

Evaluation of reproductive and milk production performances of Gudali, Holstein and crossbred cows by morphobiometry on traditional small-scale farms in Ngaoundere, Adamawa region (Cameroon)

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Abstract

This study was carried out on 27 traditional small-scale farms in Ngaoundere. The data were collected from 247 cows. The main breeds used for milk production were Gudali (55.47%), Holstein (5.26%) and crossbreeds Holstein x Gudali (HxG) F1 (20.24%), Montbeliard x Gudali (MxG) F1 (2.02%), Simmental x Gudali (SIMGOUD) F1 (5.67%), Charolais x Gudali (ChxG) F1 (2.83%), and Holstein x Gudali (HxG) F2 (3.64%). The morphobiometric traits that can be selected for better reproduction and milk production for the Gudali breed are: height at sacrum between 131 and 138 cm ($r=0.31$, $P=0.01$), inclination of pelvis between 4/9 and 5/9 ($r=0.36$, $P=0.00$), teats 4 to 5 cm long ($r=-0.38$, $P=0.00$), parallel hind legs ($r=-0.31$, $P=0.01$), deep udder furrow of -2 to -4cm ($r=-0.44$, $P=0.00$) and straight hock (149-155°) ($r=0.43$, $P=0.00$); for Holstein: height at sacrum between 136-145cm ($r=0.66$, $P=0.02$), and the voluminous udder (10-16cm) ($r=-0.771$, $P=0.005$); for HxG F₁: open foot angle varying between 36° and 43° ($r=-0.47$, $P=0.03$) and the larger udder (13-19cm) ($r=-0.51$, $P=0.01$), chest width 29 to 33 cm ($r=0.48$, $P=0.02$), more open ribs, and the flattened bone structure (angularity between 6-8) ($r=0.44$, $P=0.04$); for MxG F₁ cows: body depth between 5 and 7 ($r=0.99$, $P=0.00$); and for HxG F₂: high height at sacrum (131-140cm) ($r=-0.99$, $P=0.04$) and angular (6-8) ($r=-1.00$, $P=0.00$).

Keywords: cows, traditional husbandry, conformation traits, milk, Cameroon

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Introduction

Cameroon's economy is based, as in most African countries, on the primary sector. In this sector, livestock farming is the second most important activity after agriculture. Livestock production is dominated by ruminants (Labonne et al. 2002) and the number of cattle is estimated at about 5.8 million with 1.9 million head in the Adamawa region (MINEPIA, 2015). However, this number does not meet the food needs of the Cameroonian population in terms of meat and milk. Despite its significant potential for milk production (a favourable livestock climate with five agro-ecological zones, under-exploited dairy cow herd, existing pastures with 15% of the country's total arable land area and an existing poorly exploited market), Cameroon's current milk production level remains very low and is equivalent to an average consumption of milk and dairy products estimated at 14 liters/inhabitant/year. By exploiting the existing potential, production could provide 25 liters/inhabitant/year compared to the world average of 45 liters/inhabitant/year. In some European countries, milk consumption is around 93 kg/inhabitant/year (ACDIC, 2006). In addition, milk

imports were estimated at 23.686 tones in 2013, or about CFAF 47 billion (MINEPIA, 2015). For these reasons, the development of milk production in Cameroon must be a priority (FAO, 2015). With a view to improve the national milk and meat production, Cameroon had, since colonial times, opted to import the exotic breeds for crossing with the local breeds (Tchoumboué and Manjeli, 1990). Among the exotic dairy breeds formerly imported as a part of efforts to improve the local genetic material are Jersey, Holstein, Montbeliard and Alpine Brown. The crossing of these animals with local breeds had made it possible to obtain more appreciable milk performance in the station through hybrids (Messine et al. 1995). The main milk production sites in Cameroon are located in two regions: Adamawa and North West. Adamawa region homes about 30% of Cameroonian bovine livestock (ACDIC, 2006). Indeed, the main breeds exploited are the Gudali zebu (53.7%), the Holstein x Gudali hybrids (44.4%), and the Holstein cows (16.7%) (Kouamo and Pa-ana, 2017). In the northern part of Cameroon, the Adamawa region and more precisely, the Vina division would offer the best conditions for development of a dairy sector. Indeed, the level of milk production is the highest in the entire northern region of

Cameroon (4.4 ± 3.7 liters in the rainy season and 3 ± 3 liters in the dry season per cow per day). This is explained by the influence of a favourable climate, the availability of food resources, and the crossbred, mainly Holstein and crossbred Holstein x Gudali (Kouamo and Pa-ana, 2017).

This study was carried out with the general objective of evaluating the reproductive and milk production performances of cows exploited in Ngaoundere by morphobiometry. Specifically, it involved establishing a morphobiometric characterization of the exploited genotypes by evaluating their reproductive and milk production performances, and finally, identifying selectable conformational traits that are positively correlated with improved milk production.

