work and maintenance, which could store as glycogen in the muscle. It is possible that inadequate glycogen storage in the muscle at slaughter contributes to higher pH levels and inadequate lactic acid production in the muscle, ultimately leading to the production of DFD beef. High levels of DFD in beef reduce the meat's shelf life and deter consumers from buying it. For the meat to stay edible and suitable for use in the production of beef products like sausage, the DFD levels should not exceed 10% [40]. Lawrie [41] reported the increase in ultimate pH of meat due to stress and a low-energy diet in an extensive production system, which subsequently produces meat with a low L^* value. Tefera et al. [36] and Mume [26] reported relatively low L^* values for beef from cattle reared in the MCL system. Raes et al. [42] and Nuernberg et al. [43] reported the association between high levels of physical activity and a lower value of L^* for beef, as physical activities induce more myoglobin content in the muscle. These analyses imply to the likely influence of draft-induced stress in affecting tenderness, the level of DFD, and color of beef in MCL system. WHC of beef is the other quality indicator, which can be affected by stress due to draft service given by oxen. The WHC is the ability of the meat structure to hold water during cutting, storage, and heating. Lean meat is comprised of approximately 72%–75% water, which is retained by thin actin/tropomyosin and thick myosin filaments [44]. The WHC of beef from oxen raised in MCL system is at lower margin, which was about 72% [26, 28, 36, 38, 45]. The WHC is reflected by drip, thawing, and cooking losses. Higher drip losses are characteristic of meat with lower WHC. Cooking loss is the amount of moisture released by the meat during cooking due to heat-induced structural changes in the tissue of the meat [39]. The denaturation of the myofibrillar proteins is initiated by cooking (30–50 and 55–65°C), and the proteins (myofibrillar and sarcoplasmic) coagulate, resulting in the shrinkage of the myofilaments and the release of the water contained in these fibers [46]. According to Gadisa et al. [28] and Mume [26], beef from oxen raised in the MCL system had high cooking losses (18%–20%). Skeletal muscle containing a high concentration of insoluble collagen and a lower concentration of intramuscular fat will have a high level of cooking loss [47]. The lower WHC and higher cooking loss from beef produced in the MCL system might be associated with higher connective tissue and lower intramuscular fat due to the low nutritional content of the feed that the cattle are fed. Wang [48] reported an increase in the intramuscular fat of the longissimus dorsi and a decrease in cooking loss as a result of an increase in dietary energy levels before slaughter. Su et al. [49] similarly reported a reduction in cooking loss and drip loss due to feeding carbohydrate-rich sources of feed such as corn or barley. Jeremiah et al. [47] stated that skeletal muscle containing a lower concentration of intramuscular fat will have a higher percentage of cooking loss. This all suggest the possible implication of poor feed resource in MCL system to low intramuscular fat and more connective tissue in the muscle of oxen at slaughter, which ultimately reduced the WHC and increased cooking loss of beef. Moreover, a lower WHC and higher CL were reported for beef from oxen slaughtered during the wet season compared to the dry season in MCL system [28, 29]. This might be associated to the stress the oxen experienced during the wet season because of the draft service in crop cultivation. The high stress level may cause the muscle's glycogen storage to be depleted, which would increase the percentage of DFD meat. Meat with a higher DFD and pH has a lower WHC and a higher cooking loss. The lower the drip and cooking loss, the higher the WHC, and the better the weight and quality of the meat in terms of

