Journal of Agriculture and Environmental Sciences

Research Article

Conformation traits of crossbred dairy cows in the South Gondar Zone, Amhara Region, Ethiopia

Mequanint Biks[1], Asaminew Tassew[2,*] and Fisseha Moges[2]

[1]College of Agriculture and Environmental Sciences, Debre Tabor University, Debre Tabor, Ethiopia
[2]College of Agriculture and Environmental Sciences, Bahir Dar University, P O Box 5501, Bahir Dar, Ethiopia
Corresponding author: asaminew2@gmail.com

Received: April 4, 2023; Received in revised form: April 30, 2023; Accepted: May 8, 2023

https://dx.doi.org/10.4314/jaes.v8i1.3

Abstract: *Conformational variations between and within crossbred dairy cattle populations have significant economic and socio-cultural implications for producers. Therefore, this study was conducted to characterize conformation traits of crossbred dairy cows in the South Gondar zone, Amhara Region, Ethiopia. A total of 204 lactating crossbred dairy cows were selected for measurement purposes. The independent variables considered were location, stage of lactation, genotype level, and parity while linear body conformations (Stature (STA), Chest Width (CW), Body Depth (BW), Body Length (BL), Rump Length (RL), Heart Girth (HG), Neck Length (NL), and Neck Circumferences (NC)), linear udder conformation traits (Rump Width (RW), Udder Depth (UD), Udder Width (UW), Udder Circumferences (UC), Rear Udder Height (RUH), Teat Length (TL)), non-linear body conformations (Angularity (ANG), Rear Legs Rear View (RLRV), Rear Legs Side View (RLSV), Body Condition Score (BSC)) and non-linear udder conformation traits (Fore Udder Attachment (FUA), Rear Teat Placement (RTP), Front Teat Placement (FTP)), Teat Thickness (TT)) were the dependent variables. Data was analyzed using the General Linear Models procedure (GLM) of the Statistical Analysis System (SAS, 2004). The overall STA, CW, BD, BL, RL, HG, NL, NC, RW, RUH, UD, UW, UC and TL were 127.81±5.4 cm, 23.1±3.1cm, 99.2±4cm, 120.45±4.6cm, 32.2±3.9cm, 168.32±5.1cm, 56.7±3.2 cm, 92.88±3.6cm, 17.39±2.65cm, 14.27±1.8cm, 18.02±2.7cm, 16.85±2.5cm, 59.16±4.3cm and 4.65±0.88cm, respectively. Parity had a significant effect on linear conformational trait characteristics of crossbred dairy cows at ($p<0.01$) and ($p<0.001$) significant levels except for CW, BD, RL, and RUH. Similarly, genotype level had a significant effect on linear conformational trait characteristics of crossbred dairy cows at ($p<0.05$), ($p<0.01$), and ($p<0.001$) significant levels except for CW, RL, NL, and RUH but the stage of lactation had no significant effect ($p>0.05$) on linear body conformation except STA and had a significant effect ($p<0.01$) on linear udder traits except UD and TL of crossbred dairy cows. Therefore, selecting dairy type traits could be an ideal option to improve cow productivity and enterprise profitability. However, future studies with large populations and various genotype levels are required to associate conformation with reproductive and productive traits.*

Keywords: *Crossbred cows, dairy farm enterprise, conformation traits*

1. Introduction

One of the most important qualities for dairy cattle producers to know and understand about cattle behavior is the conformation trait. It includes all the important areas of an animal's structure, such as the legs, spine (or top-line), and hindquarters, as well as the neck and head. Conformation traits have medium to high heritability and are recorded in a single assessment, which is the least expensive method of selection index for multiple purposes (Khmelnychyi, 2021). The conformation of an animal indicates its anatomy and skeletal function, as well as how it affects the animal's health, adaptability, longevity, and productivity. Conformation traits are used to assess the condition of a cow based on its body features (Zetouni *et al*., 2016). These characteristics are used to successfully perform animal functions and have a relationship with productivity, longevity, and disease resistance potential (Posads *et al*., 2017).

Measuring actual milk production is time-consuming and expensive, but dairy cattle breeders are interested in estimating milk yield due to conformation traits (Jessica *et al*., 2020). Many studies have been conducted to investigate the relationship between conformation traits and body weight, body condition score, milk yield, longevity, and other reproductive traits. That information is critical for dairy cattle selection and improvement because it predicts the direct or correlated response to selection (Akpa *et al*., 2012). When selecting replacement herd, it's critical to consider conformation traits because dairy cattle's functionality and longevity depend on their ability to produce more milk without encountering problems caused by structural weakness. Sawa *et al.* (2013) revealed that conformation traits appear to be more suitable for predicting dairy cattle lifetime production efficiency. However, little is known about the characterization of conformation traits and their impact on milk yield in crossbred dairy cows in the South Gondar zone, Amhara region, Ethiopia. Therefore, this study aimed to characterize conformation traits in crossbred dairy cows and compare its relation to milk yield.

2. Materials and Methods

2.1. Description of the study area

The study was done in selected locations in South Gondar, Ethiopia in the Amhara region. There are 15 districts in the South Gondar zone. Four district towns with youth dairy farm enterprises were chosen for this study. The towns of Debre Tabor, Woreta, Addis Zemen, and Hamusit were chosen (Table 1, Figure 1). Crop-livestock farming is the most important source of livelihood in the South Gondar zone. Dairy cattle, beef cattle, and chicken are the most common livestock species kept by producers in urban areas.

Table 1: Description of the study areas

Characteristics of the study areas	Study sites			
	Debre-Tabor town	Woreta town	Addis Zemen town	Hamusit town
Distance from Addis Ababa (km)	666	606	566	515
Distance from Bahir Dar (km)	100	57.8	83.3	34.6
Altitude (masl)	2,706	1828	1975	1945
Latitude	11^0 51`N	12^0 07`N	12^0 07`N	11^0 46`N
Longitude	$38^0$1`E	$37^0$42`E	$37^0$47`E	$37^0$33`E
Temperature (°C)	7-21	13-26	12-26	13-24

Source: SGZAO, 2019

2.2. Study animals and their management

The dairy farms considered in this study were those in Debre Tabor, Woreta, Addis Zemen, and Hamusit town. Lactating dairy cows from these dairy enterprises were used as research animals. Lactating HF crossbred cows were purchased as parent stock from government breed multiplication centers, institution dairy farms, Erib dam dairy farms, and well-known farmers. A total of 204 crossbred dairy cows were used (84 with 50% genotype level, 61 with 62.5% genotype level, and 59 with 75% genotype level).The study animals were fed a zero-grazing diet of purchased ration (formulated), non-conventional feeds, and agro-industrial byproducts. The animals were housed in built-up barns, and the dairy cows in the enterprises were bred using both natural bulls and AI services. When animals became ill, they were treated for diseases.