Material and methods

The study area

This study was conducted in the urban and peri-urban areas of Ngaoundere, more precisely in Ngaoundere I, II and III subdivisions, in Vina's Division (Fig.1), Adamawa Region (Cameroon). The choice of this site was made on the basis of bibliographic data, which indicated the presence of a potential dairy sector in Vina's Division including the urban and peri-urban areas of Ngaoundere. The reason is the area has a humid tropical climate with high rainfall and mild temperatures, and, therefore, abundant pastures (Kouamo and Pa-ana, 2017). Sampling was random and conducted on the farms selected for the PAPA project.

Morphobiometric measurement of cows

In the field conditions, sixteen (16) quantitative morphobiometric traits were measured in 165 cows aged 7.2 ± 2.69 years (3-18) weighing 355.5 ± 48.89 kg (259-562 kg) with an average Body Score Condition (BSC) of 2.8 ± 0.44 (2-4). The cows were at different lactation stages at specific anatomical reference points based on

international dairy cattle morphology evaluation criteria (WHFF, 2003). The body parts measured either with a measuring rod or with a millimeter adjustment were:

Determination of reproductive performance

From birth, weaning and calving, the parameters such as age at first calving (age of a female at birth of her first calf) and calving interval (number of days between two consecutive calvings of the same female) were evaluated. Age at first calving (190 cows) and average calving interval (130 cows) were assessed using the owner surveys and cow tracking sheets.

Determination of milk production performance

Milk production was evaluated in 165 cows. Milking consisted of pre-stimulation for few seconds of suckling from the calf. Milking was done by hand twice a day, in the morning and evening. The working material used was a graduated bucket for collecting milk. Most of the milk produced was intended for commercial use on one hand, and the breeder's household on the other.

Statistical analyses

The data obtained were analyzed by Statgraphics® Centurion XVI.I. The Kruskal-Wallis non-parametric test was used for the non-normal variables. Significant differences were obtained at $P < 0.05$. The analysis of the main components (ACP) made it possible to group the data from the contingency table consisting of a column of morphobiometric variables as well as production and online variables of individuals (genetic types) followed by a K-means classification from XLSTAT® 2016 software.

The measured parameters explained 88.38% of the results obtained, the most significant of which were: udder depth, teat length, front teat position, rear teat position, fore udder attachment, sacrum height, body depth, angularity, width at pins, rump angle and foot angle (Fig.2).

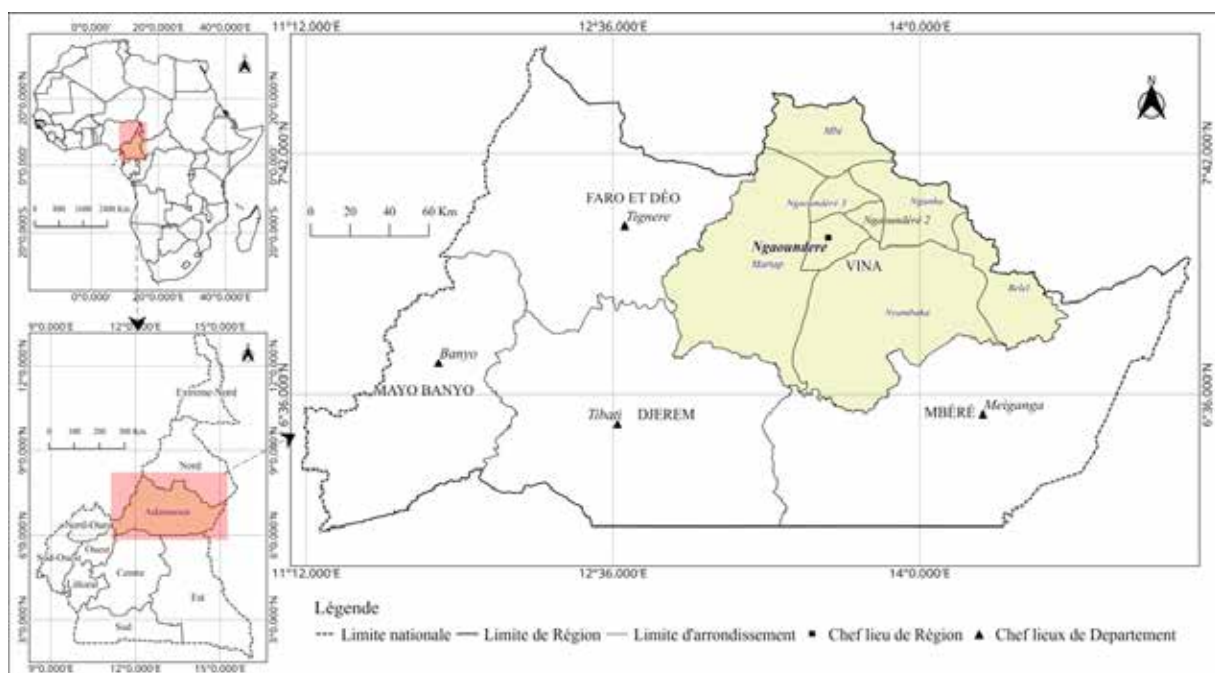


Figure 1. Geographical location of the city of Ngaoundere (INS, 2015)

Sacrum height: distance expressed in centimeter or on a linear scale range from 1 to 9.

