Slaughter weight and rib-eye area as a predictor of some carcass characteristics and premium meat production in three cattle breeds

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Abstract

This research examines the predictive capacity of age, slaughter weight (SW), and *musculus longissimus dorsi* (MLD=rib-eye) areas on carcass characteristics and the quantity of high-quality meat across three cattle breeds: Holstein, Brown Swiss, and Simmental. Correlation and stepwise regression analyses were conducted on 64 bull carcasses to assess the predictive power of SW and MLD in terms of carcass characteristics and valuable meat yield. The findings indicated significant positive correlations between SW and premium cuts, especially in the Holstein and Simmental. Furthermore, significant correlations existed between MLD and valuable meats, indicating that both SW and MLD areas are essential determinants in valuable meat production. The regression models established to predict premium meat yields based on SW achieved an explanatory power (R-squared) of 80% and higher for cold carcass weight (CCW), roast (Ro), knuckle (K), topside (TS), total high-value meat (THM), roast percentage (RoP), knuckle percentage (KP), topside percentage (TSP), total high-value meat percentage (THMP). However, low R-squared values in the regression models revealed that the MLD area had a lower predictive value for premium meat production. Despite the MLD area's strong correlation with the factors analyzed for prediction, the result implies that SW is an excellent predictor of meat production. The findings indicate methods for enhancing carcass quality and meat production, with the Simmental breed yielding the most valuable meat, followed by Brown Swiss and Holstein. These findings can guide breeders in enhancing meat quality and profitability in enterprises.

Introduction

The MLD area is a useful indicator to predict muscle mass, carcass composition, subcutaneous fatness, fat thickness, and edible yield, and this characteristic correlates with the ratio of cuts that enhance the economic value of meat products (2, 6, 11, 13, 18, 29, 30). Researchers have extensively studied the eye muscle area of MLD at the 10th, 12th, and 13th ribs to determine the quantity of muscle in carcasses and identify the optimal types of meat (1, 2, 4, 6, 11, 13, 16, 18, 30).

Zhao et al. (35) showed that the MLD area is significantly associated with carcass lean meat yield. This area, along with traits like intramuscular and subcutaneous fat depositions, directly influences meat yield and quality (27). Furthermore, studies have shown a positive correlation between the MLD area and both slaughter weight and hot carcass weight, underscoring its significance in determining overall meat production, fatness status, and bone weight (15, 17, 24, 25, 34). The United States Department of Agriculture (USDA) yield grade standard utilizes the MLD area as one of the key factors in predicting carcass retail cut yield, along with fat thickness, kidney, heart, pelvic fat, and carcass weight (5). In addition, Tadesse et al. (28) established a correlation between greater MLD areas and increased production of lean meat. As well as an improved ratio of lean meat to bone in carcasses. Furthermore, the MLD area is associated with muscle accumulation in the carcass, which is critical as the meat tissue holds greater economic value (26). Awuk and Tamir (3) observed a positive relationship between the MLD area and concentrate supplementation levels, dry matter intake, slaughter weight, dressing percentage, lean meat, and overall meat yield.

Slaughter weight (SW) and MLD area are useful indicators for estimating the quantity of meat and the valuable cuts that can be obtained from a carcass (7, 33). The assessment and correlation of these metrics, such as fatty tissue thickness, lean yield, and carcass weight, provide critical information about the overall excellence and quantity of meat production (1, 7, 23, 33). Recently, the correlations between carcass sections of many different sheep (9, 10, 14, 20, 31), goat (8, 19, 32), and cattle (21) breeds have been investigated, and low, medium, and high correlation levels have been determined. Furthermore, different regression formulas have been made to come up with ways to estimate the weight, quantity, or meat quality of body parts (8-10, 14, 19-21, 31, 32).