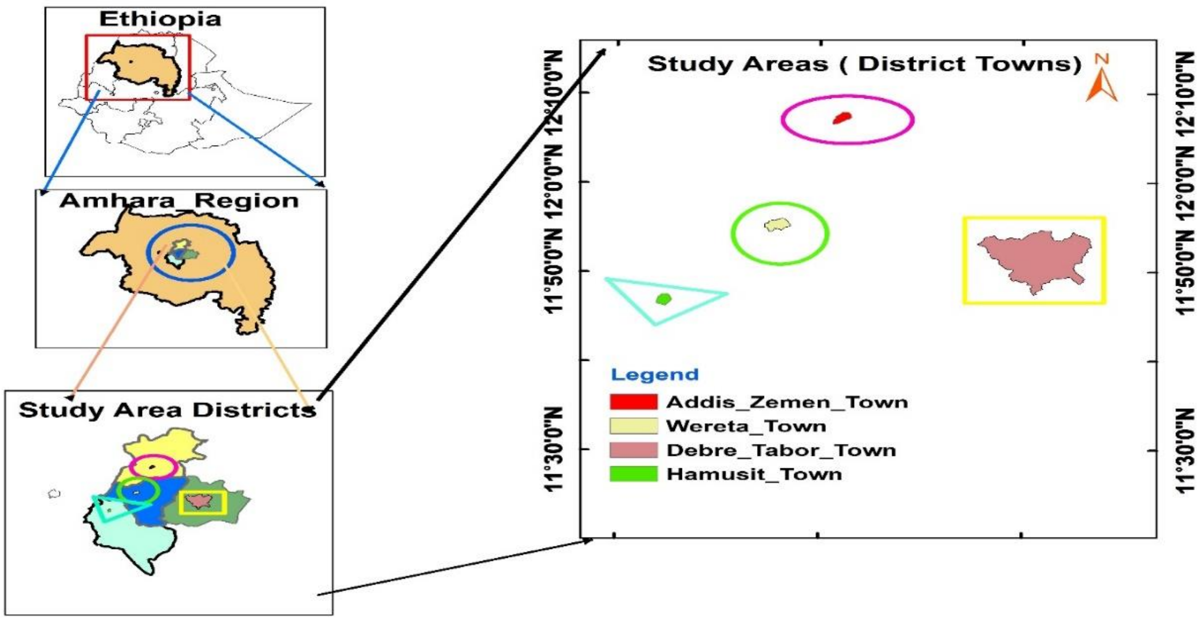

Figure 1: Maps of the study areas
Source: Prepared by Geographic Information System (GIS)

2.3. Data type and methods of data collection

A total of 204 lactating dairy cows with one or more parities from youth managed dairy farm enterprises in the south Gondar zone were studied using both quantitative and qualitative data. The linear and non-linear conformation trait characteristics of lactating dairy cows were measured. For conformational trait measurement, all lactating dairy cows managed under the youth dairy farm enterprise were chosen.

After humanely restraining the selected animals, fourteen (14) linear conformation traits were measured in centimeters: Stature (STA), Chest Width (CW), Body Depth (BW), Body Length (BL), Rump Length (RL), Rump Width (RW), Udder Circumferences (UC), Teat Length (TL), Heart Girth (HG), Neck Length (NL), and Neck Circumferences (NC). To avoid between-individual variations, all measurements were taken by the same person. To reduce measurement error, measurements were taken three times, and the average value was used as a single observation.

In addition, eleven (11) non-linear conformation traits were judged by visual observation and classified on a scale of 1 to 9, including Angularity (ANG), Rump Angle (RA), Rear Legs Set (RLS), Rear Legs Rear View (RLSV), Foot Angle (FA), Locomotion (L), Body Condition Score (BSC), Fore Udder Attachment (FUA), Front Teat Placement (FTP), Rear Teat Placement (RTP), and Teat Thickness (TT) (FAO, 2012; ICAR, 2017). Finally, the association was done on each linear conformational trait and milk yield of each dairy cow.

2.4. Data analysis

SAS software, version 9.0, was used to analyze the data (SAS, 2004). Means, frequency distributions, and percentages were used as descriptive statistics. Duncan's multiple range tests were also used to investigate differences in the levels of significance of conformation traits across lactation stages, genotype level, parity, and location.

The general linear model (GLM) was used to compute means and standard deviations for the quantitative data (SE). P-values at the critical probability of $P<0.05$were used to examine statistical significance between variables. The following model statement about the effect of different fixed factors was used to analyze conformational trait characteristics.

$$Yijk = \mu + Li + Bj + Pk + Sp + \varepsilon ijk \quad [1]$$

Where;

- Y_{ijk} = observations on conformation trait characteristics
- μ =common mean
- L_i = th effect of location (i=Debre Tabor, Woreta, Addis Zemen, and Hamusit)
- Bj = j^{th} effect of genotype level (j=50% of HF, 62.5% of HF and 75% of HF)
- P_k= k^{th} effect of parity (k=1, 2, 3, ≥4)
- S_p = p^{th} lactation stage (p=early, mid and late)
- Ɛijk = random error

3. Results and Discussion

3.1. Linear body conformation traits of crossbred dairy cows

The overall mean ± SD of crossbred dairy cows' Stature (STA), Chest Width (CW), Body Depth (BD), Body Length (BL), Rump Length (RL), Heart Girth (HG), Neck Length (NL), and Neck Circumferences (NC) were 127.81±5.4cm, 23.1±3.1cm, 99.2±4cm, 120.45±4.6cm, 32.2±3.9cm, 168.32±5.1cm, 56.7±3.2cm, and 92.88±3.6cm, respectively (Table 2). Location had a significant effect ($p<0.001$) on the body conformation traits of crossbred dairy cows, according to the findings. Debre Tabor town had the highest body conformation in all traits compared to others. This variation could be due to the environment in which the animals are kept, or it could indicate possible genetic differences between the two groups of animals. Similarly, pair-wise comparisons between study sites revealed significant ($p<0.001$) differences in all phenotypic linear body measurements of dairy cows in the Awi, East, and West Gojjam zones of Ethiopia's Amhara region (Fasil, 2006).