1= Small (1.30 cm);

5= Average (1.42 cm);

9= High (1.54 cm).

Chest width:

1 – 3 Narrow;

4 – 6 Average;

7 – 9 Wide.

Reference scale: 13 cm – 29 cm; 2 cm per notation point.

Body depth:

1 – 3 Short;

4 – 6 Average;

7 – 9 Deep.

Angularity:

1– 3 Lack of angularity, round ribs, rude skeleton

4 – 6 Intermediary level and open ribs;

7– 9 Widly open and flat ribs.

Rump angle:

1 Highly inverted;

3 Horizontal;

4 Slightly inclined;

5 Moderately inclined;

9 Highly inclined.

Width at pins:

1 – 3 Narrow;

4 – 6 Average;

7 – 9 Wide.

Reference scale: 10 cm – 26 cm; 2 cm per notation point.

Rear legs rear view:

1 Legs oriented inside;

5 Intermediary: legs slightly oriented outside;

9 Parallels.

Hock angle:

1 – 3 Straight (160°);

4 – 6 Average (147°);

7 – 9 Cranked (134°).

Foot angle:

1 - 3 Angle highly closed;

4 – 6 Intermediary angle;

7 – 9 Angle highly open.

Fore udder attachment:

1 – 3 Weak and loose;

4 – 6 Average;

7 – 9 Very strong and firm.

Front teat position:

1 – 3 Outside of the quarter;

4 – 6 At the middle of the quarter;

7 – 9 Inside of the quarter.

Teat length:

1 – 3 Short;

4 – 6 Average;

7 – 9 Long.

Reference scale: 1-9 cm; 1 cm per notation point.

Udder depth:

1 Udder floor below the hock tip;

2 Udder floor at the level of the hock tip;

5 Average;

9 Udder floor very high.

Reference scale: Level of hock tip = 2 (0 cm); 3 cm per notation point.

Rear udder height:

1 – 3 Very low;

4 – 6 Average;

7 – 9 Very high.

Central ligament:

1 Udder floor convex (+1cm);

4 Slightly marqued (-1 cm);

7 Deep depression (-4 cm);

Rear teat position:

1 – 2 Outward;

4 Central;

7 – 9 Inward.

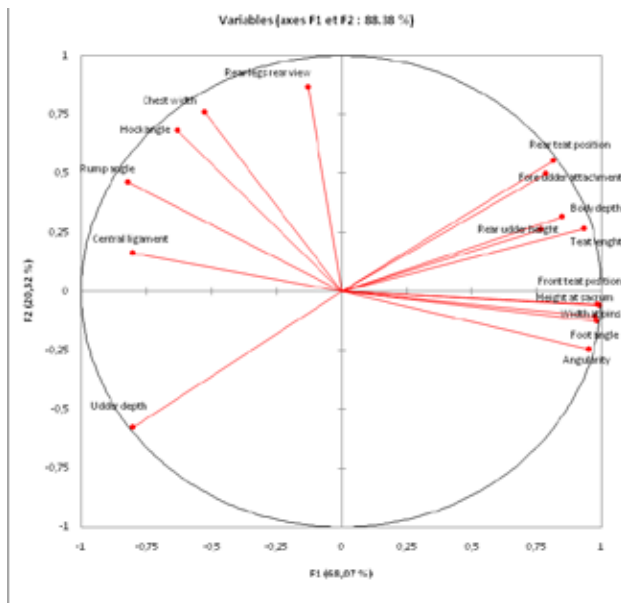


Figure 2. Correlation circle of the measured morphobiometric variables

The levels of binding between the different variables were determined by calculating the Pearson or Spearman correlation (non-parametric test) between each variable taken 2 by 2 by the statistical software Statgraphics® Centurion XVI.I. So, for each breed, the evolution from age at first calving, the calving interval, the daily milk production and the lactation time as a function of the morphobiometric parameters were obtained.

Results

Morphobiometric parameters according to the genetic types studied

Due to the distribution of cows into different genetic types, the following table illustrates the mean \pm standard deviation of morphobiometric parameters as a function of this factor (Table 1).

The pelvis of the Holstein cows was significantly less inclined than that of other breed/crossbred ($P=0.000$). Holstein and HxG F_2 hybrid cows had larger ischiums (19.5 ± 1.43 cm and 17.6 ± 2.59 cm, respectively) ($P=0.000$). The fore udder attachment was stronger in HxG F_2 and weaker in MxG F_1 ($P=0.01$). Udder depth was higher in the Holstein and HxG F_2 cows than in Gudali and MxG F_1 cows ($P=0.03$).

Reproductive performance

The Holstein breed and the HxG F_1 hybrid were the earliest, while the Gudali and the SIMGOUD F_1 hybrid were the latest ($P=0.001$); the calving interval (CI) of the Holstein and HxG F_1 cows was shorter while the SIMGOUD F_1 hybrid had a longer CI (Table 2).