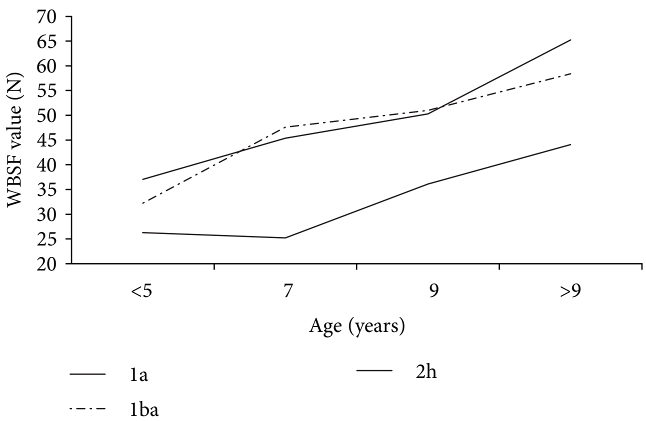

Figure 2: Trends of WBSF of beef from oxen reared under MCL and HP systems and slaughtered at different ages (1, MCL; 2, HP; a, Arsi; ba, Bale; h, Harar). Adapted from [28, 36].

juiciness and tenderness [50]. Consumers perceive meat with a high percentage of cooking loss or shrinkage during cooking as meat of poor or inferior quality [51].

The quality of beef from cattle raised under the MCL system may also be influenced by the age at slaughter. Based on the survey results by Mume [26], the majority of the farmers in the MCL system cull oxen for beef purposes due to old age. The use of oxen for beef purposes after 5 years of draft service in the MCL system was reported by several studies [21, 25]. In the MCL system, oxen are usually sold when they are found weak to pull draft implements and in poor body condition [9, 25, 52]. Figure 2 shows the increase in the WBSF of beef samples from oxen reared in the MCL system as the age increased from 5 to 9 years. The WBSF value of beef from the oxen reared under the MCL system and slaughtered below 5 years of age was between 30 and 40 N. The WBSF value of beef reared in the MCL system increases to 40–50 N as oxen advance in age from 5 to 7 years. As the age of the oxen in this system advanced beyond 9 years, the WBSF value increased to 65 N. Tefera et al. [36] reported the increase in WBSF value for beef from oxen reared under the MCL system as the age increased from 3 to 9 years. The decrease in tenderness of beef as cattle advanced beyond 3 years of age associated with an increase in the level of connective tissue [53]. The amount and composition of connective tissue, which change as the animal advances in age, highly influence tenderness [54]. The change in the quantity and degree of cross-linking in muscle connective tissue as the cattle mature in age results in an increase in the toughness of their meat. This change in connective tissue can be attributed to a change in muscle collagen solubility, which was reported as the major contributor to meat quality by Astruc [53]. The older age of grass-fed bulls at the age of slaughter was suggested as the possible cause for higher shear force values by Webb and Erasmus [55]. The scarcity of feed resources in quantity and quality in the MCL system, together with older age at slaughter, might have contributed to the low-quality beef produced in the system.

It is possible to reduce the negative effects of draft-induced stress on beef quality by feeding oxen well before, during, and after the draft service term. The tenderness of beef was improved by supplementing industrial by-products with oxen raised in the MCL system. Gibore [29] reported a mean WBSF value of 31.46 ± 1.37 N (tender beef) from oxen reared in urban areas of the southern MCL system, which was supplemented with industrial by-products. Similarly, Dereje [56] reported 30.13 ± 8.6 N WBSF value of beef for oxen reared in the dairy shade area of the central MCL system. These reports suggest the possibility of improving the quality of beef from oxen raised under the MCL system through the provision of supplemental energy and protein-sourced feed. Despite the production of tender beef, higher cooking loss values were reported for the beef samples from oxen reared in urban areas with industrial by-product supplements [29, 56]. Similar high initial and ultimate pH values of beef were reported by the same researchers.

4. Quality of Beef Produced from Oxen Reared in the Hararghe Cattle Fattening (HCF) System

The WBSF trend of beef, represented by 2h, as shown in Figure 1, suggested that the HCF system's beef quality might be classified as very tender or tender (10–40 N). In a similar condition, other quality parameters like WHC, CL, and proximal composition were deemed satisfactory. According to Gadisa et al. [28], beef from oxen raised in the HCF system had comparatively high WHC and low CL. Furthermore, the longissimus muscle of oxen finished under the HCF system had a comparatively good proportion of crude fat, polyunsaturated fatty acid (PUFA), linoleic acid, and low saturated fatty acid (SFA), according to Dagne et al. [12]. Oxen from the HCF system may have produced meat of good quality because of their access to an improved feed source, their brief draft service, low stress levels, and their relatively young age at slaughter.

