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Carcass and Meat Characteristics of Hararghe Highland Bull after Draught Work Service

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Abstract

The objectives of the study were to examine the effects of draught work on carcass characteristics, meat yield potential, and distribution along primal cuts in Hararghe highland bulls fed on net energy requirement basis. Twelve bulls were sorted into three groups of four animals each and assigned to three treatment hours: control (0), 4, or 6, using a complete randomized design (CRD). The results of the study show that there are no significant differences ($p > 0.05$) in slaughter weight, hot carcass weight (HCW), chilling loss, total edible and non-edible offal, fat thickness (FT), deboned meat yield (kg), meat to bone ratio, muscle distribution, and proportion of kidney, pelvic, and heart fat (KPH%) among the treatment groups. However, the hot carcass-based dressing percentage was significantly lowered ($p < 0.05$) in bulls that work 4 or 6 hours a day. Meat yield was strongly correlated with HCW ($r = 0.74$) and FT ($r = 0.73$). Therefore, the number of hours the bull spent on draught work did not negatively impact meat yield or quality. Consequently, the research suggests that utilizing Hararghe highland bulls for draught service, four or six hours a day is viable for dual advantages: crop cultivation and marketable carcass.

Keywords

Bulls, Draught Work, Carcass Characteristics, Meat, Muscle Distribution

1. Introduction

Globally over 340 million tons of meat are produced annually (OECD/FAO) [1]. In Africa, ruminant meat production is 7.5 million tons per year, with cattle contributing 65% of this output, accounting for about 4% of global animal products

[2]. Specifically, Ethiopia produces 1128 metric tons (MT) of meat annually and its share of the global beef market is significantly low [2] [3] [4] [5] [6]. Ethiopia's low production potential, according to Alemu *et al.* [4], may be caused by the genetic limitations of indigenous breeds of livestock and management techniques like feeding systems and health care services. Many studies [7] [8] [9] [10] [11] confirm the significant impacts of breed, age at which animal slaughter, and feeding levels. The carcass weight of Hararghe highland cattle per head varies in ranges of 46.4 to 86.80 kg, 115.1 to 165.4 kg, and 106.2 to 115.6 kg [7] [9] [10], which is less than the world and East Africa averages carcass weight, 212 kg and 143 kg [12], respectively.

The sellable meat yield is related to the body composition of an animal, specifically the proportions of muscle, bone and fat in the carcass, and muscle to bone ratio weight. The carcass with a higher lean muscle proportion and less fat waste produces more retail beef, more economical [13]. Their weight and body composition change as cattle grow and mature, as do their muscle, bone, and fat proportions [14] and this holds true for all breeds, sexes, and age groups [7] [11] [15]. Thus, retail meat cuts are significantly influenced by the physical carcass characteristics [16] [17].

Several researchers have previously reported inconsistently on the impact of exercise on the carcass characteristics of animals [18] [19] [20] [21] [22]. Wilson [23] contends that unsuitable or excessive working conditions can negatively impact the quality and acceptance of products obtained from animals. Thus, the degree of physical stress an animal endures due to the draught work may have a detrimental effect on the yield potential, palatability and marketability of animal products.

Despite, Ethiopia's agricultural system relies on animal draught power [24] [25], there was no scientific evidence concerning how much using animals for draught power can affect the physical characteristics of carcasses specific to the Hararghe highland breed, with the exception of Mengistu *et al.* [26], who have attempted to address the carcass characteristic concern with limited variables in Ethiopian highland Zebu. Ewonetu and Ashenafi [27] suggested that assessing carcass characteristics of cattle following draught service is crucial, to enhance the productivity of the carcass for economic reasons [28] in the Ethiopia context.

Thus, the objective of the study was to evaluate the impact of draught service on carcass characteristics, meat output potential and its distribution along prime cuts in Hararghe highland bulls fed on a net energy requirement basis.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted at Haramaya University, a beef farm located 515 km east of Addis Ababa, 9˚N latitude and 42˚E longitude. Located at 1950 meters above sea level and receives average annual rainfall and temperature of 790 mm and 16˚C respectively [29].

2.2. Experimental Animal and Treatment Arrangement

Animals: A total of 12 intact Hararghe highland bulls, each aged three years, were purchased from the "Chafe-bante" local market. This choice of age corresponds with the point at which local farmers typically initiate their use for draught purposes. The bulls underwent deworming and were vaccinated against anthrax and Pasteurellosis. They were individually housed in separate stalls within a tin shed and strict hygiene protocols were maintained throughout the 21-day quarantine and the entire experimental duration.

Treatment: the experiment was conducted using a complete randomized design (CRD) with three treatment hours. The bulls were categorized into three groups, each comprising four bulls based on their initial body weight. They were then allocated to 0 (control), 4, or 6 draught work hours, within the context of Ethiopian farmer's practice. This allocation was carried out considering their height within group, guaranteeing balance arrangement during harnessing and a consistent distribution of the workload.

Experimental procedures: the experiment started after the bulls in the working group were trained and familiarized with the harness system. Each working group plows sandy loam soil for 4 and 6 hours while non-working bulls are left idle. The working schedule: bulls in the 4-hour working group ploughed from 8:00 to 12:00 in the morning for 4 hours, and bulls in the 6-hour working group plowed from 8:00 to 12:00 in the morning for 4 hours, followed by 2 hours rest from 12:00 to 14:00, and concluded with an additional 2 hours of work from 14:00 to 16:00 after noon (as described in **Table 1**). The work schedule was maintained for five days a week. The total experimental period extended over seven weeks (49 days).