Table 2. Age at first calving (AFC) and calving interval (CI) of cows according to breed/crossbreed

Breed/crossbreed	Age at first calving (months)			Calving interval (months)		
	N	Mean \pm Standard deviation	Min-Max	N	Mean \pm Standard deviation	Min-Max
Gudali (G)	95	49.7 \pm 10.2 ^b	30-84	67	18.2 \pm 6.6 ^b	12-48
Holstein (H)	11	40.7 \pm 6.7 ^a	30-48	6	12.7 \pm 1.0 ^a	12-14
HxG F_1	50	43.5 \pm 10.2 ^a	24-72	36	14.7 \pm 3.9 ^a	12-24
MxG F_1	5	41.6 \pm 6.0 ^{ab}	36-48	5	15.8 \pm 2.6 ^{ab}	12-18
SIMGOUD F_1	14	50.7 \pm 10.6 ^b	36-72	8	25.8 \pm 7.0 ^c	17-36
ChxG F_1	6	42.7 \pm 5.7 ^{ab}	36-49	2	16.5 \pm 2.1 ^{ab}	15-18
HxG F_2	9	45.7 \pm 7.2 ^{ab}	36-60	6	17.7 \pm 5.4 ^{ab}	12-24
p-value		0.001			0.000	

All values in the same column with the same superscript letter are not statistically different at $P<0.05$

Table 1. Morphobiometric parameters according to the breed/crossbreed studied (results are presented as mean \pm standard deviation)

Morphobiometric parameters	Breed/crossbreed							p-value
	Gudali (G)	Holstein(H)	HxG F ₁	MxG F ₁	SIMGOUDF ₁	ChxG F ₁	HxG F ₂	
N	95	11	35	4	7	6	7	
Height at sacrum(cm)	131.9 \pm 5.3 ^{ab}	135.9 \pm 6.3 ^b	134.2 \pm 4.3 ^{ab}	133.4 \pm 6.9 ^{ab}	133.9 \pm 7.1 ^{ab}	128.5 \pm 4.8 ^a	131.0 \pm 5.4 ^{ab}	0.03
Chest width (cm)	29.8 \pm 2.8 ^{ab}	30.9 \pm 2.9 ^b	28.9 \pm 4.1 ^{ab}	26.8 \pm 1.9 ^a	31.1 \pm 3.4 ^b	30.3 \pm 4.1 ^b	29.9 \pm 3.5 ^{ab}	0.01
Body depth	5.5 \pm 1.6 ^{ab}	6.4 \pm 1.4 ^b	5.5 \pm 1.3 ^{ab}	4.7 \pm 2.1 ^a	5.7 \pm 1.4 ^{ab}	5.7 \pm 0.8 ^{ab}	5.3 \pm 0.5 ^{ab}	0.00
Angularity	6.1 \pm 1.2 ^a	6.6 \pm 1.3 ^a	6.3 \pm 1.2 ^a	6.5 \pm 1.3 ^a	6.7 \pm 0.9 ^a	5.8 \pm 0.9 ^a	6.8 \pm 1.6 ^a	0.38
Rump angle	5.4 \pm 1.3 ^b	3.4 \pm 0.7 ^a	4.9 \pm 1.2 ^b	4.8 \pm 0.5 ^b	5.5 \pm 1.0 ^b	5.3 \pm 0.8 ^b	4.7 \pm 1.3 ^b	0.00
Width at pins (cm)	14.4 \pm 1.5 ^{ab}	19.5 \pm 1.4 ^d	15.6 \pm 1.7 ^b	15.0 \pm 0.8 ^{ab}	14.1 \pm 1.3 ^{ab}	13.5 \pm 1.4 ^a	17.6 \pm 2.6 ^c	0.00
Rear legs rearview	7.1 \pm 1.9 ^a	7.3 \pm 1.7 ^a	7.2 \pm 2.1 ^a	5.6 \pm 3.3 ^a	7.1 \pm 1.7 ^a	5.8 \pm 1.0 ^a	5.4 \pm 2.2 ^a	0.17
Hock angle (°)	148.5 \pm 6.5 ^{ab}	146.8 \pm 4.7 ^{ab}	146.8 \pm 5.3 ^{ab}	145 \pm 2.2 ^a	147.9 \pm 4.1 ^{ab}	152.6 \pm 6.3 ^b	147 \pm 9.1 ^{ab}	0.03
Foot angle (°)	34.7 \pm 5.5 ^a	36 \pm 3.4 ^a	35.2 \pm 6.7 ^a	36 \pm 9.2 ^a	33.4 \pm 4.2 ^a	38.0 \pm 5.9 ^a	35.7 \pm 7.3 ^a	0.80
Fore udder attachment	6.1 \pm 2.0 ^{abc}	7.1 \pm 1.9 ^{bc}	6.2 \pm 1.7 ^{abc}	4.5 \pm 1.3 ^a	6.1 \pm 1.5 ^{abc}	5.3 \pm 2.1 ^{ab}	7.6 \pm 1.6 ^c	0.01
Front teat position	4.6 \pm 1.2 ^a	5 \pm 0 ^a	5.0 \pm 1.1 ^a	5 \pm 0 ^a	4.7 \pm 1.4 ^a	4.8 \pm 1.6 ^a	5.1 \pm 1.6 ^a	0.46
Teat length (cm)	4.3 \pm 1.0 ^{abc}	4.9 \pm 1.2 ^c	4.5 \pm 1.1 ^{bc}	3.2 \pm 0.3 ^a	4.6 \pm 0.9 ^{bc}	3.7 \pm 0.5 ^{ab}	4.1 \pm 0.9 ^{abc}	0.02
Rear udder height (cm)	17.2 \pm 3.7 ^a	18.9 \pm 4.0 ^a	17.6 \pm 4.4 ^a	15.8 \pm 5.1 ^a	19.2 \pm 3.4 ^a	16.8 \pm 3.6 ^a	17.8 \pm 4.4 ^a	0.64
Central ligament (neg. value)	-1.8(-4-0) ^a	-1.9(-4-0) ^a	-1.9(-4-0) ^a	-1.6(-2(-1)) ^a	-1.5(-2.5(-0.5)) ^a	-1.3(-2-0.5) ^a	-2.4(-4(-1)) ^a	0.50
Udder depth (cm)	19.9 \pm 4.2 ^b	16.7 \pm 3.5 ^a	19.3 \pm 5.1 ^{ab}	22.1 \pm 4.7 ^b	19.6 \pm 4.0 ^{ab}	19.8 \pm 5.3 ^{ab}	14 \pm 3.8 ^{ab}	0.03
Rear teat position	4.4 \pm 1.9 ^a	5.1 \pm 2.3 ^a	4.9 \pm 1.6 ^a	4 \pm 0 ^a	4 \pm 1 ^a	4.2 \pm 1.7 ^a	5.9 \pm 2.5 ^a	0.22

