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Effect of draft power on quality of sub-primal beef cut from hararghe highland oxen

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Abstract
The objectives of this study were to evaluate the impact of draft power on the quality of sub-primal beef cuts from 12 Hararghe highland oxen who completed their experiments on draft service at beef farm Haramaya University. The experiment was conducted over 8 weeks exposing 4 oxen for 0, 4, and 6 hrs draft service per day. At the end of the experiment, oxen were slaughtered. A total of 84 meat samples were collected from the right side of the 12 carcasses, specifically, a sample from each sub-primal cut: short rib, 7-Bone rib, blade, shoulder, cross rib (Fore quarter), tenderloin (Hind quarter) and longissimus dorsi. The meat samples were evaluated for pH, color, WHC, proximate composition, and instrumental tenderness using a WBSF device. The data collected was analyzed following the procedure of General Linear Model (GLM) using SAS software SAS version 9.4. When the GLM showed the presence of a significant difference between the different parameters, Duncan's multiple range tests will be used for mean separation. The result of the study revealed that the use of oxen for draft power significantly ($p<0.05$) affected on ultimate pH of 7-bone rib and blade among plowing oxen while the blade among plowing oxen for four hours was not significantly different. The current results show that in the mean of beef Redness (a*) and Yellowness (b*) color of Hararghe Highland oxen there was no variation in color values. The cooking loss percentage of steaks from sub-primal meat cut muscle in the current study was significant. There was a significant ($p<0.05$) difference in moisture, protein, and fat content of meat across the treatment experimental of Hararghe oxen. The water-holding capacity of Hararghe Highland Oxen was not significant ($p>0.05$). Thawing loss across treatment experimental of Hararghe oxen was significant and cooking loss also significantly different. From this study, it was concluded that the effect of draft power on the quality of beef in study areas was relatively significant. It is recommended that a strategy should be developed to encourage premium payment for young cattle marketing that is not exposed to draft service and create awareness among stakeholders on quality beef production. The pre-slaughter rest period was necessary for cattle and to fully utilize the benefit from Oxen after agricultural load strategy should be developed for cattle fattening practices to solve problems as well as to evaluate the effect of work performance on sub-primal beef cut quality of draft power cattle.

Keywords: Draft power, sub primal cut, meat pH, meat color, water holding capacity, instrumental tenderness, and warner bratzler shear force

Introduction
One of Africa's greatest populations of cattle is found in Ethiopia. According to the CSA (CSA, 2021) there are an estimated 70 million cattle in the world, along with 42.9 million sheep, 52.5 million goats, 13.33 million pack animals (Donkeys, horses, and mules), 8.1 million camels, and 42.9 million cattle. According to Sintayehu *et al.* (2013) [107], the sector accounts for 15% to 17% of the nation's gross domestic product (GDP), 35% to 40% of agricultural GDP, and 37% to 87% of family earnings. According to FAOSTAT (2013) [55], Ethiopia produced 338,150 (0.338) million tons of beef in 2012. According to Mummed and Webb (2014) [132], Ethiopian abattoirs typically used beef carcasses weighing 135 kg. Despite the vast amount of animal resources, meat and other by-products of slaughter were not fully exploited (Eyob and Zewudu, 2016) [50]. A significant source of foreign exchange from the production of cattle include live animals, meat, and leather items (Bereda *et al.*, 2016) [24].
Assefa and Hailu (2018) [1] state that the primary usage of cattle in Ethiopia's mixed crop-livestock system was to employ oxen for draft power during the crop cultivation season and

cows for milk production. A significant source of foreign exchange from the production of cattle include live animals, meat, and leather items (Bereda *et al*., 2016) [1]. The force necessary to pull an object a certain distance is referred to as the "draft" in agriculture. Comparing the productivity and effectiveness of draft animals requires an understanding of the physical concepts involved in employing animal power (FAO, 2010) [56]. According to Ethiopian farmers employ an animal-drawn plow that not much different from the original, simple ploughs that were employed millennia ago. Cropland agriculture frequently uses oxen as traction.

Draught capacity, animal husbandry, nutrition, and other performance-influencing elements are all necessary for efficient utilization of draught power. In the dry season, draft oxen frequently lose weight (Daniel, 2018) [111]. The ineffective use of draught animals was attributed, according to the same author, to a number of causes, including heat stress, inadequate feeding, management, inappropriate harnessing, and the presence of various infectious and parasitic illnesses. Along with reducing feed intake, draft work causes oxen's bodily reserves to be metabolized in order to support muscular activity. For working oxen fed on a subpar diet, this causes weight loss.

For thousands of years, Ethiopian agricultural systems have relied heavily on animal traction. The usage of cattle for plowing dates back to the latter portion of the third millennium BC (Goe and Astatke, 1989) [64].

The principal workhorses are zebu oxen, which are mostly utilized in pairs for threshing and preparing seedbeds. When oxen are scarce, ground is plowed by a combination of horses, mules, and donkeys, either of the same species or another. In the majority of the nation, all three horse species are employed for transportation. Camels are only utilized as pack and transport animals in the lowlands (Below 1500 m.a.s.l.) and arid areas. Crop wastes make up the majority of animal feed where crops and cattle are coexisting. Milk, meat, hides, dung, and draught power are the primary animal products. Additionally, livestock is a valuable economic resource that offers smallholder farmers financial stability. Ruminants provide about 3.2 million tons, or more than 72% of the nation's total meat production, to Ethiopia's economy, which depends heavily on the production and consumption of meat (Nigussie, 2001) [95].