2.3. Feed and Feeding of Experimental Animal

Estimating animal daily requirements: To estimate the total net energy requirement (NE_R) of bulls in each group, the following procedure was employed, as indicated in **Table 2**. For non-working bulls, their daily NE_R was calculated 6.68 Mcal per day. In contrast, working bulls were projected to utilize energy equivalent to 1.67 times the energy required for maintenance when working for 5.5 hours daily over five consecutive days [30]. Depending on the quality and quantity of feed, as well as the nature and duration of their work, working oxen might need between 1.2 to 1.7 times more energy than what is necessary for maintenance [30] [31]. With these considerations, the daily energy requirements for the

Table 1. Arrangement of experimental animal to treatment hours/draught work hours.

Work hour(s)	No.	Description	Work schedule	
			Morning	Afternoon
0	4	Not subjected for work (control)	-	-
4	4	Work 4 hours per day	8:00 to 12:00	-
6	4	Work 6 hours per day	8:00 to 12:00	14:00 to 16:00

Table 2. Total diet supplied (kg DM/day) for non-working and working bulls.

Work hours/day							0 hour	4 hours	6 hours
IBW (mean ± SE)							179.00 ± 5.84	180.25 ± 5.84	198.25 ± 5.84
Estimated energy requirement, Mcal/day									
NEm							3.77	3.78	4.07
NEg							2.91	2.93	3.15
NEw (NEm*1.2 or 1.5, respectively)							-	4.54	6.10
Total NE_R							6.68	12.39	13.32
		Energy in diet			Energy supplied by diet		Amount required, kg DM/day/animal		
		NEm	NEg		NEm	NEg			
Ingredients	DM%	Mcal/kg DM		% ingredien	Mcal/kg DM				
GH	89.29	1.23	0.66	46	0.56	0.30	2.70	4.20	4.80
Con. mix	-	-	-	54	0.92	0.58	3.17	4.81	5.62
MG	89.00	2.16	1.43	38.88	0.45	0.30	1.23	1.88	2.19
WS	89.00	1.63	1.03	31.49	0.27	0.18	1.00	1.52	1.77
NC	89.64	1.29	0.71	25.93	0.18	0.10	0.82	1.25	1.46
Primix	90.00			1.85			0.06	0.08	0.10
Salt	99.00			1.85			0.06	0.08	0.10
Total				100	1.48	0.88	5.87	9.01	10.42

DM: Dry Matter, GH: Grass Hay, MG: maize grain, Mcal: Megacalories, NC: noug cake, NEg: Net energy required for gain, NEm: Net energy required for maintenance, NEw: Net energy required for work, WS: Wheat short.

bulls were determined. Under current experiment, the bulls work 4 hours per day is expected to expand 1.2 times the energy needed for maintenance (NEW), 4.54 Mcal daily. On the other hand, bulls work 6 hours per day is estimated to expend 1.5 times the energy required for maintenance, resulting in 6.10 Mcal a day.

Ration formulation and feeding regime: A ration having a 54:46 concentrate to roughage ratio was used based on Mohammad [32] recommendation. The concentrate containing 38.88% maize grain, 31.49% wheat short, 25.93% Noug (*Gucia Abysinca*) cake, 1.85% pre-mix, and 1.85% salt were formulated and offered as per the daily requirement of the treatment groups. Priorly, in a week of diet adaptation, all bulls were allowed to gradually transition to their full concentrate mix diets using three step-up regimes. Throughout the experimental periods, grass hay was offered first, followed by concentrate mix, to minimize concentrate-associated risks. Non-working bulls were fed in two equal portions, which were offered twice a day at 08:00 and 16:00 hours, and working bulls were fed only when they were not at work. The pen and troughs were cleaned every day before offering feed. All bulls were allowed to access water freely after work.

2.4. Slaughtering Procedures

To minimize the bias of work stress on the subsequent evaluation of meat quality parameters, the bulls were given four days off from draught work before slaughtering, following the procedure of Aalhus and Price [33]. The bulls were kept with-out food for 12 hours but had free access to water. The weight of each bull was measured immediately before sacrifice. The bulls were slaughtered at the Haramaya University abattoir. The slaughter technique involves a swift, deep incision with a sharp knife in the spinal cord, followed by severing the throat, jugular veins, and carotid arteries. After slaughter, at the *atlanto-occipital* joint, the head was removed and at the *carpal-metacarpal* and *tarsal-metatarsal* joints, the fore and hind feet were removed, respectively. The bull was then de-hided and eviscerated. The edible (heart, liver, kidneys and empty digestive organs) and none edible [blood, head, feet, hide, spleen, lungs, trachea, genitalia, fat deposits (scrotal, kidney, pelvic, heart and omental)] offal components were weighed and recorded.

2.4.1. Carcass Characteristics Evaluation

Carcass weight: After evisceration carcass was dissected symmetrically on the right and left sides by a longitudinal cut made centrally with the chopper and knives along the spine, sternum and pubic symphysis [34]. After 45 min of post-mortem halves of the carcass were weighed and recorded as the total hot carcass weight (HCW) [35].