Similarly, parity had a significant ($p<0.001$) effect on Stature (STA), Body Length (BL), Heart Girth (HG), Neck Length (NL), and Neck Circumferences (NC) of crossbred dairy cows, but no significant effect on Chest Width (CW), Body Depth (BD), and Rump Length (RL). Dairy cows with parities four and above were taller (stature) and longer (body length) than those with parities three, two, and one. The increase in body size characteristics with parity observed in this study is similar to previous reports on crossbred dairy cows Alphonsus *et al*. (2012) who reported that older cows were bigger (ST, WH, BD, HG) than younger but peaked at 5^{th} parity and began declining. This significant effect of parity on body size characteristics demonstrates that as parity increases, so does the age of cows, and physiological and morphological growth of the animals occurs concurrently with parity or age.

Most linear body conformation traits of crossbred dairy cows had no significant effect ($p>0.05$) on lactation stage. Except for chest width, genotype level had a significant effect ($p<0.01$) on linear body conformation traits of crossbred dairy cows (CW). According to the current findings, cows in the highest genotype group were taller (stature), longer (body length, neck length), deeper (body depth), and wider (heart girth) than others. This could be attributed to genetic improvement in high genotype level cows. The length and thin neck indicate angularity, which is a common conformation of ideal dairy cattle, whereas the short and thick neck indicates rectangularity, which is a common conformation of meat-type or beef cattle (Misganaw *et al*., 2017).

Table 2: Effect of location, parity, genotype, and stage of lactation on linear body characteristics of crossbred dairy cows in the area

Variables	N	STA (cm)	CW (cm)	BD (cm)	BLN (cm)	RL (cm)	HG (cm)	NL (cm)	NC (cm)
Overall	204	127.81±5.4	23.1±3.1	99.2±4	120.45±4.6	32.2±3.9	168.32±5.1	56.7±3.2	92.88±3.6
Locations		***	***	***	**	***	***	***	Ns
DT	50	131.47±4.5[a]	25.14±3 [a]	102.29±3.9 [a]	122.96±3.9 [a]	35.52±3.7[a]	171.15±3.8	58.4±2.4[a]	92.01±4.6[a]
WO	66	126.64±4.5[b]	22.72±2.7 [b]	99.42±2.6 [b]	119.98±3 [b]	32.77±2.8 [b]	170.69±3.2	57.26±2.9 [b]	94±2.9 [b]
AZ	50	126.2±5.3[b]	22.62±2.9 [b]	96.8±3.7[c]	118.75±5.2 [c]	30.22±2.9[c]	165.77±4.5	55.24±3.3[c]	92.62±2.5 [b]
HM	38	126.5±5.6b	21.54±2.8 [b]	97.2±3.4[c]	119.67±5.2[cb]	29.04±2.8[c]	164.02±5.1	55.67±3.6[c]	92.63±3.7 [b]
Parity	204	***	Ns	Ns	***	Ns	***	***	**
1	79	122.67±3.3[d]	22.81±2.8[a]	98.5±3.9[b]	116.49±3.5[d]	31.6±4.7[a]	165.5±4.6[c]	54.7±3[d]	94.3±4.1[a]
2	55	128.98±3.1[c]	23.6±3[a]	99.9±4.1[ab]	121.25±2.4[c]	32.6±3.1[a]	168.7±4.5[b]	56.7±2.6[c]	93.2±2.8[a]
3	44	131.74±2.8[b]	22.7±3.3[a]	98.9±4.2[ab]	123.57±2.7[b]	32.3±3.1[a]	171.2±4.2[a]	58.6±2.2[b]	91.5±2.6[b]
≥4	26	134.96±1.7[a]	23.62±3.8[a]	100.2±3.5[a]	126.08±2.7[a]	32.7±4[a]	171.6±4.4[a]	60.5±1.7[a]	89.4±2.0[c]
Stage of lactation	204	*	Ns	Ns	Ns	Ns	Ns	**	Ns
First	76	129.4±5.0[a]	22.92±3.4[a]	99.4±4.1[a]	121.8±4.2[a]	32.26±4.2[a]	169.16±4.8[a]	57.9±2.9[a]	92.63±3.5[a]
Second	77	127.2±4.7[b]	23.22±3.0[a]	98.96±3.8[a]	119.8±3.7[b]	32.17±3.9[a]	168.11±5.0[ab]	56.4±3[b]	92.62±4.1[a]
Third	51	125.9±6.4[c]	23.26±2.8[a]	99.07±4.3[a]	119±5.8[b]	32.00±3.7[a]	167.10±5.7[b]	55.4±3.6[c]	93.7±2.9[a]
Genotype level	204	***	Ns	**	***	Ns	***	***	*
50%	84	122.29±2.8[c]	22.25±2.5[b]	97.25±2.9[b]	116.1±3[c]	30.53±3.2[b]	164.59±4.3[c]	54.51±3.1[c]	94.65±2.8[c]
62.5%	61	128.42±2.5[b]	23.45±3.3[a]	100.11±4.2[a]	121.25±2[b]	32.82±4.8[a]	169.41±4.3[b]	56.9±2.3[b]	92.63±4.2[b]
75%	59	133.59±2.4[a]	23.76±3.4[a]	100.47±4.2[a]	124.83±2.9[a]	33.44±3.3[a]	171.59±3.7[a]	59.3±2.2[a]	91.06±2.8[a]

Where, DT = Debre Tabor, WO = Woreta, AZ = Addis Zemen, HM = Hamusit, N = number of observation, STA = stature, CW = chest width, BD = body depth, BL = body length, RL = rump length, HG = heart girth, NL= neck length and NC = neck circumferences