Fattened cattle produced by smallholders after the utilization of oxen are the major source of meat in Ethiopia (Dawit, 2011) [40]. A report indicated that 409,869 beef cattle were used for domestic consumption and about 69,830 beef cattle were slaughtered for the export market annually. While Ethiopians consume about 8-13.9 kg of meat per capita annually, being lower than the African and the world per capita averages, which are 27 and 100 kg/year, respectively. (Ayele and Peacock, 2003; Betru and Kawashima, 2009; FAO, 2009) [17, 25, 52].

The management imposed on the animal pre-slaughter could induce stress responses that affect the final meat quality (Nogalski *et al*., 2018) [96]. Pre-slaughter stress has a role in causing DFD meat and poor handling can be detrimental to beef palatability directly. Animal handling and transportation are mainly stressful problems during transportation from the farm to the abattoir (Mpakama *et al.*, 2014; Mengistu *et al*., 2013) [91, 85] indicated that work stress had a lowering effect on slaughter weight, hot carcass weight and on the accretion of adipose tissues. The animal can be stressed by improper pre-slaughter handling that could result in undesirable pH, which causes pale soft exudative (PSE) and dark firm dry (DFD) meat, poor water-holding capacity, and end up in poor cooking loss (Adzitey and Nuru, 2011) [4]. The DFD meat has a high ultimate pH, which exposes meat for high microbial contamination (Weglarz, 2012) [127]. Pre-slaughter stress has effect on tenderness, Color and pH of beef (Birmaduma *et al.,* 2019; Ahmedin *et al.,* 2021) [28, 7].

According to some of the earlier research (Dagne, 2019; Birmaduma *et al*., 2019; Ahmedin *et al*., 2021) [118, 28, 7], the longissimus dorsi of the Harar breed of cattle showed superior instrumental softness than bovine breeds that were crossbred, Arsi, and Bale. The employment of a distinct draft power usage method, which was considered to have a comparatively smaller negative influence on the former breed than the later ones, was theorized to account for the superior quality of Harar beef over Arsi and Bale breeds. The location of the muscle and whether it is a member of the locomotor or inactive muscle have an impact on the qualities of cuts. In this study, it was expected that primal and sub-primal slices of beef would respond differently to oxen hauling draft tools. Primal and sub-primal cuts are the end product that would be used for consumption after cooking. The economic worth of these items may be determined with the aid of knowing the quality of the cuts, especially in the export market where different commercial values are assigned to cuts.

On sub-primal meat cuts, information about the employment of oxen for draft power was not recorded. In order to maximize the advantages of the draft service without considerably lowering the quality of the primal cut, it is thus helpful to understand the relationship between the durations of the draft service and the quality of the sub-primal cut. This will produce information about the potential impact of traditional draft oxen use on meat quality. Additionally, it's critical to produce pertinent data for the enhancement of beef quality generated in Ethiopia's mixed crop-livestock system. The goal of this study is to identify the degree to which draft power utilization methods affect the quality of sub-primal meat and to offer certain draft power utilization techniques for beef cattle. Therefore, this study was developed to address the following objectives

- To evaluate the effect of draft power service on the quality of sub-primal beef cuts from Hararghe highland oxen.
- To evaluate the effect of draft power working hours on the quality of sub-primal beef cuts of Harar Oxen.

Materials and Methods

Description of the Study Site

The study was conducted at Haramaya University, a beef farm which is located 527 km East of Addis Ababa. Haramaya University is located on the eastern escarpment of the Rift Valley at 9° 26' N latitude and 42° 03' E longitude and an altitude of 1, 400 to 2026 meters above sea level. It is situated in the semi-arid tropical belt of eastern Ethiopia and is characterized by a sub-humid type of climate with an average annual rainfall of about 600 to 1, 260 mm, the minimum and maximum mean annual temperatures are 9.59 °C and 24.15 °C, (Haramaya University Meteorological Observatory, 2019). The rainy season of the area is bimodal; the short rainy season stretches from March to May and the main rainy season from July to September (Tekalign and Hammes, 2005) [35].

Experimental Animals Housing, and Feeding Management

Twelve intact Hararghe bulls were purchased from *Chafe Bante* local market of West Hararghe at the age of about three years using dental estimation (Torell *et al.*, 2003) [120] and transported to Haramaya University. They have been drenched and sprayed against internal and external parasites, and ivermectin injection vaccinated against the disease before quarantine.

The oxen were housed individually in the pen separated by wooden planks equipped with feeding troughs to prevent the mixing of feed and feed spillages. During the quarantine period, animals were acclimated to the roughage and concentrated mix diet for 15 days. During the experimental period, they were supplied with roughage and concentrate mix based on their body weight total net energy (NE) requirement per day, and work level (For working oxen) into account. The total net energy (NE) required for growing (Non-working) bulls were estimated; 6.71Mcal per day. Under optimum conditions of feeding and management, oxen only use energy equivalent to 1.67 times maintenance when working a 5.5-hour day-1, for five days consecutively (Lawrence, 1985) [79], and/or depending on the level, type, and duration of work, working animal require 1.3 to 1.7 times more energy than maintenance need. Thus, NE required to oxen work for 4 and 6hrs per day were estimated; oxen work for 4 hrs per day was expended on average, net energy (NEw) of 4.54 Mcal day-1 while animal work 6hr day-1 was expended 6.32 Mcal per day for plowing.