The main goal of this study was to find regression equations between variables like SW, cold carcass weight (CCW), cold carcass percentage (CCP), and chilling loss (CHL) in three different breeds of cattle. The study also demonstrated correlations between traits. Furthermore, the research analyzed the productivity of several valuable components extracted from carcasses, including the MLD region, S, T, CR, R, ER, Ro, K, TS, and THM. Another objective is to develop prediction equations for the yields of high-value meat cuts based on the SW and the area of the MLD.

Materials and Methods

Data Collection: The data were collected from 64 head bulls brought to the slaughterhouse for processing. This study includes data from a group of 64 bull carcasses classified into three breed groups (there are a total of 31 Holsteins, 22 of which are 18 months old and 9 of which are 30 months old; a total of 21 Brown Swisss, 16 of which are 18 months old and 5 of which are 30 months old; and a total of 12 Simmentals, 5 of which are 18 months old and 7 of which are 30 months old). We collected data on various carcass parameters, including SW, CCW, CCP, CHL, MLD area, and the weight of specific cuts of meat, such as S, T, CR, R, ER, Ro, K, TS, and THM.

Carcasses were chilled for 24 h at +4°C and weighed for cold carcass weight. Carcass cuts were weighed by scales that were sensitive to 100 grams. The MLD area was drawn onto the acetate between the 12^{th} and 13^{th} ribs (12) after 24 h from slaughter, and its surface area was calculated using the AutoCAD software.

Statistical Analysis: We utilized the SPSS 30.0 software package to conduct a correlation analysis on a sample size of 64 bulls. The analysis focused on various attributes such as SW, CCW, CCP, CHL, MLD area, and the quantity of specific meat cuts, including S, T, CR, R, ER, Ro, K, TS, and THM characteristics. Furthermore, there is a normal distribution of the data. Therefore, we conducted Pearson correlations for identical breed characteristics. Percentage were calculated as the dependent variables divided by CCW. A stepwise regression analysis was used to examine the connection between the animal's weight at slaughter, the weight of its valuable meat, and the percentage of valued meat. It was also used to examine the connection between the carcass's features and the weight of its valuable meat. In addition, regression analyses sorted by breed were performed using the SPSS 30.0 statistical software package.

Results

The descriptive statistics of carcass traits and valuable cuts are given in Table 1. Table 2 provides the correlation analysis between the traits of all bulls. Tables 3, 4, and 5 present the correlation analysis for Holstein, Brown Swiss, and Simmental in the same order.

The total results of 64 bulls indicated that there is a strong positive relationship between the SW and the following: CCW, MLD area, S, T, R, ER, Ro, K, TS, and THM at the 0.01 level of significance. The SW, cold carcass yield, and C exhibit a moderate positive correlation at the 0.01 level of significance. There is a non-significant negative, moderate-degree correlation between SW and CHL. Upon analysis of Tables 2, 3, 4, and 5, it becomes evident that there exists a diverse spectrum of both positive and negative correlations among the features. However, this research primarily focuses on accurately determining the weight of high-quality meat, with the SW and the area of the MLD playing crucial roles. Within the different breeds, we found significant positive correlations between the SW and the total quantity of valuable meat for Holstein, Brown Swiss, and Simmental breeds, with correlation coefficients of 0.983, 0.882, and 0.963, respectively. In the MLD region, we observed strong positive correlations at various levels of significance (0.774, 0.546, and 0.887).

Based on the SW shown in Table 6, prediction models were made for the carcass characteristics and valuable meat estimates that had an explanatory power of 80% or more (R square≥0.80) and were statistically significant (P<0.001). Thus, these models may be used to predict the levels of CCW, Ro, TS, and THM in 64 bulls. The Holstein breed allows for the calculation of CCW, S, Ro, K, TS, and THM quantities. The Brown Swiss breed allows for the estimation of CCW and K weights. The Simmental breed allows for CCW, T, Ro, TS, and THM weights to be estimated. However, we found that the variable representing the SW was insufficient and lacked statistical significance when attempting to estimate other characteristics.

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The analysis revealed that the MLD area variable had a low coefficient of determination (R-squared) in relation to the examined carcass traits and the ability to predict the weight of valuable meat. Consequently, the article does not include the estimation equations related to the MLD area.