Dressing percentage: The carcass dressing percentage was calculated by dividing full carcass weight by slaughter weight (kg) [13].

$$\text{HCD\%} = \frac{\text{HCW}}{\text{SBW}} * 100$$

Chilling loss percentage: The left half side of the carcass was chilled for 24 hours, at 0˚C to 4˚C. Then, the carcass was removed from cold room, weighed, multiplied by two and recorded as full cold carcass weight (CCW, kg). Water loss during cooling was considered as carcass chilling loss and calculated as expressed by Schweighofer [36].

$$\text{Chilling loss}(\%) = 1 - \left[\frac{\text{CCW}}{\text{HCW}}\right] * 100$$

Rib eye area and fat thickness: Between the 12th and 13th ribs the *Longissimus dorsi* muscle area was measured, by placing plastic grid (Model number AS-234e) graded in square inches on the cut surface of the rib eye and counting all dots in the square. The area of the rib eye was then computed by dividing the number of dot in the squares to 10, in square inches [37]. Fat thickness was measured by a plastic ruler graded in millimeters.

2.4.2. Meat Yield and Meat to Bone Ratio Evaluation

Meat yield: The half left cold carcass was divided at 12th and 13th ribs into fore-and hindquarters, following the approach described by Holland *et al.* [38]. Briefly, each quarter was farther processed into "primal" cuts. Forequarter divided into: chuck, brisket, rib, plate, and fore shank. The hindquarter into: flank, loin, round, and hind shank. All "cuts in" were manually deboned. Meat (trimed, kg) and bone weight of each cut was recorded separately and multiplied by two, to gain full cut weight. The total meat weight was obtained from the sum of all meat collected from cuts.

Meat yield percentage: The meat yield proportion was calculated by dividing weigh of the meat by slaughter weight.

$$\text{Meat Yield}(\%) = \frac{\text{Meat}}{\text{SBW}} * 100$$

Meat to bone ratio evaluation: The meat to bone ratio of the carcass was computed by dividing the weight of the meat to weight of the bone in the carcass (meat: bone ratio).

2.5. Statistical Analysis

Carcass characteristics and carcass composition data were subjected to analysis of covariance (ANCOVA) in SAS-JMP Pro 17. In the model; draught work hour (0, 4, or 6 hours/day) was used as the main effect, and daily dry matter intake (kg DMI/day) as a covariate. kg DMI/day as a covariate allows the analysis to account for variations in nutrient intake among the group and to gate the specific impact of draught work hours on response variables. Prior to ANCOVA, datas were assessed for, normality using the Shapiro-Wilks test, $p < 0.05$. The datas in the tables was presented as least square means (*LS*-Mean) and standard errors of the mean (SEM). The least square mean differences among treatment groups (WH) in different parameters were separated using Tukey's studentized (HSD) range tests at $p < 0.05$. A multiple correlation analysis was employed to assess the relationship between MY and carcass characteristics.

Models:

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + \beta_3 X * Z$$

where:

Y: Response variable(s);

X: Work hour with three level: 0, 4 and 6 hour(s);

Z: Daily dry matter intake (kg DMI/day);

$X * Z$: Interaction among work hour and daily dry mater intake (kg DMI/day);

β_0: Intercept;

β_1: Effect of work hours on response variable;

β_2: Effect of daily dry matter intake (kg DMI/day) on response variable;

β_3: Interaction effects between work hour and daily dry mater intake (kg DMI/day).

3. Results

3.1. Draught Work Hour Effects on Carcass Characteristics

3.1.1. Carcass Weight, Fat Thickness and Rib Eye Area

Table 3 shows the effects of draught work hour on carcass characteristics of Hararghe highland bulls. The result showed the significant interaction effects of draught work hours and daily dry matter intake (WH*kg DMI/d) ($p < 0.05$) for hot carcass dressed percentage and fat thickness (Figure 1). The hot carcass weight (HCW) and hot carcass dressing percentage (HCD%) ($p < 0.05$) were significantly related to the covariate, daily dry matter intake (kg DMI/d), while slaughter weight (SBW), chilling loss (ChL%), fat thickness and rib eye area were not ($p > 0.05$). The results also indicated that draught work hours had a significant effect on HCD% ($p < 0.05$) after controlling for the effects of the covariate, kg DMI/day. However, in all other variables no significant changes ($p > 0.05$) were observed due to draught work. It was noted that bulls in the four and six-hour working groups tended to have lower hot carcass weights numerically compared to the non-working group.

Table 3. The draught work hour impacts on the carcass characteristics of Hararge highland bulls.

Variables	Work hour·day^{-1}			p- *Value*		
	0	4	6	WH	DMI/d	WH*DMI/d
	LSM ± SE					
SBW, kg	214.25 ± 15.38	201.69 ± 6.31	204.15 ± 5.71	0.7591	0.0982	0.1719
HCW, kg	123.80 ± 10.13	93.96 ± 4.15	98.06 ± 3.76	0.0892	0.0193	0.6568
HCD%	57.61^{a} ± 2.39	46.60^{b} ± 0.98	48.01^{b} ± 0.89	0.0153	0.0142	0.0394
ChL %	0.62 ± 0.57	1.14 ± 0.23	1.02 ± 0.21	0.6988	0.3280	0.4859
FT (mm)	1.29 ± 0.71	0.90 ± 0.29	0.81 ± 0.27	0.8245	0.5342	0.0450
RIA (inch^2)	5.85 ± 1.38	6.30 ± 0.57	7.67 ± 0.51	0.2213	0.9895	0.4086

$^{a-b}$; different letter in the same raw are significantly different at $p < 0.05$, ChL%: Chilling Loss percentage, DMI/d: daily dry matter intake (kg), HCD%: Hot Carcass dressing percentage, HCW: Hot Carcass Weight, kg: kilogram, FT: Fat thickness (mm), RIA: rib eye area (inch^2), SBW: Slaughter body weight, SE: standard error of mean, WH: work hour per day, WH*DMI/d: work hour and daily dry mater interaction effects.