Throughout the experimental periods, the diet consisted primarily of grass hay and concentrates, with a proportion of 46% grass hay supplemented with a concentrate mix, 54% made up of 21% maize grain, 17% wheat short, 14% Noug cake, and 1% pre-mix and 1% salt. To reduce the risks associated with concentrate, grass hay is provided first, followed by concentrate. When they are not at work, concentration was offered at 8:00 and 16:00 on both days for non-working groups, in two equal portions. After work, the oxen had unrestricted access to water. Every day before providing feed, the pens and troughs were cleaned. Except during working hours, the animals were housed in a barn.

Experimental Design

The CRD (Completely Randomized Design) was used for the experiment. Again, the oxen were

grouped into three teams of four oxen, and each team was purposely arranged in pairs based on their height, then assigned to working hours: 0, 4, and 6h/day, according to the average working duration practiced in Ethiopia. Accordingly, the oxen (4 pairs) were assigned to work and trained for 4-6 hours per day for a week. Four animals were randomly assigned to one of the treatment hours, 0hr (control), 4hr, and 6hrs. Then, 4 and 6hrs, working animals were paired based on their body weight, and body confirmation was trained for a week. The group was assigned to work 4hr per day plow only in the morning from 8:00 to 12:00 pm and the group worked for 6hr/day plow for 2:00 hrs commencing from 2:00 to 4:00 pm in addition to the morning work session, after resting for 2 hrs. This was sustained for five days per week, for a total of seven weeks. Hence, a completely randomized design (CRD) was used (Table 1). During working (Plowing), the harnessing system consisted of a wooden yoke and robe that connects the plow (hitch) to the yoke, and a moldboard plow with a total average weight of 22 + 0.4 kg was employed.

Table 1: Arrangement of experimental animal to treatment hours/levels of drought work

Oxen	Work Hour (s)			Total
	0 hrs/day	4 hrs/day	6 hrs/day	
3 years	4 (2pairs)	4 (2pairs)	4 (2pairs)	12

Slaughtering and Meat Sampling Procedures

Twelve intact Hararghe Highland oxen with 2PPI replaced (About 3 years) and had given draft service for 0, 4, and 6h/day per day for 8 weeks were slaughtered at the end of the experiment at Haramaya University. During experimental periods they were fed on 46% grass hay supplemented with a 54% concentrate mix. The concentrate mix contained 21% maize grain, 17% wheat short, 14% Noug cake and 1% premix, and 1% salt. The Oxen were slaughtered according to the slaughtering procedure of the Haramaya University community service abattoir. The sample was collected from sub-primal meat cut from the right side of each carcass. The samples were collected from a specific location of each sub-primal meat cut. Collected samples were immediately sealed and packed into plastic bags, and stored in the icebox, then transported to Oda Bultum University (OBU) Animal Science laboratory for instrumental meat tenderness evaluation.

Sample Collection

A total of 84 meat samples from sub-primal beef cuts were collected from the right side of each carcass. These sub-primal beef cuts were collected from the fore quarter and hind quarter. Parts of the fore quarter (short rib, 7-Bone rib, blade, shoulder, cross rib) and hind quarter (tenderloin), a total of six samples from each cut of 12 beef and a total of 84 were collected.

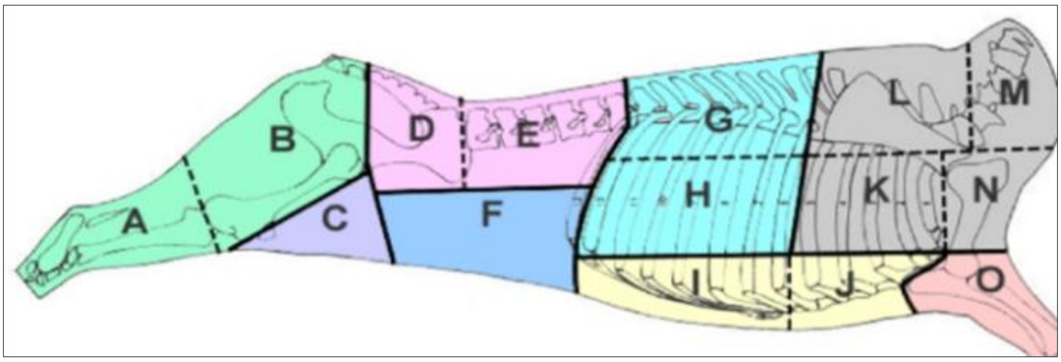

Fig 1: Beef primal and sub-primal

Meat pH Measurement

The pH was measured using a Portable microprocessor-based pH meter (model number-pH-013) at Sub-primal meat cut (C=sirloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade). The ultimate pH was measured at 24hr post-slaughter by directly inserting the probe into carcasses and the ultimate pH was measured at 24-hour postmortem on the meat sample. The pH meter probe was inserted into distilled water and a buffer solution (pH7) after each measurement, then the next sample was evaluated by inserting a probe into the meat sample and reading the value of pH after about 30 seconds (ESVLDM, 2005) [48].

Color of Sub-primal Meat Cut

Meat Colors were measured 24hr after the slaughter on each sub-primal meat cut (C=sirloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade) using a portable colorimeter (MiniScan EZ machine, model number 4500L, Hunter Associates Laboratory, Inc., Virginia, USA). The machine was calibrated before taking measurements using the black and white color standard samples, provided for this purpose. The color was expressed in terms of international standards for color measurement CIE (Commission Internationale de Eclairage) values for lightness (L*), redness (a*), and yellowness (b*) were recorded. $L*$ indicates lightness, 100 = white, 0 = black, increased values are lighter; $a*$ = measures redness, positive values are red, increased values are redder; $b*$ = measures yellowness, increases in $b*$ are more yellow. Three readings were taken on each sample by rotating the Color Guide 90° between measurements to obtain the average value for the color as presented in (AMSA, 2016) [8].