Better feed resources for oxen are the cornerstone of HCF system, and this is typically accomplished through a cut-and-carry system. Usually, oxen are tethered near agricultural farms or farmer's homes. Improved grasses, forage legumes, and forages, which are provide as a feed for cattle, are widely adopted and used by smallholding farmers in the HCF system. Cattle mostly get their feed from sorghum and maize forage during the wet season. During the dry season, crop residues of maize and sorghum are supplemented with improved grass, hay from legume plants, and various grains as feed for the oxen. Leaves of fodder trees such as *Cordia africana*, *Vernonia amygdalina*, *Erythrina burana*, *Combretum molle*, *Casimiroa edulis*, and *Olea africana* are the other sources of feed [57]. Before selling their oxen, farmers often let them fatten for 2–3 months utilizing the feed sources stated earlier [58].

In addition to improved feed resources, short period of draft service might also contribute to the quality of beef produced in this system from oxen. Oxen reared in the

Table 3: Source of oxen and reason for culling in MCL and HCF systems based on 120 respondents [26].

Oxen	MCLS* (%)	HCFS** (%)
Source		
Purchase	42.2	68.1
Owen farm	42.2	22.0
Relatives	15.6	9.9
Farmers with fattening practice before marketing	56.7	83.30
Reason for culling		
Market	20	83
Old age	63.3	16.7

*MCLS, mixed crop-livestock system; **HCFS, Hararghe cattle fattening system [26].

HCF system served draft service for short periods, with 3 : 20 hr ± 0 : 24 min per day and 27 ± 5.3 days per year (Table 1). The brief period of draft service may not cause oxen to experience severe stress that could compromise the quality of the beef.

The quality of the beef produced in the HCF system may be influenced by the age at which oxen slaughtered. In the HCF system, oxen were sold for use as beef after serving an average of 2.85 years in the draft service (Table 1). The younger the oxen slaughtered might also be another reason for the good-quality beef produced in this system. This is further supported by the finding, which states that 83% of farmers' decisions to cull oxen in the system were motivated by the market (Table 3). Farmers sell their oxen at the end of the draft service, and a portion of the income is utilized to buy new young bulls that will be used in the draft service in the next cycle. The table also reveals that 68.1% of the HCF system's new draft oxen were bought on the open market. Similarly, the market is the primary source of bulls (>60%) for draft service in the HCF system, according to Gebreselassie [59]. According to the same researcher, the oxen from this system had a 50% higher premium in the tertiary market because of their excellent physical body condition. The cycle of purchase of young bulls, short draft service, fattening, and finally sale characterized the system as market oriented. Oxen reared in the HCF system loss 4.25% of its liveweight during draft delivery period (Table 2). Small proportion of liveweight losses during draft service may be the result of the shorter period of the draft service and availability of improved feed resources. According to some other researchers [58, 60], HCF systems are characterized as traditional market-oriented production systems.

The WBSF value trends of the beef, as shown in Figure 2, indicate that highly tender beef (WBSF value: 20–30 N) was produced by oxen slaughtered between the ages of 5 and 7 years, whereas tender beef (WBSF value: 7–9 N) was produced by oxen slaughtered between the ages of 7 and 9 years. Tender beef produced from oxen up to 9 years of age further confirms that the HCF system is a substantial contributor to the production of high-quality beef.