3.2. Linear udder conformation traits of crossbred dairy cows

The overall mean± SD of Rump Width (RW), Rear Udder Height (RUH), Udder Depth (UD), Rear Udder Width (RUW), Udder Circumferences (UC), and Teat Length (TL) were 17.39±2.65cm, 14.27±1.8 cm, 18.02±2.7cm, 16.85±2.5cm, 59.16±4.3cm, and 4.65±0.88cm, respectively (Table 3). The current results indicated that location had a significant effect on linear udder conformation traits of crossbred dairy cows at ($p<0.001$), and ($p<0.01$) significant levels. Rump width was lower in Woreta town than in others, but rear udder height and width were higher in Hamusit town and lower in Woreta town. Udder depth, udder circumferences, and teat length were all greater in Debre Tabor town than in the other study locations. These differences in udder morphology across locations could be attributed to differences in the genotype of dairy cows entered into the enterprises as well as environmental variations.

Similarly, except for rear udder height, parity and genotype level had a significant effect ($p<0.01$) in most udder conformation traits, whereas stage of lactation had a significant effect ($p<0.001$ and $p<0.01$) on udder conformation trait characteristics of crossbred cows (Table 3). Rump width, udder depth, rear udder width, udder circumferences, and teat length increased during the fourth parity and early lactation but decreased during the first parity and late lactation. This increase with parity may be due to the progressive development of udder morphology with respect to cow age and parity, or it may be due to the continuous development of udder tissues up to the fourth parity, after which the tissues begin to regress as the age advances. Whereas the decrease in udder traits as the lactation stage increases could be attributed to a decrease in milk yield from the early to the late stage of lactation because good udder size was dependent on the presence of milk, the udder is enlarged with high milk secretion and shrinks with low milk secretion. It is consistent with the findings of Kilekoung *et al*. (2017), who found that linear udder traits of dairy cows increased ($p<0.05$) at the third parity and decreased ($p<0.05$) at the third stage of lactation. Crossbred cows' udder linear traits were low at 50% HF genotype level and high at 75% genotype level. This could be due to genetic advancements that increased udder growth in cows with high HF genotype levels.

A total of 39 pollen and/or nectar source plant species belonging to 23 families were identified during the survey work (Table 1). The species of bee plants reported by beekeepers through survey were more or less comparable to those found by plant inventory and pollen analysis. This has demonstrated that beekeepers' indigenous knowledge is significant for bee plant inventory results.

3.3. Pearson correlation between conformation traits and daily milk yield of crossbred dairy cows

Udder circumferences have a significant ($p<0.001$) strong positive correlation ($r=0.72$) with daily milk yield of crossbred dairy cows, whereas stature ($r=0.64$), rear udder width ($r=0.64$), neck length ($r=0.59$), heart girth ($r=0.53$), and teat length ($r=0.52$) have a significant ($p<0.001$) moderate positive correlation with daily milk yield of crossbred dairy cows (Table 4). Furthermore, body length ($r=0.33$), body depth ($r=0.3$), udder depth ($r=0.22$), and rump width ($r=0.18$) had a weak positive correlation with daily milk yield at a highly significant level ($p<0.001$), and neck circumferences ($r=-0.39$) had a weak negative correlation with milk yield, but chest width, rump length, and rear udder width had no correlation ($p>0.05$).

According to Alphonsus (2012), stature, heart girth, body length, and teat length have a highly positive relationship with the milk yield of Holstein Frisian crossbred dairy cows, whereas chest width and body depth have a highly positive correlation with bodyweight but no correlation with milk yield. Similarly, this study supports the findings of Sawa *et al*. (2013), who found that conformation traits are related to milk yield and can be used to predict cow production performance. It also agrees with Stephania and Julian's (2014) finding that the correlation between stature and milk yield was moderately positive, but that this relationship could have been stronger if the first parity animals had not reached adult size.

Table 3: Effect of location, genotype level, stage of lactation, and parity on linear udder trait characteristics of crossbred dairy cows

Variables	N	RW (cm)	RUH (cm)	UD (cm)	RUW (cm)	UC (cm)	TL (cm)
Overall	204	17.39±2.65	14.27±1.8	18.02±2.7	16.85±2.5	59.16±4.3	4.65±0.88
Location		**	***	**	***	***	***
DT	50	17.93±1.9[a]	14.22±1.5[b]	19.23±3.2[a]	16.42±2.06[b]	61.84±2.7[a]	5.04±0.8[a]
WO	66	16.34±2.0[b]	13.4±1.1[c]	16.67±2.2[c]	15.95±2.4[b]	58.54±3.6[b]	4.61±0.7[b]
AZ	50	17.84±2.7[a]	14±1.1.8[bc]	17.87±2.2[b]	17.84±2.6[a]	57.42±4.8[c]	4.67±08[b]
Dera	38	17.72±3.6[a]	15.86±2.0[a]	18.54±2.3[ab]	17.62±2.4[a]	58.44±4.7[b]	4.21±1.0[c]
Parity	204	***	Ns	*	***	***	***
1	79	15.61±1.7[d]	14.26±1.8[a]	16.39±2.5[c]	15.08±1.6[d]	55.31±3.4[d]	4.02±0.4[c]
2	55	17.27±2.1[c]	14.45±1.8[a]	18.37±2.6[b]	16.68±1.7[c]	60.39±2.3[c]	4.84±0.8[b]
3	44	19.04±2.2[b]	14.18±2.1[a]	19.25±1.7[b]	18.48±2.0[b]	61.93±2.6[b]	5.02±0.8[b]
≥4	26	20.58±2.4[a]	14.08±1.2[a]	20.37±1.6[a]	20.17±2.2[a]	64.04±1.0[a]	5.62±0.6[a]
Genotype level	204	***	Ns	**	**	***	**
50%	84	15.35±1.7[c]	14.38±2.05[a]	16.12±108[c]	14.12±1.7[c]	54.95±3.0[c]	4.03±0.6[c]
62.5%	61	17.76±2.2[b]	14.42±1.7[a]	18.37±2.6[b]	16.6±2.1[b]	60.09±2.2[b]	4.63±0.7[b]
75%	59	19.39±2.3[a]	14.01±1.5[a]	19.88±2.1[a]	18.73±2.4[a]	63.14±2.0[a]	5.39±0.6[a]
Stage of lactation	204	**	***	Ns	*	***	Ns
Early	76	18.32±2.8[a]	13.71±1.6[c]	18.69±2.6[a]	17.69±2.8[a]	60.72±3.7[a]	4.9±0.9[a]
Mid	77	17.04±2.27[b]	14.46±1.8[b]	17.72±2.7[b]	16.31±2.1[b]	58.69±3.9[b]	4.5±0.8[b]
Late	51	16.21±2.27[c]	15.02±1.8[a]	17.25±2.4[b]	16.13±2.0[b]	57.02±4.7[c]	4.4±0.9[b]