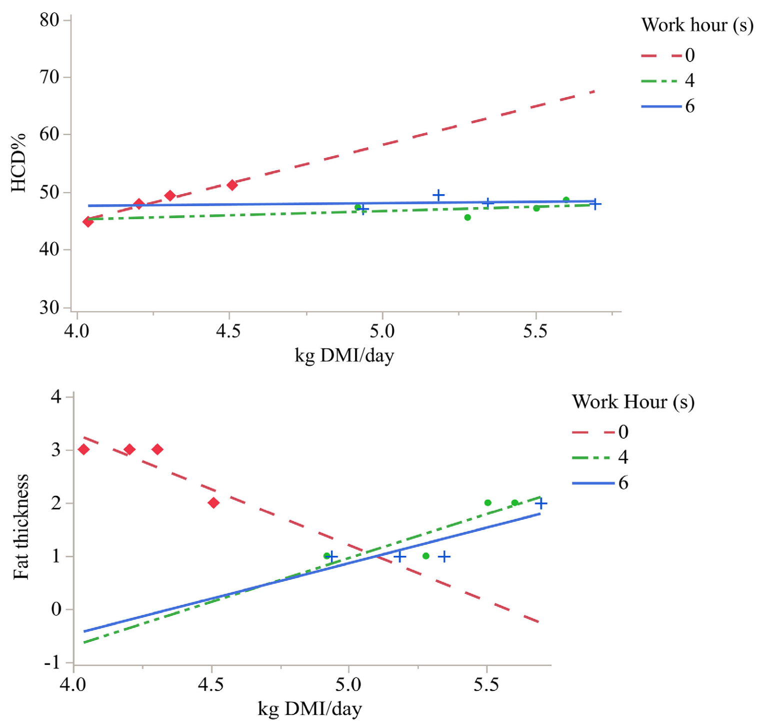

Figure 1. Work hour × daily dry matter intake (kg DMI/day) interaction for dressed percentage and fat thickness.

3.1.2. Draught Work Hour Effects on Offal's

Table 4 presents the impact of draught work hours on the offals of Hararghe highland bulls. Work hours and daily dry matter intake had no significant interaction effect on the weight of total edible (TEO) and none-edible (NEO) offal's except heart weight ($p < 0.05$) (Figure 2). The daily dry matter intake had only a significant correlation with liver weight ($p < 0.05$). The effect of draught work hours on the weight of organs, independently of the covariate, was not found to be significant ($p > 0.05$).

3.2. Draught Work Hours Effects on Carcass Composition

3.2.1. Organ Fat Depot

Except for kidney fat ($p < 0.05$) (Figure 3), the interaction between work hours and dry matter intake per day (WH*DMI/d) did not demonstrate a significant effect on any organ's fat (scrotal, pelvic, heart, omental) and KPH%. It was also discovered that the variables under the current study did not significantly correlate with the daily dry matter intake (kg DMI/d), ($p > 0.05$) (Table 5). After adjusting for the covariate of dry matter intake, the effect of draught hour worked on organ fat was not statistically significant ($p > 0.05$).

3.2.2. Total Meat Yield and Meat to Bone Ration

Table 6 presents the impact of work hours on meat, bone yield (kg), and meat to bone ratio. The results show that the covariate, kg DMI/day, did not exhibit a significant effect on meat yield, yield percentage, and meat to bone ratio ($p > 0.50$). Furthermore, the meat yield, yield percentage, and meat to bone ratio did not demonstrate significant differences ($p > 0.05$) among the treatment groups that underwent varying work hours, regardless of the level of daily dry matter intake (DMI/d).

3.2.3. Primal Cut's Meat Yield

The effects of draught work on the distribution of meat along the primal cut in bulls subjected to different work hours are presented in Table 7. The results indicate that, except chuck ($p < 0.05$), there was no significant daily dry matter intake (kg) effect on each primal cut the meat yield (kg). Additionally, there were no statistically significant changes ($p > 0.05$) between the treatment groups in the meat yield of each cut. The LS-mean value of chuck in the working group did, however, tend to be lower than in the non-working group, despite the fact that this difference was not statistically significant (Table 7).

3.2.4. Carcass Characteristics Traits Correlation with Total Meat Yield

The correlation between meat yield and carcass traits is depicted in Table 8. The results indicate meat yield (MY) has a very strong positive correlation with hot carcass weight (HCW, $r = 0.74$) and fat thickness (FT, $r = 0.73$), $p < 0.05$. It has also a high correlation with the slaughter weight ($r = 0.59$) and hot carcass dressing percentage (HCD%, $r = 0.58$). In contrast, MY and RIA are not correlated ($r = -0.02$). High positive correlations between slaughter weight and HCD% and HCW are observed ($r = 0.86$ and 0.69, respectively).

Table 4. The draught work hour impact on the offal's weight of Hararghe highland bulls.