5. Quality of Beef from Bulls Raised under the Ranch

Very tender beef was produced from bulls raised in ranch settings until they reached the age of 3PPI as shown trendline 3bo in Figure 1. The very tender beef changed to tender beef as the bulls' ages increased past 3PPI. Tefera et al. [36] also reported exceptionally tender beef from bulls raised on ranches, with a WBSF value ranging from 15.83 to 24.73 N. For bulls younger than 3 years old, the same researchers reported production of good L^* value of beef from this system. The fatty acid content of beef from bulls raised in ranch settings was of good quality. Bulls raised on ranches have high levels of PUFA and MUFA in their longissimus muscles, according to Dagne et al. [12].

The ability to efficiently use feed resources by grazing natural pastures made up of grasses, forbs, and browses on species like *Cenchrus ciliaris*, *Cynodon dactylon*, *Pennisetum mezianum*, *Enteropogon somalensis*, *Chloris roxburghiana*, *Sporobolus* spp., *Eragrostis* spp., *Digitaria neghellensis*, *Alchiso*, and *Heteropogon contortus* species [61] could be one of the causes of high-quality beef from cattle raised on the ranch. In pastoral areas, the practice of ranch production and the formation of cooperative unions may contribute in driving subsistence pastoralists in the direction of a market-oriented mindset, making them to sell animals at an early age. This could be one of the reasons for the quality of beef produced by the system. Another factor contributing to the production of high-quality beef could be the formation of unions based on ranches, which made it easier to use technology and communicate directly with processors.

For this study, bulls were acquired from the DD Tiyara ranch, a ranch mostly produced Boran cattle breeds. A significant portion of the high-quality beef produced by the ranch may have also come from breeding strategies developed and implemented since 1960 in an effort to enhance the Boran breed on Borana rangeland. Mummed and Webb [25] described the long-term plan put in place to enhance the quality of the beef carcass in the Borana range region, specifically for the Boran breed.

The WBSF values, as shown in Figures 1 and 2, were based on evaluation of beef samples that came from the breed of Boran cattle that were bred at the DD Teyara ranch. These bulls are not subjected to draft-induced stress because they are not required to serve in the draft. Moreover, they were not exposed to market-induced environmental stress as they were purchased from the ranch directly for the experiment. Bulls from this system had comparatively low levels of stress prior to loading for transport, according to Birhanu [38]. It's possible that the bulls' reduced exposure to draft and market stressors contributed to the system's ability to produce high-quality beef.

6. Quality of Beef from Bulls Finished under the Research Station

This component of the review assessed reports on the quality of beef from the Arsi, Boran, and Harar cattle breeds that

Table 4: Proximate compositions of beef from bulls finished under research station (Adapted from [12, 13]).

Production system	MCL	HCF	Research station	
Breeds	Arsi (mean ± SD)	Harar (mean ± SD)	Arsi (mean ± SE)	Harar (mean ± SE)
Moisture	76.74 ± 0.71	77.27 ± 1.16	74.44 ± 0.48	74.65 ± 1.42
Dry matter	23.26 ± 0.71	22.27 ± 1.16	25.56 ± 0.48	25.35 ± 1.42
Crude protein	22.76 ± 1.04	20.52 ± 0.53	25.62 ± 1.36	26.25 ± 0.98
Ash	1.1 ± 0.07	0.63 ± 0.33	1.76 ± 0.14	1.80 ± 0.20
Crude fat	4.32 ± 0.14	5.58 ± 0.45	6.74 ± 0.26	8.96 ± 2.65

MCL, mixed crop-livestock; HCF, Harar production; MCLS, mixed crop-livestock system; HCFS, Hararghe cattle fattening system; SD, standard difference.