Table 1. Descriptive statsitics of carcass traits and valuable cuts of three cattle breeds.

Breed	Traits	N	Min.	Max.	Mean	StD. Dev.
Holstein	SW (kg)	31	220.00	600.00	358.06	76.13
	CCW (kg)	31	112.60	338.00	186.28	44.62
	CCP (%)	31	0.48	0.56	0.52	0.02
	CHL (%)	31	0.01	0.04	0.03	0.01
	MLD Area (cm^2)	31	50.90	95.00	71.59	11.17
	S (kg)	30	2.64	7.62	4.45	1.33
	T (kg)	31	1.16	4.46	2.19	0.59
	C (kg)	30	4.80	23.00	9.88	3.58
	R (kg)	31	1.80	10.30	5.76	2.33
	ER (kg)	31	1.20	5.41	2.72	0.85
	Ro (kg)	30	3.49	13.45	7.45	2.22
	K (kg)	30	2.59	10.24	6.45	2.24
	TS (kg)	31	4.50	16.90	9.85	2.96
	THM (kg)	27	26.28	88.78	49.04	13.36
Brown Swiss	SW (kg)	21	300.00	480.00	390.48	48.42
	CCW (kg)	21	154.60	244.50	203.99	27.08
	CCP (%)	21	0.49	0.58	0.52	0.02
	CHL (%)	21	-0.03	0.03	0.01	0.01
	MLD Area (cm^2)	21	55.00	90.30	69.50	10.25
	S (kg)	21	3.16	7.86	5.48	1.33
	T (kg)	21	1.21	2.92	2.14	0.46
	C (kg)	21	3.14	10.66	6.48	1.62
	R (kg)	20	4.20	9.90	7.63	1.81
	ER (kg)	20	1.20	3.19	2.28	0.54
	Ro(kg)	20	5.77	10.61	8.68	1.48
	K (kg)	20	4.64	10.74	7.86	1.67
	TS (kg)	20	7.78	14.25	11.42	2.13
	THM (kg)	20	38.72	63.16	52.22	8.63
Simmental	SW (kg)	12	300.00	580.00	421.67	79.75
	CCW (kg)	12	148.60	329.40	221.95	47.65
	CCP (%)	12	0.49	0.57	0.52	0.02
	CHL (%)	12	0.01	0.03	0.02	0.01
	MLD Area (cm^2)	12	53.00	92.00	73.34	11.77
	S (kg)	10	3.44	7.60	5.39	1.48
	T (kg)	11	1.86	4.00	2.56	0.60
	C (kg)	12	5.88	21.00	10.28	4.51
	R (kg)	12	3.72	10.94	7.54	2.20
	ER (kg)	12	1.74	5.30	3.24	1.05
	Ro(kg)	12	5.80	13.14	9.24	2.17
	K (kg)	11	4.31	13.75	8.49	2.66
	TS (kg)	11	7.43	16.47	12.03	2.86
	THM (kg)	9	37.62	85.65	57.35	14.73
Total	SW (kg)	64	220.00	600.00	380.63	72.24
	CCW (kg)	64	112.60	338.00	198.78	42.02
	CCP (%)	64	0.48	0.58	0.52	0.02
	CHL (%)	64	-0.03	0.04	0.02	0.01
	MLD Area (cm^2)	64	50.90	95.00	71.23	10.90
	S (kg)	61	2.64	7.86	4.96	1.42
	T (kg)	63	1.16	4.46	2.24	0.56
	C (kg)	63	3.14	23.00	8.82	3.64
	R (kg)	63	1.80	10.94	6.70	2.31
	ER (kg)	63	1.20	5.41	2.68	0.86
	Ro(kg)	62	3.49	13.45	8.19	2.10
	K (kg)	61	2.59	13.75	7.28	2.28
	TS (kg)	62	4.50	16.90	10.74	2.81
	THM (kg)	56	26.28	88.78	51.51	12.26

SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, CHL: CHL area, MLD: MLD area, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast, K: Knuckle, TS: Topside, THM: Total high-value meat

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Table 2. Correlation analysis of all traits in all sixty-four bulls.