a,b,c,d: All values in the same line with the same superscript letter are not statistically different at p<0.05

HxG F₁: Holstein and Gudali cross in first generation; MxG F₁: Montbeliard and Gudali cross in first generation; SIMGOUDF₁: Simmental and Gudali cross in first generation; ChxG F₁: Charolais and Gudali cross in first generation; HxG F₂: Holstein and Gudali cross in second generation; N=size.

Milk production performance

The average overall milk quantity for each cow was 3.24± 3.27 liters per day for average cow parity of 2.78 (lactation average). However, it varied according to the breed/crossbreed (Table 3).

The best daily milk production is obtained with the Holstein and HxG F₂ hybrid genotypes. On the other hand, other breed/crossbreed (Gudali and F₁ hybrids in general) have similar daily milk production, while SIMGOUD F₁ has the lowest daily milk production (P<0.0000).

Average lactation length (LL)

The lactation length (months) for each cow was on average 9.7± 3.7 months, and there was no difference between genotypes (table 4).

Table 4. Lactation length (months) according to the breed/crossbreed studied

Breed/crossbreed	N	Mean± Standard deviation	Min- Max
Gudali (G)	107	9.6±4.1	3-24
Holstein (H)	5	10.0±1.0	8-11
GXH F ₁	30	8.6±3.2	5-18
MxG F ₁	4	8.0±2.8	6-12
SIMGOUD F ₁	9	10.9±3.5	3-16
ChxG F ₁	3	8.7±2.8	7-12
GXH F ₂	6	10.8±4.3	6-18
p-value	0.62		

At the significance threshold p<0.05, there is no significant difference between the lactation lengths of the cows.

Correlation between morphobiometric parameters and reproductive and milk production performances

Fig. 3 describes the superposition of the correlation circle on different genotypes.

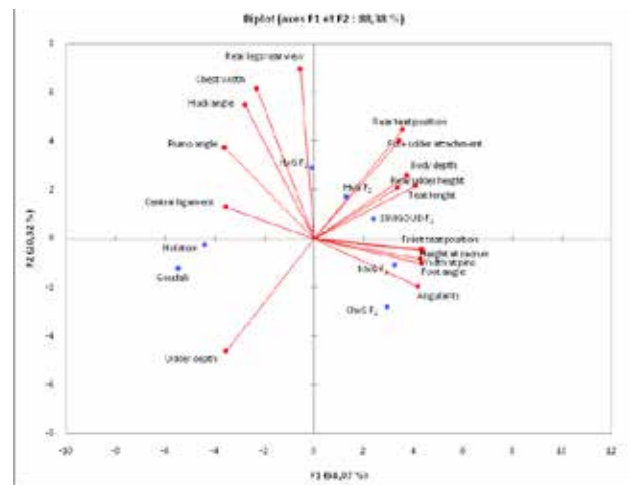


Figure 3. Correlation plot between morphobiometric parameters and breed

Holstein and Gudali cows are strongly correlated to udder depth and central ligament parameters, HxG F₁ cows to rear legs rear view, chest width, hock angle and rump angle, HxG F₂ cows to rear teat position and fore udder attachment, SIMGOUD F₁ with body depth, rear udder height and teat length, MxG F₁ with front teat position, height at sacrum, width at pins, foot angle and angularity and finally, ChxG F₁ with angularity.