Where; DT = Debre Tabor, WO = Woreta, AZ = Addis Zemmen, HM = Hamusit, N = number of observation, RW = rump width, RUH = rear udder height, RUW = rear udder width, UC = udder circumferences, and TL = teat length

Table 4: Pearson correlation between conformation traits and daily milk yield of crossbred dairy cows

	STA (cm)	CW (cm)	BD (cm)	BLN (cm)	RL (cm)	RW (cm)	RUH (cm)	UD (cm)	RUW (cm)	UC (cm)	TL (cm)	HG (cm)	NL (cm)	NC (cm)	DMY (litter)
STA		0.22	0.35	0.9	0.3	0.6	-0.05	0.6	0.55	0.9	0.7	0.6	0.7	-0.47	0.64
		0.001	<0.001	<0.001	<0.001	<0.001	0.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CW			0.65	0.25	0.4	-0.1	-0.02	-0.006	-0.01	0.2	0.14	0.3	0.14	-0.04	0.07
			<0.001	0.0002	<0.001	1.4	0.7	0.9	0.8	0.003	0.03	<0.001	0.03	0.54	0.3
BD				0.4	0.4	0.11	-0.1	0.11	0.01	0.36	0.25	0.38	0.3	-0.13	0.3
				<0.001	<0.001	0.12	0.14	0.1	0.86	<0.001	0.0002	<0.001	<0.001	0.04	<0.001
BLN					0.3	0.6	-0.038	0.53	0.55	0.83	0.66	0.65	0.73	-0.43	0.33
					<0.001	<0.001	0.58	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
RL						0.09	-0.1	0.18	-0.056	0.3	0.23	0.4	0.29	-0.1	0.12
						0.2	0.13	0.008	0.4	<0.001	0.0007	<0.001	<0.001	0.14	0.08
RW							-0.04	0.65	0.63	0.66	0.61	0.25	0.55	-0.45	0.18
							0.55	<0.001	<0.001	<0.001	<0.001	0.0003	<0.001	<0.001	0.009
RUH								0.19	-0.13	-0.04	-0.28	-0.29	-0.16	0.04	-0.08
								0.004	0.06	0.47	<0.001	<0.001	0.01	0.5	0.2
UD									0.36	0.6	0.4	0.16	0.32	-0.24	0.22
									<0.001	<0.001	<0.001	0.01	<0.001	0.0006	<0.001
RUW										0.59	0.55	0.19	0.53	-0.48	0.64
										<0.001	<0.001	0.004	<0.001	<0.001	<0.001
UC											0.7	0.64	0.68	-0.43	0.72
											<0.001	<0.001	<0.001	<0.001	<0.001
TL												0.53	0.6	-0.39	0.52
												<0.001	<0.001	<0.0001	0.002
HG													0.59	-0.28	0.53
													<0.001	<0.001	<0.001
NL														-0.59	0.59
														<0.001	<0.001
NC															-0.39
															<0.001
MY															

Where: STA = stature, CW = chest with, BD = body depth, BLN = body length, RL= rump length, RW = rump width, RUH = rear udder height, UD = udder depth, RUW = rear udder width, UC = udder circumferences, TL= teat length, HG = heart girth, NL= neck length, NC = neck circumferences and DMY = daily milk yield

3.4. Non-linear body conformation trait characteristics of crossbred dairy cows

The overall frequency value indicated that the highest proportion of non-linear body conformation traits were scored at intermediate levels rather than high and low levels in all crossbred dairy cows (Table 5). It is consistent with the findings of Misganaw *et al*. (2017), who found that the overall result of the most common conformations was observed at intermediate levels. Except for foot angle, body condition score, and bone structure, lactation stage had no significant effect (p>0.05) on nonlinear body conformation trait characteristics of crossbred dairy cows. A higher percentage of very low angular foot angle (26.96%) was observed in the early stage of lactation than in the mid and late (4%) stages of lactation, but a higher percentage of intermediate foot angle (30.88%) was observed in the mid-stage of lactation than in the early and late (7.35%) stages of lactation, and a higher percentage of very steep foot angle (15.96%) was observed in the late stage of lactation than in the early (2.94%) and mid-stage (4.94%) of lactations. This indicated that as the stage of lactation increased, the foot angle changed from a very low angle to a very steep foot angle because the cow changed their foot structure during parturitions due to parturitions forces and accumulation of high milk from the udder at an early stage, and they changed to a normal position at the mid and late stages when the udder contained a small amount of milk.

Body condition score (BCS) is a subjective assessment of energy reserves in a dairy cow's adipose tissue that is used to manage dairy cows. It is a widely accepted noninvasive, subjective, quake, and low-cost method of estimating the degree of fatness in dairy cows based on appearances and palpation of the back and hindquarters (Mishra *et al*., 2016).

Crossbred dairy cows scored the highest percent of poor body condition score (19.6 percent) than intermediate (12.25 percent) and grossly fat (5.39 percent) body condition scores early in lactation, and cows scored the highest percent of intermediate body condition score (36.28 percent) than poor (1.47 percent) and grossly fat (0 percent) body condition scores late in lactation. This indicated that most cows in the early lactation stage had poor body condition scores, whereas cows in the mid and late lactation stages had intermediate body condition scores. This is because cows in the early lactation mobilize or utilize body reserves to support milk yield, and loss of body condition score due to high milk yield production at an early stage was greater in cows in the early lactation stage than in others. However, cows in the middle and late stages of lactation may be dry off and reserve body fat. This finding is consistent with Wissal and Rachid's (2019) finding that cows in early lactations had lower body condition scores than others, which could be due to the high mobilization of body reserves in high-yielding cows.