	SW	CCW	CCP	CHL	MLD	S	T	CR	R	ER	Ro	K	TS	THM
SW	1	0.986**	0.472**	-0.399	0.637**	0.831**	0.759**	0.360**	0.780**	0.602**	0.932**	0.884**	0.918**	0.959**
CCW		1	0.605**	-0.406	0.658**	0.825**	0.786**	0.394**	0.769**	0.637**	0.951**	0.870**	0.927**	0.975**
CCP			1	-0.342	0.461**	0.445**	0.519**	0.276*	0.455**	0.475**	0.630**	0.467**	0.592**	0.639**
CHL				1	-0.222	-0.627	0.010	0.600**	-0.728	0.283*	-0.491	-0.651	-0.496	-0.306
MLD					1	0.578**	0.526**	0.367**	0.524**	0.526**	0.611**	0.564**	0.641**	0.708**
S						1	0.541**	-0.002	0.805**	0.257*	0.824**	0.868**	0.827**	0.797**
T							1	0.666**	0.432**	0.801**	0.709**	0.558**	0.720**	0.838**
CR								1	-0.196	0.866**	0.263*	-0.018	0.228	0.481**
R									1	0.165	0.830**	0.913**	0.847**	0.755**
ER										1	0.534**	0.332**	0.539**	0.701**
Ro											1	0.902**	0.944**	0.947**
K												1	0.934**	0.878**
TS													1	0.950**
THM														1

*P<0.05, **P<0.01, SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, CHL: CHL area, MLD: MLD area, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast, K: Knuckle, TS: Topside, THM: Total high-value meat

Table 3. Correlation analysis of all traits in Holstein bulls.

	SW	CCW	CCP	CHL	MLD	S	T	CR	R	ER	Ro	K	TS	THM
SW	1	0.993**	0.640**	-0.449	0.759**	0.895**	0.816**	0.458*	0.817**	0.715**	0.971**	0.903**	0.945**	0.983**
CCW		1	0.718**	-0.456	0.746**	0.892**	0.834**	0.469**	0.805**	0.716**	0.972**	0.901**	0.939**	0.982**
CCP			1	-0.434	0.484**	0.613**	0.637**	0.310	0.585**	0.480**	0.701**	0.676**	0.641**	0.743**
CHL				1	-0.438	-0.636	-0.051	0.535**	-0.793	0.226	-0.539	-0.724	-0.515	-0.339
MLD					1	0.762**	0.587**	0.262	0.699**	0.525**	0.728**	0.728**	0.748**	0.774**
S						1	0.625**	0.212	0.862**	0.434*	0.927**	0.922**	0.876**	0.873**
T							1	0.735**	0.478**	0.855**	0.781**	0.616**	0.757**	0.859**
CR								1	-0.088	0.862**	0.366	0.094	0.319	0.577**
R									1	0.331	0.849**	0.954**	0.860**	0.783**
ER										1	0.632**	0.456*	0.651**	0.780**
Ro											1	0.942**	0.952**	0.969**
K												1	0.939**	0.891**
TS													1	0.958**
THM														1

*P<0.05, **P<0.01, SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, CHL: CHL area, MLD: MLD area, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast, K: Knuckle, TS: Topside, THM: Total high-value meat

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Table 4. Correlation analysis of all traits in Brown Swiss bulls.