Water Holding Capacity of Sub-Primal Meat Cut

The water-holding capacity of sub-primal meat cut (C=sirloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade) was determined after 24hr and 14 days of postmortem aging in triplicate using the method suggested by Whiting and Jenkins, (1981) [28]. Two What man number-1 filter papers were weighed (A) and 50 grams of meat sample (C) were placed between two filter papers, this, in turn, was placed between two glass sheets. Over it, a weight of 2.52 kg weight was placed while the glass sheet weighed 0.45 kg sheet, giving a total compression weight of 2.97 kg load for 5 minutes. Then the weight was removed, and the meat was separated from the filter papers and weighed (D). In the end, the filter paper was dried and the weight was recorded (B). After that, the amount of protein attached to the filter paper and the actual weight of meat after pressure treatment were determined.

Amount of protein attached to the filter paper (E) = B - A
Actual weight of meat after pressure treatment (F) = E + D

Instrumental Tenderness of Sub-primal Beef Cuts

Approximately 350gm of meat samples were collected from each of the sub-primal cuts (Total of 84) samples taken were sealed and packed into plastic bags, stored in the icebox, and then transported to Oda Bultum University. The samples were aged for 14 days in a refrigerator at a temperature of -4 before steaks were prepared for instrumental tenderness analysis.

Determination of instrumental tenderness

Steak preparation

The steak preparation was done according to the Warner-Bratzler Shear Force Procedures protocol which was developed by AMSA (2016) [8] as shown below.

1. The steaks were cut 1 cm^3 perpendicular to the long axis the grain of the longissimus dorsi.
2. Three steaks were prepared per each sample
3. Steaks' initial weights were taken and recorded.
4. The thermocouple thermometer type T (450 ATT) was inserted into the geometric center of the steak for measuring internal temperature while the external, infrared thermometer with class II laser targeting item 60725 that uses 2A batteries was used.
5. Initial steak temperatures were recorded.
6. The steak was placed in a pan that was pre-heated to 204 °C, and a small amount of cooking oil was added to prevent the steak from sticking to the pan.
7. Steaks were flipped when the internal temperature of the meat reached 45 ˚C
8. Steaks were removed from the heat source when the steak reached 70 ˚C
9. The final cooking weight of the steaks was weighed and recorded.

The sensitive precision balance was used for weight steaks before and after cooking. Cooking loss was calculated based on the following formula.

Before WBSF assessed the tenderness of the steak, it was cooled at room temperature for an hour in accordance with AMSA (2016) [8] procedures. After samples had cooled, 2.5 cm of the steak's long axis were removed to reveal the fiber direction. Using the core of the WBSF device, six cores were removed from each sample in a line with the muscle fibers. Using the WBSF value in (N) for each core, the shear force was calculated across the middle (center) of each core. The values for each core were averaged for the determination of a single value of steak through weighing across the middle (center) of scientific balance using WBSF (G-P shear machine model- no GR - 151; serial no; 1612021 produced by GP-electric manufacture company PLC), expressed by newton (N) measurement value. The values for each core were averaged for the determination of a single value for each steak.

Thawing loss evaluation

The samples were analyzed in batches. After (14 days aged) samples were thawed for 24 hours, and frozen sample weight and thawed sample weight were recorded. Accordingly, the Thawing loss of the thawed sample was calculated according to the formula (AOAC, 1995) [11]:

Proximate Analysis

The proximate determination was conducted at the HU Animal Nutrition laboratory. 100gm steaks without subcutaneous fat, all exterior muscles and connective tissue were cut, chopped, thoroughly mixed then vacuum-packed and kept frozen at -20 until dried. The frozen fresh samples were dried at 55 for 72 hr, packed in polyethylene bags, and stored in a refrigerator at -4 pending proximate chemical analysis. The proximate composition of muscle moisture, protein, fat, and ash content was determined. The samples were thawed at 0, ground, homogenized, and analyzed in triplicate. The standard methods used for the analysis of meat samples were (AOAC, 2007) for muscle protein, and fat, and the (AOAC, 1990) [10] method 720-65 was used for the determination of ash contents of meat.

Data Analysis

The data of all activities was analyzed following the procedure of General Linear Model (GLM) using SAS software SAS version 9.4. When the GLM showed the presence of a significant difference between the different parameters, Duncan's multiple range tests were used for mean separation.

Models

$Y_{ij}=\mu+\beta_i+ e_{ij}$.

Where; Y_{ij} = Response variables for sub-primal cuts
μ = overall mean, Bi = fixed effect of the j^{th} working hours, j=0, 4 and 6hrs /day, eij = random residual.

Result and Discussion

Effect of Draft Power on sub-primal cut pH of Hararghe highland oxen: The effects of draft power on the sub-primal pH of beef were presented in (Table 2). The result of the analysis of variance indicated that draft power significantly effect on ultimate pH for group two sub-primal cuts (Sirloin, short rib,7-bone rib, cross rib, shoulder, blade) while the ultimate pH for group one experiment was not significantly different. The current result indicated that all of the sub-primal cuts included in the current study were significantly (p<0.05) influenced by the levels of draft power on ultimate pH for experimental group two animals. This might be due to variations in resting and working time as well as the level, type, and duration of work and the requirement of energy for working animals.