In Gudali, only age at first calving is not significantly correlated with morphobiometric parameters. The CI would be reduced with a less inclined pelvis, longer teats, more parallel rear legs and deeper breast furrow. Daily

Table 3. Daily milk production (DMP) according to the breed/crossbreed

Breed/crossbreed	Daily Milk Production (liters)			
	N	Mean parity (Min-Max)	Mean± Standard deviation	Min-Max
Gudali (G)	95	2.71 (1-8)	2.1±1.9 ^a	0.2-11.5
Holstein (H)	11	2.68 (1-6)	9.1±4.8 ^b	5-20
HxG F ₁	35	2.79 (1-14)	4.5±2.6 ^a	1-10
MxG F ₁	4	2.91 (1-4)	3.9±1.9 ^a	2-6
SIMGOUD F ₁	7	2.87 (1-6)	1.8±0.7 ^a	1-3
ChxG F ₁	6	2.61 (1-6)	2.1±1.0 ^a	0.75-3
HxG F ₂	7	2.92 (1-6)	8.6±6.5 ^b	1-20
p-value			0.000	

All values in the same column with the same superscript letter are not statistically different at P<0.05

milk production would increase with height at sacrum, more parallel hind legs, and the deeper breast furrow. In the end, the morphobiometric traits positively associated with better reproduction and milk production are: high height at sacrum (>131.9 cm) ($r=0.3134$; $P=0.013$), pelvis inclination $<5.4/9$ ($r=0.364$; $P=0.004$), teats' length > 4.3 cm ($r=-0.3897$; $P=0.002$), parallel rear legs ($r=-0.319$; $P=0.011$), the udder furrow depth <-1.8 cm ($r=0.444$; $P=0.000$) and the straight hock $>148.5^\circ$ ($r=0.432$; $P=0.001$).

In Holstein cows, CI and LL have a significant correlation with height at sacrum, ($r=0.668$; $P=0.025$), udder depth ($r=-0.771$; $P=0.005$) and central ligament depth ($r=0.684$; $P=0.020$). The LL would increase with height at sacrum, and as the udder depth increases, the CI decreases. Thus, the selectable morphobiometric features for better reproductive and milk production performances are: height at sacrum > 135.9 cm ($P=0.025$), and the voluminous udder (< 16.7 cm udder depth) ($P=0.005$).

Only the AFC and LL parameters have a significant correlation with conformational traits such as chest width, angularity, foot angle and udder depth in HxG F_1 . The earliest HxG F_1 cows would have more open foot angle and the deeper udder. A longer lactation period could be attributed to angular HxG F_1 cows with wider chest, more open ribs, and flatter costal bone. The selection criteria applicable for this crossbreed are: open foot angle $>35.2^\circ$ ($r=-0.474$; $P=0.030$) and the larger udder (<19.3 cm) ($r=-0.519$; $P=0.016$) with wide chest >28.9 cm ($r=0.488$; $P=0.029$), more open ribs, and the flatter bone structure (angularity $>6.3/9$) ($r=0.444$; $P=0.047$).

The significant correlation between conformation traits and reproduction and milk production parameters in MxG F_1 cows is very strong. Thus, the CI is positively correlated with chest width ($r=1.000$; $P<0.0001$), and negatively correlated with rear teat position ($r=-0.968$; $P=0.032$). This result reflects the fact that cows with small chest width as well as rear teats that are more internal to the centre of the quarter, would have a smaller CI. Moreover, strong producing MxG F_1 cows would have fairly deep bodies. However, cows with short teats would have a relatively long lactation period. As a result, for better reproductive performance and milk production in this crossbreed, the morphobiometric parameter to be selected first and foremost is body depth $>4.7/9$ ($r=0.994$; $P=0.006$).

In Charolaise x Gudali F_1 cows, CI is significantly correlated with width at pins ($r=0.889$; $P=0.018$), fore udder attachment ($r=-0.870$; $P=0.024$) and udder depth ($r=0.817$; $P=0.047$) reflecting that cows that give birth early enough would have a stronger and firmer fore udder attachment. There is a significant relationship between daily milk production and pelvic inclination ($r=-0.820$; $P=0.046$) on one hand, and daily milk production and rear view rear limbs on the other hand ($r=0.851$; $P=0.032$). This shows that the most productive cows would have less inclined pelvis ($< 5.3/9$) and more parallel hind legs ($9/9$).

Only daily milk production is significantly correlated with one of the morphobiometric parameters in SIMGOU

F_1 cows: the rump angle, the degree of association being positive and very strong ($r=1.000$; $P=0.000$) attesting that the DMP would increase with increasingly inclined pelvis.

In HxG F_2 hybrids, there is a significant correlation between all reproductive and milk production performances and certain body conformation traits. Early onset would be closely related to the very large chest, and the very high udder attached to the back of the thighs. In addition, HxG F_2 cows with high height at sacrum and angular, would have a short calving interval. Daily milk production would be very strongly and positively related, and this in an equivalent way, to the width at pins and body depth ($r=0.999$; $P=0.029$) meaning that a high daily milk production would correspond to cows with large ischiums and the deep abdomens. Cows with parallel feet would certainly have a high daily milk production, but a shorter lactation period. The following selection criteria for HxG F_2 cows therefore emerge: high height at sacrum (> 131.0 cm) ($r=-0.997$; $P=0.048$) and angular ($> 6.8/9$) ($r=-1.000$; $P=0.000$), broad chest (> 29.9 cm) ($r=-1.000$; $P=0.000$), broad ischiums (>17.6 cm) ($r=0.999$; $P=0.029$), deep bodies ($> 5.3/9$) ($r=0.999$; $P=0.029$) with the rear upper udder attachment (≤ 17.8 cm) ($r=1.000$; $P=0.000$).