	SW	CCW	CCP	CHL	MLD	S	T	CR	R	ER	Ro	K	TS	THM
SW	1	0.960**	0.093	-0.377	0.457*	0.759**	0.500*	0.169	0.815**	0.189	0.780**	0.940**	0.822**	0.882**
CCW		1	0.366	-0.507	0.497*	0.753**	0.536*	0.199	0.862**	0.344	0.872**	0.950**	0.894**	0.944**
CCP			1	-0.523	0.229	0.173	0.260	0.135	0.356	0.597**	0.523*	0.251	0.453*	0.430
CHL				1	-0.359	-0.455	0.024	0.421	-0.478	-0.008	-0.531	-0.501	-0.483	-0.397
MLD					1	0.436*	0.245	0.302	0.485*	0.362	0.394	0.494*	0.464*	0.546*
S						1	0.462*	-0.023	0.546*	0.162	0.626**	0.799**	0.666**	0.730**
T							1	0.508*	0.447*	0.541*	0.512*	0.521*	0.658**	0.706**
CR								1	0.005	0.739**	0.034	0.083	0.214	0.341
R									1	0.160	0.909**	0.841**	0.807**	0.850**
ER										1	0.281	0.250	0.489*	0.513*
Ro											1	0.864**	0.887**	0.900**
K												1	0.881**	0.923**
TS													1	0.953**
THM														1

*P<0.05, **P<0.01, SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, CHL: CHL area, MLD: MLD area, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast, K: Knuckle, TS: Topside, THM: Total high-value meat

Table 5. Correlation analysis of all traits in Simmental bulls.

	SW	CCW	CCP	CHL	MLD	S	T	CR	R	ER	Ro	K	TS	THM
SW	1	0.981**	0.475	-0.176	0.706*	0.783**	0.897**	0.585*	0.601*	0.753**	0.914**	0.760**	0.896**	0.963**
CCW		1	0.633*	-0.099	0.780**	0.784**	0.938**	0.660*	0.564	0.783**	0.946**	0.712*	0.912**	0.987**
CCP			1	0.157	0.780**	0.466	0.658*	0.585*	0.272	0.522	0.678*	0.279	0.657*	0.694*
CHL				1	0.032	-0.637	0.091	0.652*	-0.788**	0.469	-0.131	-0.655*	-0.298	-0.137
MLD					1	0.690*	0.780**	0.602*	0.414	0.694*	0.775**	0.511	0.779**	0.887**
S						1	0.601	0.122	0.895**	0.298	0.751*	0.813**	0.867**	0.792*
T							1	0.817**	0.376	0.902**	0.836**	0.481	0.811**	0.946**
CR								1	-0.208	0.927**	0.568	-0.003	0.460	0.682*
R									1	0.029	0.609*	0.857**	0.788**	0.669*
ER										1	0.717**	0.293	0.602	0.792*
Ro											1	0.793**	0.944**	0.977**
K												1	0.944**	0.869**
TS													1	0.964**
THM														1

*P<0.05, **P<0.01, SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, CHL: CHL area, MLD: MLD area, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast, K: Knuckle, TS: Topside, THM: Total high-value meat

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Table 6. Predict weights of some carcass traits and valuable meats using SW.