The mean values of the current finding for ultimate pH fall under the normal standard of meat pH of 5.4-5.8 Warris (2000) [124]. The current finding coincides with Gadisa *et al.* (2019) [60], who reported the ultimate pH of 5.73±0.02 for Beef carcasses from Harar, Arsi, and Bale Cattle. The current result of the study indicated that group two experimental of Hararghe highland oxen was a significant source of variation (p<0.005) on ultimate pH. This result contrasts with the report of Yesihak *et al*. (2019) [113] who revealed that there were not shown significant differences (p>0.05) in the ultimate pH of beef from Harar, Arsi, and Bale cattle breeds in Oromia, Ethiopia. This might be happened due to environmental differences, feed resources and the level of stress animals exposed made chronic stress on beef cattle. In another way, Arik and Karaka (2017) [13] reported that there were no significant differences in the ultimate pH of the carcass of beef cattle in a commercial abattoir in Turkey. Birhanu *et al*. (2019) [27] also reported the absence of significant differences in the ultimate pH of carcass qualities of meat in the Arsi, Harar, and Boran cattle breeds in Ethiopia.

Generally, meat from stressed Hararghe highland oxen due to draft power with high pH while meat from well-rested animals generally has better keeping quality due to desirable low pH. To enhance the keeping quality of meat it's always suggested that animals should be provided rest of at least 24 hours before slaughtering.

Overall, in carcass even though meat pH fall under the normal range there is not enough glycogen available in the animal, insufficient lactic acid will be produced and the PH will stay high in some sub-primal cuts.

Table 2: Effect of sub-primal cuts on the ultimate pH of beef

Treatment (working hours)			
T_0		T_1	T_2
Ultimate Sub Primal cut pH (24hr) Mean ±SE		Ultimate pH (24hr) Mean ±SE	Ultimate pH (24hr) Mean ±SE
Overall 5.86± 0.05		5.87± 0.07	5.76± 0.06
G	5.92±0.047	5.95±0.06	6.0±0.10^a
H	5.85±0.06	5.97±0.10	5.90±0.08^b
C	5.82±0.09	5.80±0.04	5.95±0.02^b
L	5.87±0.04	5.85±0.08	5.03±0.06^b
N	5.90±0.01	5.82±0.07	5.85±0.06^b
K	5.85±0.08	5.87±0.08	5.85±0.06^b
P-value	Ns		Ns **

Where, C=sirloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade
^{ab} Means bearing different superscripts are significantly different **p<0.05, Ns $p>0.05$

Effect of working hours of oxen on the sub-primal cut of beef color

Color is one of the most important quality parameters to determine the quality of beef, which is considered to be an indication of freshness and suitability for consumption. The normal ranges for beef color set were; L* = 33.2 - 41, a* = 11–23.6, b* = 6.1–11.3. The current results show that the mean value of beef lightness (L*), redness (a*), and yellowness (b*) color of Hararghe Highland oxen shows no variation in all sub-primal meat cut of color values). The mean value of all sub-primal cuts of beef lightness (L*), redness (a*), and yellowness (b*) fell within the normal ranges of meat quality set. In line with this result, Birhanu *et al*. (2019) [27] reported the absence of significant differences in color values (L*, a*, and b*) for Hararghe bulls. The absence of significant variation (p>0.05) observed in this result might be due to breed and environmental similarities as well as feed consumption and myoglobin content of muscles.

However, even if statistically there were no significant differences (p>0.05) among the three experimental groups in color values (L*, a*, and b*) for Hararghe Highland bulls were showed higher than the values reported by Ahmedin (2021) [7] and lower than the values reported by Birhanu *et al.* (2019) [27] in Arsi, Boran and Harar cattle breeds. This variation in color values as compared with the previous findings on the similar breed (Harar) with current work might be due to differences in animal diet, time of color evaluation after slaughter, and carcass management. Generally, in the present study, there was the absence of significant differences in meat color (L*, a*, and b*) for Hararghe Highland oxen.

Table 3: Effect of different working times of oxen on the sub-primal cut of beef color

Sub-primal cuts	Color value							
	Lightness (L*)			Redness (a*) T_1 T_2 p-v	Yellowness (b*)			p-v
	T_0	T_1	T_2 p-v T0		T_0	T_1	T_2	
Overall	31.67±2.41	32.14±1.56	3 3.13±1.47 Ns 12.04 ±0.65	12.66±0.46 11.95±0.94 Ns	11.45±0.90	11.35±0.77	11.13±0.67	Ns
G	32.67±1.11	34.36±1.94	35.88±2.18 Ns 11.36±0.79	12.87±0.50 10.82±0.74 Ns	11.11 ±0.41	11.84±0.71	11.38±0.33	Ns
H	34.93± 1.08	34.20±0.98	33.63±1.49 Ns 10.65±0.82	11.64±0.27 12.66±1.12 Ns	10.78±0.54	12.05±0.60	10.67±0.59	Ns
C	25.21±4.35	30.84±1.23	29.65±1.41 Ns 11.90±0.59	12.29±0.36 11.34±1.03 Ns	12.26±1.15	11.25 ±0.54	11.08±0.62	Ns
L	34.72±1.92	28.68±2.72	35.10±1.52 Ns 12.33±0.54	13.06±0.94 12.06±0.68 Ns	11.48±0.54	11.60±1.02	11.70±0.29	Ns
N	32.70±2.38	33.01±1.81	32.79±1.44 N s 11.25±0.28	12.22±0.34 12.40±0.41 Ns	10.17±1.22	9.40±1.10	11.40±0.67	Ns
K	25.84±3.64	31.45±0.66	31.75±0.81 Ns 14.75±0.91	13.88±0.35 12.46±1.67 Ns	12.92±1.59	11.97±0.67	10.55±1.55	Ns

Where, C=tenderloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade, Ns (None significant) at $p>0.05$