Discussion and conclusions

Height at sacrum of Charolais x Gudali F_1 hybrids cows (128.5 ± 4.76 cm) was significantly lower than that of the Holstein cows (135.9 ± 6.32 cm). Such high height at sacrum is characteristic of the format of dairy cows. In addition, a positive and significant correlation was observed between height at sacrum of the Holstein cows and lactation length ($r=0.668$; $P=0.025$) and also with that of the Gudali cows and daily milk production ($r=0.3134$; $P=0.013$). Height at sacrum and chest width of the Holstein cows are lower than the results obtained by Marian et al. (2000) at Kamieniec Zabkowicki in Holland, which reported results of 140.8 ± 2.8 cm and 47.9 ± 3.1 cm, respectively. This difference could be explained by the fact that the Holstein cows raised in tropical conditions had less optimal growth, and therefore more delayed body development than cows of the same breed raised in a temperate environment where they best express their growth potential. The width at pins of the Holstein cows and HxG F_2 crossbreed being 19.5 ± 1.43 cm and 17.6 ± 2.59 cm respectively, are significantly different from each other and superior to those of another breed/crossbreed. These higher values are explained by the fact that large width of the pelvis is characteristic of the dairy type because, according to Atkins et al. (2008), the pelvis should be as wide as possible in order to ensure easy passage of the calf during calving. In addition, good pelvis width increases the width between the hind legs and promotes the correct positioning of the udder, which will not have to be installed in depth. Indeed, in HxG F_2 cows, the daily milk production is significantly and very strongly correlated to the width of ischiums ($r=0.9989$; $P=0.029$). These values are higher than those reported by Kouamo et al. (2018) (15.08 ± 1.63

cm) on zebu females Mbororos Akou and Djafoun in the north region of Cameroon as reported by Misganaw et al. (2017) in Ethiopia (9.98 ± 1.41 cm). This difference could be explained by the fact that their study focused on native cows that did not belong to breeds highly specialized in milk production, such as Holsteins.

Adamou et al. (2017b) reported in a study carried out among Kouri cattle breeders in Niger that the most commonly cited morphobiometric trait for milk performance indicators by breeders was teat length (90.0%). Misganaw et al. (2013) found that the average daily milk production of native Fogera cattle in northwest Ethiopia increased with udder size ($P < 0.01$), while this study showed no significant correlation between milk production, teat length and udder depth ($P > 0.05$) in Gudali. Indeed, in accordance with the hypothesis supported by Atkins et al. (2008), Yakubu (2011) and Tapki and Guzey (2013), the cows with well balanced, strongly attached and very deep udders have sustained and persistent production. However, the nature of this association between the udder conformation traits and milk production is far from general. Lactation length is significantly correlated only with the hock angle, which would reflect the fact that straight hock would correspond to longer lactation in Gudali.

The average age at first calving differs significantly between the crossbreeds. For Holstein and its crosses F_1 and F_2 , the AFC is higher than obtained by Messine et al. (1995) at the IRZV station in Wakwa (31.0 ± 5.4 months for Holstein, and 26.0 ± 6.5 months for HxG F_1), Bayemi et al. (2005) in Bambui, Cameroon (31.7 months for Holstein, and 25.6 months for HxG F_1) and Boujenane and Aïssa (2008; 28.9 ± 3.1 months) in the Tadla region in central Morocco. This difference could be attributed to uncontrolled conditions of the cows.

The calving interval is one of the most important reproductive parameters for assessing reproductive performance in cattle. Indeed, the interval between calvings of 365 days or one calf per year, which is the optimal objective in dairy farming, is conditioned by better heat period detection and a short interval between calvings (Alkoiret and Gbangboche, 2005). The average calving interval of the cows in this study corresponds on average to the production of 0.69 calves per year. In addition, the interval between calvings is directly related to the time required to return to breeding and the success rate for insemination or natural mating (Byishimo, 2012). According to Hanzen et al. (1996), prolongation of the interval between calvings would cause significant economic losses and would originate in cows, environmental management and herd reproduction. In this study, the CI of the Holstein and HxG F_1 cows (12.7 ± 1.03 and 14.7 ± 3.98 months, respectively) was shorter than in the Gudali cows (18.2 ± 6.62 months). Our result is similar to those reported by Messine (2003) at the IRZV station in Wakwa, Kamga et al. (2001) in the western highlands of Cameroon and Boujenane and Aïssa (2008) in intensive breeding in the Tadla region of Morocco. However, they are higher than the values obtained by Sokouri et al. (2010)

for local zebu cows in Côte d'Ivoire. Different conditions of breeding could explain the differences.