Breed	Depended Variable	Prediction Equations	Significance	R square	MAE	RMSE
Total	CCW	Y=-19.575 + 0.574 × SW	<0.001	0.973	5.223	6.970
	CCP	Y=0.474 + 0.000 × SW	<0.001	0.223	0.014	0.0168
	S	Y=-1.200 + 0.016 × SW	<0.001	0.691	0.628	0.797
	T	Y=-0.008 + 0.006 × SW	<0.001	0.576	0.255	0.369
	CR	Y=0.044 + 0.123 × MLDcm^2	0.003	0.135	1.853	3.415
	R	Y=-2.737 + 0.025 × SW	<0.001	0.609	0.926	1.457
	ER	Y=-0.037 + 0.007 × SW	<0.001	0.363	0.603	0.694
	Ro	Y=-2.016 + 0.027 × SW	<0.001	0.868	0.605	0.770
	K	Y=-2.610 + 0.029 × SW - 0.732 × Age	<0.001	0.803	0.723	1.029
	TS	Y=-2.783 + 0.036 × SW	<0.001	0.843	0.843	1.121
	THM	Y=-14.815 + 0.148 × SW + 0.146 × MLDcm^2	<0.001	0.930	2.558	3.298
	SP	Y=-1.200+0.016×SW	<0.001	0.691	0.628	0.798
	TP	Y=-0.008+0.006×SW	<0.001	0.576	0.255	0.369
	CRP	Y=0.044+0.123×MLDcm2	0.003	0.135	1.853	3.416
	RP	Y=-2.737+0.025×SW	<0.001	0.609	0.926	1.458
	ERP	Y=-0.037+0.007×SW	<0.001	0.363	0.603	0.694
	RoP	Y=-2.016+0.027×SW	<0.001	0.868	0.605	0.771
	KP	Y=-2.610+0.029×SW−0.732×Age,	<0.001	0.803	0.723	1.029
	TSP	Y=-2.783+0.036×SW	<0.001	0.843	0.843	1.121
	THMP	Y=-14.815+0.148×SW+0.146×MLDcm^2	<0.001	0.930	2.558	3.299
Holstein	CCW	Y=-22.140 + 0.582×SW	<0.001	0.987	4.116	5.271
	CCP	Y=0.465 + 0.000×SW	<0.001	0.410	0.011	0.014
	S	Y=-1.174 + 0.016×SW	<0.001	0.802	0.521	0.610
	T	Y=-0.064 + 0.006×SW	<0.001	0.666	0.238	0.354
	CR	Y=1.990 + 0.022×SW	0.011	0.210	2.258	2.757
	R	Y=-3.195 + 0.025×SW	<0.001	0.668	0.970	1.815
	THM	Y=3.214 + 0.547×SW	<0.001	0.960	1.824	2.735
	RoP	Y=0.036 + 0.010 × Age	0.048	0.132	0.012	0.015
	KP	Y=0.027 + 0.013 × Age	0.024	0.169	0.010	0.013
	TSP	Y=0.045 + 0.015 × Age	0.034	0.151	0.011	0.014
	THMP	Y=0.234 + 0.058 × Age	0.043	0.139	0.051	0.064
Brown Swiss	CCW	Y=-5.640 + 0.537×SW	<0.001	0.922	5.403	7.604
	CHL	Y=0.072 - 0.015×Age - *0.000×SW*	0.017	0.436	0.007	0.011
	S	Y=-2.641 + 0.021×SW	<0.001	0.576	1.099	1.327
	T	Y=0.270 + 0.005×SW	0.021	0.250	0.386	0.464
	CR	Y=8.507 - 1.635×Age	0.046	0.193	1.186	1.624
	R	Y=-6.222 + 0.032×SW + *1.208*×Age	0.047	0.735	0.869	1.079
	THM	Y=2.876 + 0.501×SW	<0.001	0.766	3.274	4.175
	SP	Y=0.011 + 0.017 × Age	0.004	0.371	0.005	0.007
	RP	Y=0.016 + 0.021 × Age	0.002	0.412	0.011	0.014
	RoP	Y=0.035 + 0.015 × Age	0.042	0.211	0.012	0.015
	KP	Y=0.027 + 0.015 × Age	0.011	0.309	0.011	0.012
	TSP	Y=0.045 + 0.020 × Age	0.045	0.195	0.017	0.020
Simmental	CCW	Y=-45.797 + 0.512×*SW + 0.705*×MLDcm^2	<0.001	0.977	7.838	10.450
	CCP	Y=0.416 + 0.001×MLDcm^2	0.003	0.608	0.010	0.015
	S	Y=-0.198 + 0.013×SW	0.007	0.613	1.200	1.477
	T	Y=-0.162 + 0.006×SW	<0.001	0.805	0.193	0.266
	CR	Y=-6.615 + 0.230×MLDcm^2	0.038	0.362	3.404	4.507
	R	Y=0.549 + 0.017×SW	0.039	0.361	1.831	2.201
	THM	Y=4.102 + 0.531×SW	<0.001	0.926	11.663	14.729

SW: Slaughter weight, CCW: Cold carcass weight, CCP: Cold carcass percentage, S: Sirloin, T: Tenderloin, CR: Cube roll, R: Rump, ER: Eye round, Ro: Roast K: Knuckle, TS: Topside, THM: Total high-value meat, SP: Sirloin percentage, TP: Tenderloin percentage, CRP: Cube roll percentage, RP: Rump percentage, ERP: Eye round percentage, RoP: Roast percentage, KP: Knuckle percentage, TSP: Topside percentage, THM: Total high-value meat percentage.