Effect of working hours on WHC of sub-primal cuts

The effect of draft power on WHC is shown in Table 4. Water holding capacity was not significantly influenced by the level of working time after slaughter. The mean water-holding capacity of Hararghe Highland oxen ranged from 64.2-68.18. This study showed that the mean water-holding capacities of all slaughtered cattle were higher than the mean (49.4±5.85) reported by Hailesilassie *et al*. (2018) [68] for cattle slaughtered in Mekele, Ethiopia. This is variation probably due to the genetic, environmental factors, post-mortem glycolysis, and rate of carcass temperature. However, the current result obtained in this study agreed with the report of Muchenje *et al.* (2008) [75] for Nguni, Bonsmara, and Angus steer in South Africa, who reported that the water-holding capacity of meat is influenced by pre-slaughter animal stress and the mean water holding capacity of the present study were found in the normal range of meat characteristics.

Nevertheless, this contrast with the report of Nega, (2022) [94] who suggests the highly significant source of variation ($p<0.001$) in water holding capacity in meat quality of Guraghe cattle in Gibe Woreda, Hadiya Zone. This implies that at different slaughter seasons, availability of feed resources and rest periods without a draft as well as breed differences. The findings obtained in this study are similar to some other studies by Birmaduma *et al.* (2019) [28] who reported that cattle had different body conformation at different seasons commonly related to feed resource availability. In line with the current result, Timketa (2019) [118] reported that there was no variation ($p>0.05$) observed in water holding capacity between an experimental group of Arsi, Boran, and Harar cattle. The similarities in water holding capacity may be due to similar intramuscular and fat thickness deposition.

The absence of differences between water holding capacity might be due to less variation of muscle structure which is determined by genes and collagenase enzyme. This is corroborated by Aparecida *et al.* (2017) [12] reported that water-holding capacity was influenced by genetic factors. The variation in the water-holding capacity in the case of aged meat was influenced by enzymatic reactions by endogenous enzymes, such as collagenase which are produced by bacteria within beef or by ionic solubilization, progresses at faster rates as aging increases. The collagenase enzymes disintegrate the myofibrillar proteins and connective tissue thereby improving the water-holding capacity of proteins.

Table 4: Effect of working hours on water holding capacity of the sub-primal cut

Treatment	Change in WHC %						
	G	H	C	L	N	K	Overall
T_0	66.05±1.97	67.44±1.71	66.70±1.77	67.66±1.22	67.79±1.28	66.11±2.25	67.21±1.73
T_1	66.6±2.62	67.63±1.27	67.65±1.07	65.88±1.51	67.68±1.41	67.45±0.98	66.51±1.12
T_2	68.18±0.83	67.44±2.73	65.86±0.53	65.75±2.00	67.27±1.52	64.2±1.73	65.18±1.40
P-Value			Ns				

Where, C=tenderloin, H= short rib, G= 7-bone rib, K=cross rib, N= shoulder, L=blade, change in WHC were non-significant at $p>0.0001$

Effect of working hours on thawing and cooking loss of beef: There were significant differences between the groups in cooking and thawing loss (Table 5). The cooking loss percentage of steaks from different sub-primal cut muscles in the current study shows that working time significantly affected the cooking loss percentage of sub-primal cuts except for L and K. In G and C sub-primal cut cooking loss percentage was significantly ($p<0.05$) reduced as the level of working time increased while the percentage of cooking loss increased as working time increased for H and N sub-primal cut. The differences in cooking and thawing loss might be due to the level of animals exposed to physical work as well as muscles having varying amounts of collagen, fat, and fiber from different parts of cut location even animals are the same breed. The effect of work on this parameter leads to variation as the animals are exposed to stress and weight loss due to drip loss and meat toughness. In addition, muscles vary in tenderness from one end to the other and the précises anatomical location from which samples are derived as well as differences in a muscle, meaning one portion of the muscle is often different from another portion of the same muscle for the various parameters studied.

The cooking loss percentage of Hararghe Highland oxen in the current study was slightly higher than those reported by Birmaduma *et al.* (2019) [28] which averaged 16.56% from Arsi, Bale, and Harar bulls, but lower than those reported for beef in Hawassa Ethiopia, and Muchenje *et al*. (2008) [75] who reported about 30% for north-eastern Switzerland oxen feed on grass. These differences might be due to cooking procedures, availability of feeds, breeds difference, and level of animals exposed to physical work as well as age variation of animals. The high cooking loss percentage observed in the current finding indicated that Hararghe Highland oxen had endogenous enzymatic reactions, such as collagenase disintegrating the myofibrillar proteins and making connective tissue thereby improving cooking loss.

Thawing loss of all sub-primal cuts also significantly ($p<0.001$) influenced by pre-slaughter working time. The current finding was lower than the report suggested by Ahmedin (2021) [7] who revealed significantly ($p<0.05$) higher thawing loss percentage were recorded from Harar bull. i.e., the difference in thawing loss depends on the variation of muscle structure, age, and environmental variation in which they are grouped. In line with the current result, Birmaduma *et al.* (2019) [8], Aparecida *et al.* (2017) [12] reported that thawing loss was influenced by physical work before slaughter which made animals' chronic stress.