Variables	Work hour·day^{-1}			p- *Value*		
	0	4	6	WH	DMI/d	WH*DMI/d
	LSM ± SE					
TNEO	48.73 ± 6.79	51.91 ± 2.78	51.50 ± 2.52	0.9114	0.3184	0.1131
TEO	21.15 ± 2.38	17.62 ± 0.97	19.59 ± 0.88	0.2760	0.3574	0.4864
		Organ's weight (kg)				
Work hour·day^{-1}		Em. Viscera	Heart	Liver	Kidney	
0		16.25 ± 2.23	0.81 ± 0.07	3.68 ± 0.74	0.40 ± 0.10	
4		14.55 ± 0.91	0.80 ± 0.03	1.90 ± 0.30	0.37 ± 0.04	
6		15.47 ± 0.83	0.70 ± 0.02	2.98 ± 0.27	0.44 ± 0.04	
p value	WH	0.6792	0.0698	0.0587	0.5299	
	DMI/d	0.9647	0.0035	0.0368	0.9290	
	WH*DMI/d	0.6758	0.0106	0.0550	0.9210	

DMI/d: daily dry matter intake (kg), kg; kilogram, SE: Standard Error, WH: work hour, TEO: total edible offal's, TNEO: total non-edible offal's, WH*DMI/d: work hour and daily dry mater interaction effects.

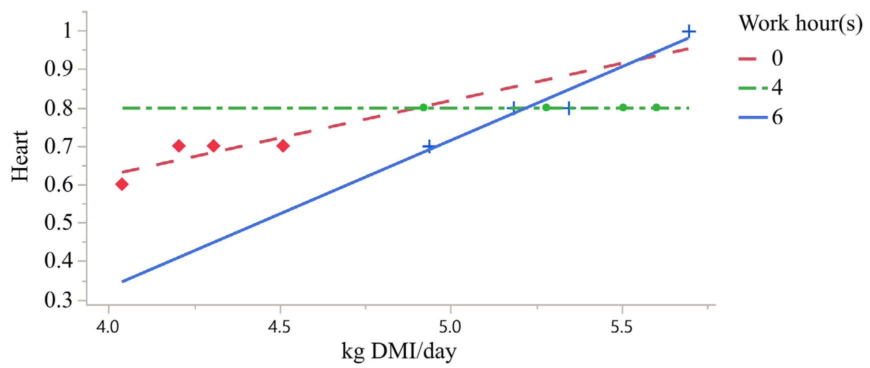

Figure 2. Work hour × daily dry matter intake (kg DMI/day) interaction for Heart (kg).

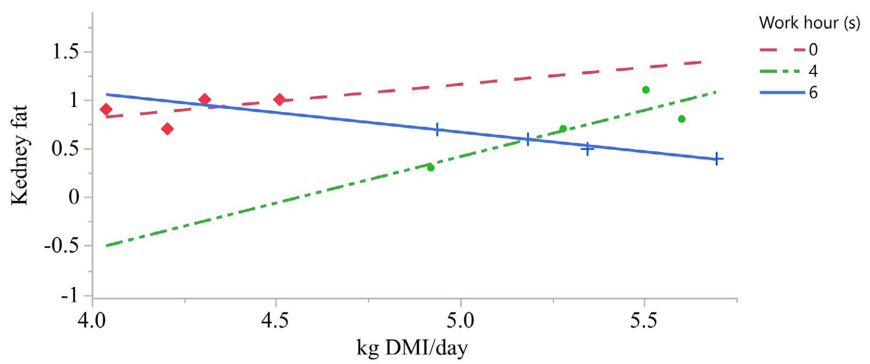

Figure 3. Work hour × daily dry matter intake (kg DMI/day) interaction for Kidney fat (kg).

Table 5. The draught work hour impact on internal organ's fat depot of Hararghe highland bulls.

Variable	Work hour·day^{-1}			p-*value*		
	0	4	6	WH	DMI/d	WH*DMI/d
	LSM ± SE					
Scrotal fat	0.66 ± 0.37	0.41 ± 0.15	0.77 ± 0.14	0.2819	0.5508	0.0747
Kidney fat	1.14 ± 0.30	0.38 ± 0.12	0.68 ± 0.11	0.1006	0.1665	0.0335
Pelvic fat	0.66 ± 0.63	0.41 ± 0.26	0.62 ± 0.24	0.8286	0.6945	0.9182
Heart fat	0.44 ± 0.14	0.39 ± 0.06	0.52 ± 0.05	0.3317	0.5458	0.3232
Omental fat	2.18 ± 0.79	0.92 ± 0.32	1.47 ± 0.29	0.2986	0.4016	0.1420
KPH%	1.04 ± 0.42	0.59 ± 0.17	0.88 ± 0.15	0.4044	0.5046	0.2823

DMI/d: daily dry matter intake (kg), kg: kilogram, KPH%: kidney, pelvic and heart fat percentage, SE: standard error of mean, WH: work hour per day.

Table 6. The impact of draught work hour on meat yield, yield percentage and meat to bone of Hararghe highland bulls.

Carcass component	Work hour·day^{-1}			p *value*		
	0	4	6	WH	DMI/d	WH*DMI/d
	LSM ± SE					
Yield (kg)						
Meat	89.74 ± 11.14	68.03 ± 4.56	69.66 ± 4.13	0.2669	0.2153	0.9385
Bone	33.15 ± 5.63	27.04 ± 2.31	27.40 ± 2.09	0.6200	0.0503	0.1094
	Proportion (%)					
Meat	41.74 ± 3.70	33.74 ± 1.51	34.01 ± 1.37	0.2025	0.5006	0.2685
	Ratio (kg)					
Meat: bone	2.59 ± 0.77	2.52 ± 0.32	2.53 ± 0.29	0.9970	0.4066	0.3331

DMI/d: daily dry matter intake (kg), WH: work hour per day, SE: standard error of mean.