were purchased from MCL, ranch, and HCF systems and finished under research stations. The instrumental tenderness of beef from bulls of the Arsi, Harar, and Boran breeds finished under research stations was very tender and tender, based on the trend of WBSF of beef shown by 4a, 4h, and 4bo, as shown in Figure 1. These bulls were finished on a feed formulation that included 40%–48% concentrate and 52%–60% roughage to meet nutrient needs [13, 14]. The figure shows that the tenderness of beef from Boran bulls (4bo) is better than the tenderness of beef from Harar (4h) and Arsi (4a) bulls when finished under the research station, while the latter two breeds performed similarly. Musa [14] and Erge [13] didn't find a significant difference in the tenderness of beef obtained from Arsi and Harar bulls finished under similar feeding conditions. Similar proximate beef compositions, including moisture, crude protein, crude fat, and ash, were obtained by finishing bulls of the Arsi and Harar cattle breeds under the research station (Table 4). Additionally, there was hardly any DFD issue in the beef from bulls that were finished under the research station [13].

If the nutritional needs for maintenance, growth, and work were met, there was no significant difference in the WBSF value of beef from oxen that served draft service and those that did not (unpublished data). Accordingly, WBSF values of 29.31, 25.14, and 24.43 N were determined for beef from those oxen that have served 0, 4, and 6 hr per day. The results of the study showed that, as long as nutrient requirements were met, draft service-related stress had less impact on beef quality.

7. Implications of the Study and Opportunities to Improve Quality of Beef from Smallholders

Based on the analysis of beef quality for bulls and oxen finished under the research station, there are more opportunities to improve the quality of beef produced from bulls raised in ranch systems and oxen raised in the MCL and HCF systems. The WBSF value of beef from Arsi breed bulls, which were tough and intermediate under the MCL system, turned very tender and tender when bulls were finished under the research station. This suggests that by improving the quality of the feed supply and meeting the requirement of oxen, there are opportunities to improve the quality of beef from cattle raised under the MCL system. When compared to beef from the same breed finished under the research station (4h), the WBSF value of beef obtained from oxen of the Harar cattle breed finished under the HCF system (2h) was comparatively lower (better in tenderness). This shows the presence of good beef cattle husbandry practices in the HCF system. As was previously indicated, the system makes use of improved feed supplies, sell oxen for beef at a young age, and uses oxen for draft service for brief periods of time. When oxen of the Arsi and Harar breeds finished under the research stations, they produced comparable WBSF value of beef. The difference in WBSF value of beef, which was observed between the oxen of Arsi and Harar breeds in their respective MCLP and HCF systems, diminished when they were finished under similar feeding condition at the research station. Moreover, finishing Arsi and Harar breed oxen at the study station as opposed to smallholder MCL and HCF systems, the proximate composition of the beef was also enhanced. Beef from bulls finished under a research station had proximate components such as crude protein, crude fat, and ash that were better to those of beef from oxen and bulls raised under MCL and HCF systems (Table 4). This suggests the need to add more nutrients to the feed of oxen raised under the MCL and HCF systems in order to improve proximate composition of the beef. The proximate composition of the beef is heavily influenced by the nutrients found in the diet [62]. The proportion of DFD beef that was higher from oxen raised under the MCL system, relatively lower from oxen reared under the HCF system, and was almost absent from bulls finished under the research station. This suggests the presence of opportunities to minimize the problem in the MCL by sharing management practices from the former two systems.

Compared to their contemporaries raised on ranches, Boran bulls (up to the age of 3PPI), which were finished under the research station, had superior instrumental tenderness. However, as the bulls' ages increased past 3PPI, the tenderness of the beef produced by those bred in a ranch system was better (Figure 1; 3bo, 4bo). This suggests the presence of opportunities to improve tenderness of young bulls raised on the ranch by sharing management practices from the research station.

The quality of beef from bulls and oxen raised in the ranch and the HCF systems was generally as good as that of bulls finished at the research station. However, the beef produced by research stations was of higher quality than that of oxen raised in the MCL systems. The relatively lower qualities of beef from oxen raised under the MCL system might be attributed to a number of factors, including inadequate feed supplies, old age of oxen at slaughter, and a higher level of stress incurred by the oxen as a result of the long-term draft service used in MCL systems. Feed supplies don't seem to be able to meet the requirement of young bulls in the ranch system in order for them to produce quality beef.