Similarly, a higher percentage of broad and thick bone structure (6.86 percent) was observed at an early stage of lactation than at the mid (1.96 percent) and late (1.47 percent) stages of lactation, but cows at the mid-stage of lactation had a higher level of intermediate bone structure (23.53 percent) than cows at the early (18.83 percent) and late (17.65 percent) stages of lactation, and cows at the mid-stage of lactation had a higher level. This indicated that the cow's bone structures were broad and thick in the early stages of lactation, while intermediate and flat bone structures were observed in the mid-stages of lactation.

All nonlinear body conformation traits of crossbred dairy cattle were significantly affected by parity (p<0.05). The current results show that most parity one cows have less angularity, a higher pin rump angle, a straight rear leg set view, an extreme rear leg rear view, a very low foot angle, a poor body condition score, and a broad bone structure than parity two and three cows. Cows at parity one had poor body conformations, while cows at parity two and three had intermediate to very good body conformations. Cows at parity four and above may have poor body conformations because first parity cows were not mature enough compared to second and third parity cows, but the decline in fourth and above parity cows was due to decline in body condition and degeneration of the body system.

Table 6 showed that genotype had a significant (p<0.001) effect on angularity, rump angle, and rear leg set view. It had no effect on the foot angle or body condition scores of crossbred dairy cows ($p>0.05$). Most 50 percent genotype level crossbred dairy cows had less angularity, a higher pine rump angle, a straight rear leg set view, and an extreme rear leg rear view than 62.5 percent and 75 percent genotype level cows. However, 75 percent genotype level crossbred dairy cows had significantly better angularity, extremely sloppy rump angle, sickled rear leg set view, and parallel feet rear leg rear view than 50 percent and 62.5 percent genotype level cows. It was discovered that cows with the highest genotype level had better body conformation than cows with the lowest genotype level, which could be attributed to the high percentage of dairy type Holstein Frisian cows.

Similarly, location had a significant effect ($p<0.05$) on rump angle, rear leg set view, and rear leg rearview, and it has a significant effect ($p<0.01$) on the angularity of crossbred dairy cows. Most crossbred dairy cows in Woreta Town had poor angularity, straight rear leg set view, extreme rear leg rearview, and very low foot angle compared to others, while the majority of cows in Debre Tabor Town had good angularity, extremely sloppy rump angle, and flat bone structure compared to others (Table 6).

3.5. Non-linear udder conformation trait characteristics of crossbred dairy cows

The overall frequency value indicated that intermediate levels scored a higher proportion of non-linear udder conformation traits than high and low levels (Table 7). It is consistent with the findings of Misganaw *et al*. (2017), who found that the overall result of the most common conformations was observed at intermediate levels (4-6 points).

Most non-leaner udder conformation traits of crossbred dairy cows had no significant effect ($p>0.05$), but for-udder attachment had a significant effect ($p<0.001$) (Table 7). The majority of cows were scored intermediate and extremely strong for udder attachment at the mid and late stages of lactation, but the majority of cows were scored weak and loose fore udder attachment at the early stage of lactation. Parity, on the other hand, had a significant effect ($p<0.01$) on all nonlinear udder conformation traits of crossbred dairy cows. According to the current findings, the majority of cows in parity one had weak and loose fore udder attachment, outside of quarter and intermediate front teat placement, intermediate rear teat placement, and thin teat thickness, whereas cows in parity three had inside of quarter front and rear teat placement, and thick teat thickness. This showed that as parity increased, cows' udder structure improved due to the development of udder morphology.

Table 5: Effect of stage of lactation and parity on non-linear body conformation traits of crossbred dairy cows

Parameters	Stage of lactation			Parity				Overall
	Early (N =76)	Mid (N =77)	Late (N = 51)	1(N = 79)	2 (N = 55)	3 (N = 44)	≥4 (N = 26)	(N = 204)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Angularity		Ns				***		
Lack angularity	18(8.82)	12(5.88)	7(3.43)	22(10.78)	1(0.49)	3(1.47)	11(5.39)	32(18.14)
Intermediate	27(13.24)	37(18.14)	28(13.73)	44(21.57)	25(12.25)	13(6.37)	10(4.9)	92(45.1)
Very angular	31(15.2)	28(13.73)	16(7.84)	13(6.37)	29(14.22)	28(13.73)	5(2.45)	75(36.76)
Rump angle		Ns				***		
High pines	17(8.33)	12(5.88)	7(3.43)	30(14.71)	1(0.49)	2(0.98)	10(4.9)	43(21.08)
Intermediate	33(16.18)	37(18.14)	28(13.73)	40(19.61)	27(13.24)	18(8.82)	7(3.43)	93(45.59)
Extremely sloppy	26(12.75)	28(13.73)	16(7.84)	18(3.92)	27(13.24)	24(11.76)	9(4.41)	68(33.33)
Rear leg set view		Ns				***		
Straight	14(6.86)	11(5.39)	5(2.45)	15(7.35)	3(1.47)	3(1.47)	9(4.41)	30(14.71)
Intermediate	34(16.67)	35(17.16)	31(15.2)	50(24.51)	26(12.75)	13(6.37)	11(5.39)	100(49.02)
Sickled	28(13.73)	31(15.2)	15(7.35)	14(6.86)	26(12.75)	28(13.73)	6(2.94)	74(36.27)
Rear leg rear view		Ns				***		
Extreme	15(7.35)	10(4.9)	5(2.45)	16(7.84)	3(1.47)	3(1.47)	8(3.92)	30(14.71)
Intermediate	34(16.67)	39(19.12)	32(15.69)	50(24.51)	30(14.71)	13(6.37)	12(5.88)	105(51.47)
Parallel feet	27(13.24)	28(13.73)	14(6.89)	13(6.37)	22(10.78)	28(13.73)	6(2.94)	69(33.82)
Foot angle		***				*		
Very low angle	55(26.96)	4(1.96)	4(1.96)	23(11.27)	12(5.88)	13(6.37)	15(7.39)	63(30.88)
Intermediate	15(7.35)	63(30.88)	15(7.35)	39(19.12)	29(14.22)	19(9.31)	6(2.94)	93(45.59)
Very steep	6(2.94)	10(4.9)	32(15.96)	17(8.33)	14(6.86)	12(5.88)	5(2.45)	48(23.53)
Locomotion		*				*		
Sever abduction	32(15.69)	23(11.27)	18(8.82)	32(15.69)	12(5.88)	13(6.37)	16(7.84)	73(35.78)
Slightly abduction	31(15.)	45(22.06)	31(15.2)	39(19.12)	35(17.16)	24(11.76)	9(4.41)	107(52.45)
No abduction	11(6.37)	9(4.41)	2(0.98)	8(3.92)	8(3.92)	7(3.43)	1(0.49)	24(11.76)
Body condition score		**				**		
Poor	40 (19.6)	3(1.47)	1(0.49)	34(11.76)	8(3.92)	3(1.47)	10(4.9)	45(22.06)
Intermediate	25(12.25)	74 (36.28)	41(20.08)	49(24.02)	42(20.59)	35(17.16)	14(6.86)	140(68.63)
Grossly fat	11(5.39)	0	9(4.41)	6(2.94)	5(2.45)	6(2.994)	2(0.96)	19(9.31)