Table 7. The impact of draught work hour on primal cut's meat yield (kg) of Hararghe highland bulls.

Cuts (kg)	Work hour·day^{-1}			p *value*		
	0	4	6	WH	DMI/d	WH*DMI/d
	LSM ± SE					
Chuck	31.29 ± 3.35	21.881.37	20.63 ± 1.25	0.0656	0.0154	0.7367
Brisket	1.13 ± 1.41	2.39 ± 0.58	0.81 ± 0.52	0.2056	0.8044	0.1463
F. shank	2.96 ± 2.50	1.00 ± 1.03	2.34 ± 0.93	0.5893	0.8986	0.7269
Rib	8.55 ± 2.33	7.57 ± 0.95	7.85 ± 0.86	0.9225	0.9739	0.8789
Plate	2.20 ± 0.85	1.71 ± 0.35	1.25 ± 0.32	0.4826	0.7321	0.9117
Loin	17.48 ± 3.81	13.12 ± 1.56	14.61 ± 1.42	0.5542	0.5893	0.8819
Flank	3.01 ± 1.70	2.57 ± 0.70	2.64 ± 0.63	0.9725	0.9798	0.9409
Round	18.58 ± 3.28	16.16 ± 1.34	16.53 ± 1.22	0.7987	0.6852	0.9913
H. shank	4.54 ± 3.06	1.63 ± 1.26	2.99 ± 1.14	0.6006	0.8849	0.7080

DMI/d: daily dry matter intake, F. shank: fore shank, H. shank: hind shank, WH: work hour per day.

Table 8. Correlation of carcass traits with total meat yield (kg) of Hararghe highland bulls treated under different level of draught work hour.

	SW	HCW	HCD%	RIA	FT	MY
SW	1	0.86 (0.0003)	0.23 (0.4731)	0.22 (0.4932)	0.56 (0.0604)	0.59 (0.0435)
HCW		1	0.69 (0.0127)	0.13 (0.6843)	0.42 (0.1760)	0.74 (0.0059)
HCD			1	−0.06 (0.8486)	0.02 (0.9618)	0.58 (0.0477)
RIA				1	−0.11 (0.7230)	−0.02 (0.9514)
FT					1	0.73 (0.0065)
MY						1

FT: Fat thickness (mm), HCD%: Hot carcass dressing percentage, HCW: Hot carcass weight, MY: total meat yield, RIA: Rib eye area (inch2), SW: Slaughter weight. Size of correlation [±1 = perfect, [±0.90 to 0.99] = very high, [±0.70 to 0.90) = high, [±0.50-to 0.70) = moderate, [±0.30 to 0.50) = low, [±0.10 to 0.30) = very low, and [0 to ± 0.10) = markedly low].

4. Discussion

4.1. Draught Work Hour Effects on Carcass Characteristics

The observed, work hour × daily dry matter intake interaction for hot carcass dressed percentage (HCD%) and fat thickness (FT) of the experimental bulls ($p < 0.05$), suggested that both HCD% and FT of the experimental bulls varied with the amount of diet consumed. The HCD% of non-working bulls increased with increased intake, while the working group showed stagnant improvement (as shown in **Figure 1**). On the other hand, the fat thickness of non-working bulls showed decreasing trends, while it still remained higher than both 4- and 6-hours working bulls. The fat thickness of the working bulls showed a trend of improvement with increased dry matter intake. The amount of time bull spent doing draught work has no remarkable impact independently of daily dry matter intake on various carcass characteristics of bulls except HCD% ($p > 0.05$) (**Table 3**). The findings of the present study are consistent with the previous studies. Mengistu *et al.* [26] reported that using Ethiopian highland zebu oxen for draught purpose has no impact on their carcass characteristics. But, Zhang *et al.* [22] found that physical training had little impact on the carcass characteristics of sheep. Additionally, the physical exercise responses reported by Dunne *et al.* [19] and Gerlach and Unruh [20] showed, no difference in carcass weight of steer, and crossbred heifers that were exercised compared to their non-exercised counterparts. Murray *et al.* [18] also found that exercise did not have an effect on the carcass weight of growing pigs.

The bulls in the four- and six-hour working groups had a significantly lower dressed percentage compared to the control group. The difference among treatment groups may have resulted from disparity in intensity of work level or could be associated with reduced dressed difference [39]. On the contrary, Mengistu *et al.* [26] noted that the dressing percentage of castrated Ethiopian highland zebu (EHZ) and Friesian × Boran (F × B) crossbred oxen was found to be invariable among the oxen subjected to draught work for three years and the non-working group. Also, Dunne *et al.* [19] reported that dressed yields were unchanged when cattle were exposed to walking exercise. The reported dressed percentage in the current findings for bulls in the non-working group was comparable to the average value of 56% reported for different Ethiopian cattle breeds [28] whereas, bulls in the working group had a comparable proportion with a value, of 47.80% reported for Harar bulls [7].