Now the question is, how can the quality of beef produced from oxen raised by smallholders in a MCL system be improved? Adopting practices from other systems recognized for producing high-quality beef is undoubtedly the solution. Is it possible to adopt the practice used in the three production systems—the ranch, the research station, and the fattening of Hararghe cattle—in order to improve the quality of beef produced in the MCL system? The ranch practice in this regard is less likely to be considered for adoption in MCL due to the notable distinctions existed between the two systems. Furthermore, because the MCL system has restricted access to concentrates like cereal grains and industrial by-products, the research station practice is less likely to be considered for adoption in that system. The practice in HCF is the final alternate candidate practice to be taken into consideration for implementation in order to raise the quality of beef produced under the MCL system. The following query comes. Is it feasible to scale up the practice in the HCF to MCL system to improve the quality of beef? Let's analyze the two systems based on their similarities and differences. The HCF and MCL systems have a number of similar characteristics, among which the main ones are: first, the two systems are practiced by smallholders in MCL systems. Second, both are traditional systems by their nature. Third, oxen provide draft service in both systems. Some of the main differences between HCF and MCL systems are: first, the HCF system uses improved feed resources, but the MCL system did not. Second, oxen offer short-term draft service in the HCF system, but long-term draft service in the MCL system. Third, the practice of feeding oxen using a cut-and-carry system and tethering makes HCF resemble an intensive system, while the MCL system has more characteristics of an extensive system. Fourth, the HCF system is tilted to market-oriented system, while the MCL system is purely subsistent oriented.

Transforming smallholder livestock production systems toward intensification in developing countries is being suggested as one of the possibilities to improve the income of smallholders while safeguarding the environment. Moreover, transforming the widely practiced subsistent livestock production system into a market-oriented system was also suggested as one of the main approaches that should be considered to improve the livelihood of smallholder farmers in developing countries [3].

Since HCF and MCL systems have more similar practices, scaling up the practice of HCF to MCL help to fulfill deficiency and improve the quality of the beef in the MCL system. The scaling-up and adoption practices need to focus mainly on the following components:

(1) The use of sorghum/maize fodder, legume plants, and improved grass as feed resources.
(2) The use of oxen for draft service for a short period (2–3 years).
(3) The practice of fattening 2–3 months before selling oxen for beef purpose.
(4) The market-oriented attitude of smallholders (multiple cycle of sale of oxen).

Scaling up those basic practices from HCF to the MCL system benefits the smallholder farmers, the country, and the environment in the following ways:

(1) The quality of beef produced from oxen raised in the MCL system will be improved.
(2) The supply of more young oxen to the markets and processing plants increases.
(3) Transformation of MCL toward market-oriented system.
(4) Improves the income of smallholder farmers in MCL system and improves the contribution of the beef sector to the economy of the region.
(5) Greenhouse gas (GHG) emitted from the MCL systems will be minimized by the adoption of improved feed resources.

8. Conclusion and Recommendation

In general, the quality of beef from oxen and bulls reared under the HCF and ranch systems was as good as the quality of beef produced from bulls finished under the research station. But the quality of beef produced by oxen raised in the MCL systems was lower than the quality produced under the research stations. Major determinants for the quality of beef produced from the oxen raised in the MCL system were inadequate feed supplies (quantity and quality), the old age at slaughter of the oxen, and a higher level of stress incurred by the oxen as a result of the long-term draft service. The HCF system is the best candidate to scale up its practices to the MCL system in order to improve the quality of beef from the latter system. The benefits of scaling-up practices would not be limited to the improvement of the quality of beef. It further benefits the smallholder farmers in the MCL system to be transformed toward a market-oriented system.

The scaling up improves supplies of young oxen to the market, the income of smallholder farmers, and the economy of the region. Last but not least, it contributes to safeguarding the environment by minimizing the amount of GHG emissions from the MCL system.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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