Where; N = number of observation

Table 6: Effect of genotype level and location on non-linear body conformation traits of crossbred dairy cows

Parameters	Genotype level			Locations				Overall N=204
	50% (N= 84)	62.5% (N=61)	75% (N=59)	DT (N=50)	WO (N= 66)	HM (N=34)	AZ (N=50)	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Angularity		***				**		
Lack angularity	24(11.76)	7(3.43)	6(2.94)	4(1.96)	14(6.86)	3(4.41)	10(4.9)	37(18.14)
Intermediate	42(20.59)	29(14.22)	21(10.29)	18(8.82)	26(12.75)	9(10.78)	26(12.75)	92(45.1)
Very angular	18(8.82)	25(12.25)	32(15.69)	28(13.73)	26(12.75)	22(3.43)	14(6.86)	75(36.76)
Rump angle		***				*		
high pines	29(14.22)	8(3.92)	6(2.94)	6(2.94)	12(5.88)	13(6.37)	12(5.88)	43(21.08)
Intermediate	44(21.57)	30(14.71)	19(9.31)	19(9.31)	31(15.2)	15(7.35)	28(13.73)	93(45.59)
Extremely sloppy	11(5.39)	23(11.27)	34(16.67)	25(12.25)	23(11.27)	10(4.9)	10(4.9)	68(33.33)
Rear leg set view		***				*		
Straight	18(8.82)	7(3.43)	5(2.45)	2(0.98)	14(6.86)	7(3.43)	7(3.43)	30(14.71)
Intermediate	50(24.51)	27(13.24)	23(11.27)	25(12.25)	25(12.25)	19(9.31)	31(15.2)	100(49.02)
Sickled	16(7.84)	27(13.24)	31(15.2)	23(11.27)	27(13.24)	12(5.88)	12(5.88)	74(36.27)
Rear leg rear view		**				*		
Extreme	19(9.31)	6(2.94)	5(2.45)	5(2.45)	12(5.88)	6(2.94)	7(3.43)	30(14.71)
Intermediate	50(24.51)	29(14.22)	26(12.75)	22(10.78)	28(13.73)	21(10.29)	34(16.67)	105(51.47)
Parallel feet	15(7.35)	26(12.75)	28(13.75)	23(11.27)	26(12.75)	11(5.39)	9(4.41)	69(36.82)
Foot angle		Ns				Ns		
Very low angle	19(9.31)	26(12.75)	18(8.82)	16(7.84)	28(13.73)	8(3.92)	11(5.39)	63(30.88)
Intermediate	41(20.1)	26(12.75)	26(12.75)	21(10.29)	26(12.75)	17(8.33)	29(14.22)	93(45.59)
Very steep	24(11.76)	9(4.41)	15(7.35)	13(6.37)	12(5.88)	13(6.37)	10(4.9)	48(23.53)
No abduction	4(1.96)	6(3.97)	12(5.88)	6(2.94)	9(4.41)	4(1.96)	5(2.45)	24(11.76)
Body condition score	Ns			Ns				
Poor	24(11.76)	10(4.9)	11(5.39)	5(2.45)	19(9.31)	8(3.92)	13(6.37)	45(22.06)
Intermediate	56(27.45)	44(21.57)	40(19.61)	39(19.12)	39(19.12)	29(14.22)	33(16.18)	140(68.63)
Grossly fat	4(1.96)	7(3.43)	8(3.92)	6(2.94)	8(3.92)	1(0.49)	4(1.96)	49(9.31)

Where; DT = Debre Tabor, WO = Woreta, AZ = Addis Zemmen, HM = Hamusit, N = number of observation

Table 7: Effect of stage of lactation and parity on non-linear udder conformation traits of crossbred dairy cows

Parameters	Stage of lactation			Parity				Overall
	Early (N=76)	Mid (N=77)	Late (N=51)	1 (N=79)	2 (N=55)	3 (N=44)	≥4 (N=26)	(N=204)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Fore udder attachment		***				**		
Week and loose	47(23.04)	3(1.47)	5(2.45)	17(8.33)	11(5.39)	11(5.39)	16(7.84)	55(26.96)
Intermediate	18(8.82)	64(31.37)	16(7.84)	38(18.63)	30(14.71)	25(12.25)	5(2.45)	98(48.04)
Extremely strong and tight	11(5.39)	10(4.9)	30(14.71)	24(11.76)	14(6.86)	8(3.92)	5(2.45)	51(25)
Front teat placement		Ns				**		
Out-side of quarter	12(5.88)	13(6.37)	8(3.92)	17(8.33)	7(3.43)	2(0.98)	7(3.43)	33(16.58)
Intermediate	45(12.06)	44(21.57)	28(13.73)	52(25.49)	33(16.18)	22(10.78)	10(4.9)	117(57.35)
Inside of quarter	19(9.31)	20(9.8)	15(7.35)	10(4.9)	15(7.35)	20(9.8)	9(4.41)	54(26.47)
Rear teat placement		Ns				**		
Outside of quarter	8(3.92)	11(5.39)	6(2.94)	13(6.37)	6(2.94)	2(0.98)	4(1.96)	25(12.25)
Intermediate	48(23.53)	44(21.57)	31(15.2)	58(28.43)	30(14.71)	22(10.78)	13(6.37)	123(60.29)
Inside of quarter	20(9.8)	22(10.78)	14(6.86)	8(3.92)	19(9.31)	20(9.8)	9(4.41)	56(27.45)
Teat thickness		Ns				***		
Thin	12(5.88)	12(5.88)	15(7.35)	30(14.71)	3(1.47)	2(0.98)	4(1.96)	39(19.12)
Intermediate	35(17.16)	41(20.11)	21(10.29)	42(20.59)	30(14.71)	15(7.35)	10(4.9)	97(47.55)
Thick	291(4.22)	24(11.76)	15(7.35)	7(3.43)	22(10.78)	27(13.24)	12(5.88)	68(33.33)