In the red meat industry, weight loss during carcass chilling is significant economic consideration [40]. The acceptable chilling loss percentage ranges from 1.5% - 2% of carcass weight [13]. This suggests that the lower chilling loss value observed could be associated with the low level of subcutaneous fat thickness of the carcass or the higher water holding capacity of the meat. According to Boito *et al.* [41], lean muscle reduces chilling losses, whereas greater fat thickness leads to increased loss. The cooling shrinkage reported in this study could indicate the importance of the Harar cattle breed in significant cost savings for the beef carcass industry [42].

The lack of significant change in fat thickness among the treatment group ($p > 0.05$) in the current finding (**Table 3**), was in line with the findings of Mengistu *et al.* [26], who reported that the fat thickness of EHZ cattle did not appear to be significantly affected by draft work. Similarly, Zhang *et al.* [22] and Morrison *et al.* [43] found no exercise training effects on fat thickness in sheep. On the other hand, Pethick and Rowe [44] observed a decreased subcutaneous fat due to exercise training in young growing sheep. These findings highlight the variability in the effects of exercise or work on fat thickness across different animal species and experimental conditions.

Generally, both bulls in non-working and working groups had lower FT compared to the same breed bull slaughtered at different ages [11] [45] and finished under a similar level of concentrate supplement [7]. Also, much lower than the optimum range stated for fat thickness, 0.2 to 0.5 inch, with a good target being 0.3 inch [46]. The ribeye area, RIA ($inch^2$) ranges from 5.85 to 7.67 and was slightly comparable to the mean rib eye area, 6.84 and 7.98 reported for the fattened bull of Harar breed slaughtered at the age of 4 - 6 and 7 - 9 [7], respectively and higher than 6.05 ± 4.58 [11].

4.2. Draught Work Hour Effects on Offal's

The lack of significant impact on both edible and non-edible offal among the treatment group (**Table 4**), suggests that the use of draught work did not result in noticeable changes. In the current finding, the weight of edible offal (EO) and non-edible offal (NEO) was found to be higher than the weights reported by [11], which were 12.5 kg for EO and 35 kg for NEO, respectively. However, it was lower than the weight of EO (29.6 kg) and the range of NEO yield between 69.8 kg and 81.09 kg reported by Tsigereda *et al.* [10] for Hararghe highland bulls.

A work hour × daily dry matter intake interaction ($p < 0.05$) for heart in experimental bulls varied with daily dry matter intake (**Figure 2**). This finding suggests that adequate nutrition plays a crucial role in supporting the cardiovascular health of bulls subjected to workloads. Some studies suggest that exercise can lead to an increase in the size and weight of the heart in animals due to cardiac hypertrophy [47] [48] [49]. The heart weight in the current study was similar to that reported by Mengistu *et al.* [26], who reported 0.7 ± 0.05 kg for Ethiopian highland Zebu bulls, but lower than the heart weight of Zebu breeds (1.033 kg) [50], and oxen released for beef after draught service (1.01 kg) [27].

Similar findings from earlier research by [26] on the lack of a significant difference in organ (viscera, liver, and kidney) weight between working and non-working oxen support the lack of an effect on other organs of bulls after draught services. Additionally, Murray *et al.* [18] discovered that forced exercise had no effect on the weight of the heart, liver, or kidneys in pigs. Also, except for a greater liver weight due to increased feed intake, endurance exercise had no influence on the components of sheep's offal, according to Aalhus and Price [33].

4.3. Draught Work Hour Effects on Carcass Composition

4.3.1. Organ Fat Depots

The observed interaction effect between work hours and daily dry matter intake per day (WH*DMI/d) for kidney fat ($p < 0.05$) (**Table 5** and **Figure 3**), implies that work hours and daily dry matter intake collectively influence kidney fat accumulation and mobilization in bulls. The tendency for lower kidney fat accumulation with increased work hours can be attributed to the energy expenditure involved in plowing activities. This suggests that the physical exertion involved in plowing activities leads to fat mobilization and utilization as an energy source. However, it was also observed that higher daily dry matter intake per day (kg DMI/day) reduced the mobilization of fat stored during energy expenditure. This indicates that increased food intake supplies the necessary energy for plowing activities, reducing the need for fat mobilization. However, further investigation is still important to understand the underlying mechanisms and potential implications of the observed effect.

Exercise is known to change the body's composition, and it is believed that exercising with enough intensity can decrease body fat [51]. Previous studies have shown that exercising cattle can reduce their fat score [19], however, in the current study, although the intense exercise was expected to affect the development of fat tissue, the fat tissue depots of organs and KPH% (kidney, pelvic, and heart fat as a percentage of carcass weight) were not significantly affected by draught work, irrespective to daily dry matter intake, this could suggest that the dry matter intake per metabolic body weight may maintain the effect. Similarly, Murray *et al.* [18] reported that enforced exercise in growing pigs did not affect the weight of the alimentary tract fat. The study by Gerlach and Unruh [20] also found that exercise did not affect cattle carcass fat, possibly because the exercise intensity was not sufficient. According to a study conducted by Mengistu *et al.* [26], draught work stress has a negative impact on the amount of KPH% fat. The average KPH fat, of 0.86% in the current finding was significantly lower than the average value of 3.5% and 2.5% reported by Hale *et al.* [52] and (Mengistu *et al.* [26] respectively. Hale *et al.* [52] suggested that a carcass with less than 3.5% KPH fat is considered lean. As confirmed by (Berg and Butterfield [14] the variation in the figures between the current and another study could attributed to age and breed differences.