Table 5: Effect of working hours on thawing loss and Cooking loss of sub-primal cut

Treatment	Sub-primal cuts					
	Thawing loss %					
	G	H	C	L	N	K
T_0	4.01±1.87^{a}	2.41±0.37^{b}	2.81±0.78^{a}	2.91±0.49^{a}	3.29±0.64^{a}	2.34±0.45^{ab}
T_1	3.50±0,09^{b}	2.84±0.60^{a}	2.17±0.17^{b}	2.17±0.10^{b}	2.40±0.64^{ab}	2.30±0.20^{b}
T_2	3.52±0.41^{ab}	2.61±0.43^{ab}	2.69±0.53^{ab}	2.50±0.53^{ab}	2.18±0.73^{b}	2.40±0.43^{a}
P-Value		*				
Cocking loss %						
Treatment	**G**	**H**	**C**	**L**	**N**	**K**
T_0	18.21 ± 3.21^{a}	23.64±6.18^{ab}	25.98 ±4.91^{ab}	19.58±2.06^{b}	11.32±0.72^{b}	19.65±2.19^{b}
T_1	13.95 ±1.68^{b}	21.71±2.02^{b}	21.03±2.41^{b}	22.44±8.72^{a}	16.68±4.20^{ab}	21.23± 4.28^{ab}
T_2	17.85±3.28^{ab}	29.05±3.48^{a}	23.25± 4.70^{a}	20.69±3.70^{ab}	18.91±4.02^{a}	26.73± 5.33^{a}
P-Value		**				

Where, C = Sirloin, H = Short rib, G = 7- bone rib, K = Cross rib, N = Shoulder, L = Blade, different superscript letters are significantly different at* $p<0.05$ for thawing loss, **=$p<0.05$ for cocking loss.

Meat proximate composition

The effect of working hours on the chemical composition of longissimus dorsi muscle were presented in Table 6. Determining the chemical composition of meat is necessary for assessing the nutritive value of meat because it is an important factor in determining both its nutritional value and its suitability for cookery purposes and processing. There was a significant ($p<0.05$) difference in moisture, protein, and fat except for the ash content of meat across the treatment experimental of Hararghe Highland oxen. This result was close to the report noted 76.0% and (74.41 to 76.8%) for moisture content respectively, and noted 0.99% for ash content. And also the moisture content in the current finding was comparable with the report of reported that the moisture content of longissimus dorsi ranges from 69.87 to 70.19%, reported moisture content ranges from 72.37 to 72.67% due to breed variation. The moisture content in the current finding was lower than the value reported noted 77.32% in the longissimus dorsi muscle for *Bos indicus* bulls.

The protein content for Hararghe Highland Oxen was lower than the report who reported the average value of meat protein is 23%. And also, the present finding was lower than the report and Dagne, (2019) [118] noted 22.1% and 20.08% of beef protein content for Arsi bulls. Similarly, a lower percentage of beef protein content 16.1% was reported by Tsegay *et al.* (2013) [121] from beef in Hawassa city. Relatively the lower value of meat protein percentage in the current finding as compared with the result of previous literature on similar breeds especially Harar bulls might be due to concentrate supplementation in the current finding and Hararghe, farmer's utilized maize and sorghum Stover as a dominant feed resource for cattle fattening. Generally, there was not a significant ($p>0.0001$) difference between the three groups of Hararghe oxen experiments in the ash content of meat. Moisture and fat accumulation recorded from Hararghe Highland Oxen were high for T0, this might be due to feed consumption as well as genetic or environmental factors and muscle tissue. In support of this suggestion, Springfield *et al.* (2013) [106] supported that the variations in the chemical composition of meat (protein and fat) seem to be linked or associated with differences in the genome and expression of proteins, which intervene in the extent and kinds of fat deposition. The variation in the moisture, protein, and fat among the parameters might be due to the précises anatomical location from which samples are derived as well as differences in a muscle, meaning one portion of the muscle is often different from another portion of the same muscle for the varies parameters studied.

Table 6: Chemical composition of meat (*Longissimus dorsi* muscle)

Treatment	Proximate composition (%)			
	Moisture (Mean ±SE)	Protein (Mean ±SE)	Fat (Mean ±SE)	Ash (Mean ±SE)
T_0	70.06±0.17^{a}	18.08±0.04^{b}	3.12±0.47^{a}	1.07±0.15
T_2	65.91±1.11^{ab}	20.34±0.06^{a}	2.18±0.56^{ab}	1.41±0.26
T_3	68.14±0.13^{b}	18.01±1.03^{b}	2.23±0.32^{b}	0.87±0.19
P-Value	**	*	*	Ns

Mean values under the same category that bear different superscript letters are significantly different, **=$p<0.001$,*=$p<0.05$ Ns= $p>0.05$

Warner-Bratzler shear force measures

Table 7 shows the average WBSF value for all Hararghe Highland oxen. Based on categories described by Calkins and Sullivan, who divided beef muscles into three tenderness groups, the current result suggested that the instrumental tenderness of the meat was mostly tender. These were measured as follows: instrumental tenderness 37.31 N (8.46 lb) tender, intermediate 37.49-44.54 N (8.5 - 10.07 lb), and tough meat >44.98 N (10.1 lb). The current result is less than that reported by Giusti *et al*. (2013) [62], who stated that the shear force values for the Canchim (37.71 N) and Nellore (41.67 N) animals after seven days of aging (42.66 N) at zero days of age of three beef cattle breeds in Brazil were 37.71 N and 41.67 N, respectively. Ethiopian beef needs to be heavily promoted in international

markets because Ethiopia plans to enter the Middle Eastern beef market.
The mean values of instrumental tenderness showed that the tenderloin (C), short rib (H), 7-bone rib (G), cross rib (K), and shoulder (N) had significantly different levels of tenderness. This could be as a result of the availability of feed resources in both quantity and quality, the rest of the draft cattle for an extended period of time without physical work, and less stress from cold and warm weather.