Where; N = number of observation

Location had no significant effect ($p>0.05$) on non-linear udder morphology in crossbred cows, and genotype level had a significant effect on front teat placement ($p<0.01$), rear teat placement ($p<0.05$), and teat thickness ($p<0.001$), but no significant effect on fore udder attachment ($p>0.05$) (Table 8). The majority of crossbred cows (7.35 percent) scored outside of the quarter in their front teat placement at 50 percent HF genotype level than 62.5 percent (5.39 percent) and 75 percent (3.43 percent) genotype levels, respectively, but the highest percent (11.76 percent) of in-side quarter front teat placement were scored at 75 percent crossbred dairy cows than 50 percent and 62.5 percent (7.35 percent) genotype level crossbred cows. Similarly, cows with 50% HF genotype had higher outside rear teat placement and thinner teat thickness than others, but cows with 75% HF genotype had higher inside quarter front teat placement and thicker teat thickness. This meant that the cows with the highest HF genotype level had better udder morphology than the cows with the lowest HF genotype level.

Table 8: Effect of genotype level and location on non-linear udder conformation traits of crossbred dairy cows

Parameters	Genotype levels			Locations				Overall
	50% (N=84)	62.5% (N=61)	75% (N=59)	DT (N=50)	WO (N=66)	HM (N=38)	AZ (N=50)	(N=204)
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Fore udder attachment		Ns				Ns		
Week and loose	18(8.82)	20(9.8)	17(8.33)	17(8.33)	17(8.33)	5(2.45)	16(7.84)	55(26.96)
Intermediate	41(20.1)	30(14.71)	27(13.24)	20(9.8)	37(15.69)	20(9.8)	26(12.75)	98(48.08)
Extremely strong and tight (7-9)	25(12.25)	11(5.39)	15(7.35)	13(6.37)	17(8.33)	13(6.27)	8(3.92)	51(25)
Front teat placement		**				Ns		
Outside of quarter	15(7.35)	11(5.39)	7(3.43)	7(3.43)	11(5.39)	6(2.94)	9(4.41)	33(16.18)
Intermediate	54(26.47)	39(19.12)	24(11.76)	24(11.76)	37(18.14)	22(10.78)	34(16.67)	157(57.35)
Inside of quarter	15(7.35)	15(7.35)	24(11.76)	19(9.31)	18(8.82)	10(4.9)	7(3.43)	54(26.47)
Rear teat placement		*				Ns		
Outside of quarter	12(5.88)	7(3.43)	6(2.94)	5(2.45)	9(4.41)	7(3.43)	4(1. 96)	25(12.25)
Intermediate	57(27.94)	37(18.14)	29(14.22)	24(11.76)	37(18.14)	23(11.27)	39(19.12)	123(60.29)
Inside of quarter	15(7.35)	17(8.33)	24(11.76)	21(10.29)	20(9.8)	8(3.92)	7(3.43)	56(27.45)
Teat thickness		***				Ns		
Thin	25(12.25)	8(3.92)	6(2.94)	5(2.45)	12(5.88)	11(5.39)	11(5.39)	39(19.12)
Intermediate	45(22.06)	32(15.69)	20(9.8)	21(10.29)	32(15.69)	16(7.84)	28(13.73)	97(47.55)
Thick	14(6.86)	21(10.29)	33(16.18)	24(11.76)	22(10.78)	11(5.39)	11(5.39)	68(3.33)

Where, DT = Debre Tabor, WO = Woreta, AZ = Addis Zemmen, HM = Hamusit, N = Number of observations

4. Conclusion and Recommendation

Most linear body conformation traits of crossbred dairy cows in this study had variations in location, parity, and genotype levels. Cows with party four and above were taller (stature) and longer (body length) than other parties. Similarly, cows with the highest HF genotype level (75%) and high altitude location (Debre Tabor town) were taller (stature), longer (body length, neck length), deeper (body depth), and broader (heart girth) than others. Similarly, most linear udder conformation traits of crossbred dairy cows had variations in location, parity, genotype level, and stage of lactation. The result showed that rump width, udder depth, rear udder width, udder circumferences, and teat length increased at the fourth parity and the early stage of lactation but decrease at the first parity and the late stage of lactation. This might be due to the continuous development of udder tissues up to 4th parity, after which the tissues start to regress as age advances and decreases milk yield from early to the late stage of lactation. In this study, udder circumferences have a strong positive correlation (r=0.72) with daily milk yield whereas, stature (r=0.64), rear udder width (r=0.64), neck length (r=0.59), heart girth (r=0.53) and teat length (r=0.52) had a moderate positive correlation with daily milk yield of crossbred dairy cows. To sum up, the study suggests that the narrower and longer cows might produce more milk and be useful for milk production selection criteria in genetic improvement programs than wider and dipper cows. However, future studies with large populations and various genotype levels are required to associate conformation with reproductive and productive traits.

Funding statement
This research did not receive any financial and material supports.

Data availability statement
Data will be made available on request.

Declaration of interest's statement
The authors declare no competing interests.

Acknowledgements
The authors would like to thank dairy farm owners of the respective study areas for their willingness and cooperation to participate in this study and for providing valuable information.

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