4.3.2. Total Meat Yield and Meat to Bone Ratio

The non-working bulls had produced more meat quantitatively than both the 4 and 6 hours worked bulls (**Table 6**), indicating that the draught work hour may not have had as much of an impact on the Hararghe highland breed's overall meat production

Mengistu *et al.* [26], who made a related observation reported, no change in the lean meat mass of EHZ oxen following draught services. On the other hand even though, the intensity of exercise was incomparable with current work Aalhus and Price [33] observed no total muscle weight change in sheep in association with exercise. Also, the full carcass dissection in exercised pig [18] has shown no difference in the proportion of muscle or bone from the non-exercised counterpart. On the contrary, Richmond and Berg [53] reported that total muscle weight increased as live weight increased over the exercised group compared to the controlled.

According to Pesonen *et al.* [54], the value of a carcass is mostly determined by its composition; a high amount of muscle, an appropriate amount of fat, and a minimum level of bone [55]. The changes in the proportions of meat, bone, and fat in an animal as it grows are due to differences in growth rates of various body parts, but as long as positive growth is maintained, muscle and bone growth will proceed at the same relative rates [13]. Thus, improvement in muscularity is measured in terms of the muscle to bone ratio [13]. The animals with a higher meat to bone ratio are evidently more desirable, as this corresponds to a greater amount of lean meat that can be marketed. The current study indicated that Hararghe highland breeds had the capability and adaptability for meat production even after draught services. Similarly, Mengistu *et al.* [26] found that lean meat to bone ratio among the working and non-working groups was not altered by work status,

4.3.3. Primal Cut's Meat Yield

According to Berg and Butterfield [14] the distribution of muscles in an animal's body is a reflection of the activities it is likely to perform. There is a commonly held belief that engaging in exercise training produces mechanical stress in the skeleton, increases muscle mass, and boosts the activity of osteoblasts [56] [57]. However, the weights of the muscles in the various regions did not vary significantly according to the current study, with the exception of a numerical drop in the weight of the chuck muscle shown in the working group (**Table 7**).

One possible reason for the slightly lower meat yield in the chuck among the working group could be attributed to the physical strain and pressure applied to this specific region during the draught work. The continuous exertion of force on the chuck area, potentially due to the nature of the work or the equipment used, could result in muscle fatigue or stress, leading to a slightly lower meat yield compared to the non-working group. Similarly, previous studies on the dissection of cattle muscles conducted by Berg [58] and Butterfield and Berg [59], indicated that muscle distribution remained relatively constant, and individual muscles grew either in mono- or diphasic patterns.

Murray *et al.* [18] found that enforced exercise treatment had no significant effects on muscle weight distribution in any of the standard muscle groups. Interestingly, Skjervold *et al.* [60] found no increase in the weight of certain hindquarter muscles of pigs forced to stand in a semi-upright position during feeding. In contrast, the dynamic progressive-resistance jumping exercise performed by sheep resulted in a small change in muscle distribution [61]. Aalhus and Price [33] also found that endurance exercised sheep tended to have a higher proportion of muscle in the proximal pelvic limb and in the abdominal wall. Richmond and Berg [53] also reported that very little change in muscle weight distribution as live weight increased in the exercised group compared to the control group. As Aalhus and Price [62] reported, there were small shifts in muscle distribution in load-carrying sheep. The same author also stated that the changes in muscle distributions were assumed to be a direct response to increased load bearing.

4.4. Carcass Characteristics Traits Correlation with Meat Yield

The very strong correlation between total meat yield (MY), hot carcass weight (HCW), and fat thickness (FT) showed that the total meat yield increases as the weight and thickness of the carcass do. The observations obtained on cattle by Ahmedin *et al.* [11] show that the meat output of the Hararghe highland breed increases with subcutaneous fat thickness. On the contrary, Timketa *et al.* [7] found no correlation between meat yield and FT ($r = 0.16$). The weight of the carcass in relation to the weight of the live animal is an essential measurement of meat yield [13] and, as a result, carcass value [63]. Of all the carcass metrics, dressing percentage has undoubtedly received great importance. A high positive correlation between MY, slaughter weight, and HCD%, reported in the current finding, was in line with the report of Timketa *et al.* [7], which found beef carcasses with higher live weight were heavier in total meat yield. Also, a positive correlation ($p < 0.05$) was observed between live weight and lean meat mass, suggesting that selecting larger-framed animals could yield more lean meat [26]. In the present finding, the results suggest that the hot carcass weight, fat thickness, slaughter weight, and dressed percentage are important factors affecting the total meat yield of Hararghe highland bulls.

5. Conclusion

It was noted that draught work has no significant effect on slaughter weight, hot carcass weight, chilling loss percentage, edible and non-edible offal, fat thickness, total meat yield (kg), meat yield percentage, meat to bone ratio, primal cuts (chuck, brisket, fore shank, rib, plate, loin, flank round, and hind shank), muscle distribution, and accretion of organ fat tissue. However, draught work significantly lowered the dressed percentage, HCD%. Total meat yield had a strong positive correlation with hot carcass weight, fat thickness, slaughter weight, and HCD%. However, RIA had no correlation with meat yield. Thus, taking into account the importance of bulls in agricultural services and using Hararghe highland bulls for draught purposes does not compromise carcass characteristics, meat yield, or muscle distribution along prim cuts, independently of daily dry matter intake.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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