Discussion and Conclusion

Increasing populations require meat as a vital protein source. Recently, there has been a growing interest in the quality of this protein source. The robust positive correlations observed between SW and CCW, in conjunction with various premium cuts including Ro, TS, and THM, correspond with prior research emphasizing the substantial influence of live weight on carcass composition and meat production (7, 22). These findings corroborate the hypothesis that augmented SW enhances meat production potential, especially for premium cuts that substantially impact economic returns in beef production systems.

A correlation was observed between MLD area, carcass characteristics, and meat yield; however, the predictive capability of MLD was comparatively inferior to that of SW. This result is consistent with the findings of Hopkins et al. (12), who reported that MLD has moderate explanatory power in predicting meat yield. On the other hand, it is different from the results of Scapol et al. (27), who found that MLD had a bigger effect on the performance of meat cuts in Nellore bulls. The difference may be due to breed traits, slaughter age, or feeding.

When evaluating the breeds, Simmental bulls demonstrate superior values relative to Brown Swiss and Holstein breeds, respectively, concerning various carcass characteristics and elevated meat yield. Consequently, it indicates that under comparable management conditions, Simmental cattle may be more adept for high-quality meat production. These results corroborate earlier studies showing that Simmentals have better muscling and carcass quality than dairy-type breeds (16, 17). Despite being bred primarily for milk production, the Holstein breed showed lower but still significant correlations between SW and meat yield, suggesting that it could be used for dual purposes if properly handled during fattening stages.

Regression analyses showed that SW was even better at predicting carcass and meat characteristics, with R-squared values (>0.80) for CCW, Ro, TS, THM, and other traits. Producers can use these models to determine the amount of meat they can extract from a specific animal weight before slaughter. Nonetheless, models utilizing solely the MLD variable proved inadequate for elucidating the data. MLD serves as a sufficient indicator of muscle development; however, it should be integrated with additional variables, such as age or SW, to enhance predictive accuracy.

Interestingly, CHL showed weak and mostly non-significant correlations with SW and other traits, indicating that carcass shrinkage during cooling may not be strongly influenced by body size or muscle area in this dataset. This finding may have implications for post-slaughter handling practices, emphasizing the need for standardized cooling protocols to minimize variability in carcass yield.

Some regression models found that age was a small but statistically significant factor that had a big effect on K and some carcass percentages. This means that SW is still the most important factor in determining meat yield, but adjusting for age may make predictions more accurate for certain cuts, especially in crossbreeding or extended finishing systems.

In conclusion, this study confirms that slaughter weight is a robust and reliable predictor of carcass traits and premium meat production across Holstein, Brown Swiss, and Simmental cattle breeds. While the MLD area offers extra information about muscular development, its predictive value is secondary to SW when used independently. Among the studied breeds, Simmental cattle consistently produced the highest quantities of high-value meat, making them a preferred choice for beef-focused breeding programs. These findings offer practical guidance for livestock producers and breeders aiming to optimize carcass quality and profitability through targeted selection and management strategies. Future research should focus on integrating genomic and phenomic indicators to enhance the predictive accuracy of carcass characteristics. Moreover, examining the interaction between genetic background and feeding systems may yield insights into improving meat quality and yield across diverse production contexts.

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Ethical Statement

This study does not present any ethical concerns.

Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

AK and CÖ conceived and planned the experiments. AK and CÖ carried out the experiments. AK and CÖ contributed to sample preparation. AK and CÖ contributed to the interpretation of the results. AK took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Animal Welfare

The authors confirm that they have adhered to ARRIVE Guidelines to protect animals used for scientific purposes.

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