Table 7: Effect of working hours on instrumental beef tenderness of experimental bulls

	WBSF (Mean ± SE)		
Sub-primal cuts	**T_0**	**T_1**	**T_2 P-value**
G	26.20±8.13 ^{a}	20.88±3.39 ab	16.07±1.26 ^{b} **
H	19.81±3.48 ^{b}	20.65±1.60 ^{a}	15.50±2.17 ^{ab} *
C	18.45±2.46 ^{a}	11.96±4.09 ^{ab}	17.41±1.19 ^{b} *
L	19.94±3.43	19.01±3.76	21.89±3.16 Ns
N	27.30±2.13 ^{a}	20.15±3.8 ^{b}	19.20±5.58 ^{ab} *
K	14.40±2.95 ^{ab}	16.02±0.96 ^{b}	19.95±4.72 ^{a} *
Overall	21.01±3.76	18.11±2.93	18.34±3.01

Where, C = Tenderloin, H = Short rib, G = 7-bone rib, K = Cross rib, N = Shoulder, L = Blade, different superscript letters are significantly different at** $p<0.05$, *=$p<0.001$, Ns=0.05

The result was supported by Calkins and Sullivan who reported that aging is the most important way to improve meat tenderness. Generally, the mean value of WBSF (N) had a high significant difference ($p<0.001$) on the sub-primal cut. Hararghe Highland oxen had good instrumental tenderness.

Summary and Conclusion

Summary: The total cattle population is estimated to be 70 million, with 42.9 million sheep, 52.5 million goats, 13.33 million pack animals (donkeys, horses, and mules), and 8.1 million camels. Ethiopia produces about 338,150 (0.338) million tons of meat in 2012 from cattle. The average beef carcass weight at Ethiopian abattoirs was 135 kg. The study was conducted at Haramaya University cattle fattening farm to determine the level of influence of draft power utilization practices on sub-primal beef quality and fatty acid profile to suggest some recommendable beef cattle draft power utilization practices.
The CRD (Completely Randomized Design) was used for the experiment. Again, the oxen were grouped into three teams of four oxen, and each team was purposely arranged in pairs based on their height, then assigned to working hours: 0, 4, and 6h/day, according to the average working duration practiced in Ethiopia. The sample from sub-primal beef cuts a total of 84 meat samples were collected from the right side of each carcass. These sub-primal beef cuts were collected from the fore quarter and hind quarter. Parts of the fore quarter and hind quarter, a total of six samples from each cut of 12 beef, and a total of 84 were collected.
The result of the analysis of variance indicated that draft power was a significant effect on the sub-primal cut of the ultimate pH. Meat from stressed Hararghe highland oxen due to draft power with high pH while meat from well-rested animals generally has better keeping quality due to desirable low pH. The current results show that the mean value of beef lightness (L*), redness (a*), and yellowness (b*) color of Hararghe Highland oxen shows no variation in color values. The mean value of beef lightness (L*), redness (a*), and yellowness (b*) fall within the normal ranges of meat quality. Water holding capacity was not significantly influenced by the level of working time after slaughter. The mean water-holding capacity of Hararghe Highland oxen ranged from 64.2-68.18. The cooking loss percentage of steaks from different sub-primal cut muscles in the current study shows that working time significantly affected the cooking loss percentage of sub-primal cuts except for L and K. In G and C sub-primal cut cooking loss percentage was significantly ($p<0.05$) reduced as the level of working time increased while the percentage of cooking loss increased as working time increased for H and N sub-primal cut. Thawing loss of all sub-primal cuts also significantly ($p<0.001$) influenced by pre-slaughter working time. There was a significant ($p<0.05$) difference in moisture, protein, and fat except for the ash content of meat across the treatment experimental of Hararghe Highland oxen. Moisture and fat accumulation recorded from Hararghe Highland Oxen were high for T0, this might be due to feed consumption as well as genetic or environmental factors and muscle tissue. The mean values of instrumental tenderness indicated that there was a significant difference between Tenderloin (C), Short rib (H), bone rib (G), cross rib (K), and shoulder (N). This might be due to the availability of both quantity and quality feed resources, the rest of draft cattle for a long time without physical work, and less cold and warm weather stress.

Conclusion

Draft power significantly affected the ultimate pH of the sub-primal cut of treatment group two animals. The mean value of beef lightness (L*), redness (a*), and yellowness (b*) color of Hararghe Highland oxen shows no variation in color values. There is no significant variation in water holding capacity. The cooking loss percentage of steaks from different sub-primal cut muscles significantly affected working time except for L and K. In G and C sub-primal cut of cooking loss percentage was significantly reduced as the level of working time increased while the percentage of cooking loss increased as working time increased for H and N sub-primal cut. Moisture, protein, and fat except for the ash content of longissimus muscle was significantly affected by the difference in working hours. The mean values of instrumental tenderness indicated that there was a significant difference between Tenderloin (C), Short rib (H), 7-bone rib (G), cross rib (K), and shoulder (N) under the experimental treatment. Generally, Based on the current finding, it was concluded that Hararghe highland oxen in the current study produced a beef with very tender, stable color, nutritionally better suggesting high-quality beef.

Recommendations

- Introducing technologies that can reduce the draft load from the bulls or creating awareness to use bulls for the draft purpose for a season or two and sale for meat purposes with replacement with new ones for the draft may help in increasing the quality of meat from Hararghe Highland Oxen.
- Better feeding conditions and management need to be practiced to improve the quality of beef in the different farming systems.
- Further works and studies are recommended to investigate the effect of draft power related to age and seasons difference on meat quality in different environments.

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