For milk quantity, the Holstein breed was significantly higher in pure breed (9.1 ± 4.86 liters/day) and F_2 crossing (Holstein x Gudali) (8.6 ± 6.55 liters/day) than in all other crossbreeds studied, in particular those of Gudali (2.1 ± 1.99 l/day) and HxG F_1 (4.5 ± 2.64 litres/day). Production of Gudali cows is similar to that obtained by Messine et al. (1995) (2.57 ± 0.19 l/day). The DMP of the Holstein and HxG F_1 crossbreeds are lower than those observed by Messine et al. (1995) (11.53 ± 0.12 l/day and 6.50 ± 0.10 l/day, respectively) in stations (controlled area). On the other hand, Djoko et al. (2003) (8.05 l/day for Holstein and 6.18 l/day for HxG F_1), Bayemi et al. (2005) (11.5 l/day for Holstein), and Kamga et al. (2001) (8.6 l/day for Holstein and 7.2 l/day for HxG F_1) in Bambui in the West Cameroon Highlands all report similar results to this study.

Tapki and Guzey (2013) found a significant but low correlation ($r = 0.29$) between angularity and daily milk production in the Holstein cows in Ceylanpinar State in Turkey as well as a significant but negative correlation between udder depth and daily milk production ($r = -0.31$). However, daily milk production does not have a significant correlation with morphobiometric parameters in Holstein in this study. This result is inconsistent with specific characteristics of the Holstein, a breed specialized in milk production. Therefore, one would expect to observe a significant correlation between milk production and morphobiometric parameters. This corroborates the results of Marian et al. (2000) in Holland who reported that the values of correlation coefficients obtained between conformation traits and milk production in cows were low and statistically insignificant. In the context of our study, this contradiction could be explained by several factors, in particular: farming conditions (temperature of the environment not adapted to optimal production of the Holstein breed), feeding often not rationed, often insufficient water supply, lack of reproductive monitoring, free-range farming and pathologies with almost always negative impact on dairy production.

Following the correlation between AFC and udder depth in HxG F_1 ($r = -0.519$; $P = 0.016$) as well as between LL and angularity ($r = 0.444$; $P = 0.047$), it can be deduced that udder depth and angularity are selection criteria in HxG F_1 hybrid cows. In addition, daily milk production is positively correlated with body depth in MxG F_1 ($r = 0.994$; $P = 0.006$), showing that body depth is a selection criterion in MxG F_1 cows.

In Charolais x Gudali F_1 cows, there is a positive correlation between CI and width at pins ($r = 0.889$; $P = 0.018$), and CI and udder depth ($r = 0.817$; $P = 0.047$). The latter result is opposed to the correlation between lactation length and width at pins ($r = -0.889$; $P = 0.018$), and lactation length and udder depth ($r = -0.817$; $P = 0.047$). This is contradictory because a short calving interval and longer duration of lactation would be related to the narrow pelvis and low udder depth, characteristics unfavourable

for calving and milk production in dairy breeds. This is attributable to the Charolais breed being a suckling breed specialized in meat production, instead of the dairy breed (Sepchat et al. 2018).

SIMGOUD F_1 cows have a single significant link between morphobiometric parameters and reproductive and milk production parameters. This is a very strong and positive correlation between daily milk production and rump angle ($r=1.000$; $P=0.000$) showing that SIMGOUD F_1 cows as good producers would have more inclined pelvis. This is contradictory to the criteria sought in selection of dairy cows since less inclined pelvis is thought to facilitate a calf passage (Atkins et al. 2008). This proves that the use of the SIMGOUD F_1 for milk production is wrong because the Simmental being a mixed breed and crossed with the Gudali would probably favour the inhibition of the dairy character. Another hypothesis would support the origin of the Simmental seeds or bulls used to obtain SIMGOUD F_1 crossbreeds in this study. Indeed, it has been found in the literature that the Simmental breed could be of mixed type or meat type depending on the country.

In HxG F_2 cows, unlike the Goudali, Holstein and HxG F_1 genotypes, there is a significant correlation between morphobiometric parameters and all reproductive and milk production parameters evaluated. Moreover, the correlations are very strong, being higher than 0.8. In this breed, daily milk production is very strongly and positively related to the width at pins ($r=0.9989$; $p=0.029$). Indeed, the results of Kouamo et al. (2018) seem to support the result in Mbororo cows from North Cameroon region having the daily milk production significantly higher in cows with ischial width between 16 and 19 cm. The result presented here is similar to that obtained by Adamou et al. (2017^a) who report that in the Kouri cow in Niger the daily milk production was positively and significantly correlated to conformation traits - ischial width ($r=0.35$) and chest width ($r=0.29$).

In conclusion, this study indicated that the morphobiometric traits that can be selected for better reproduction and milk production are variable according to the breed/crossbreed involved. Further studies will have to be carried out in zootechnic stations in order to validate the selection criteria and integrate them into cow selection strategies for milk production in the Cameroonian Adamawa plateau.

References

- ACDIC, 2006. Filière laitière au Cameroun [WWW Document]. <https://www.cfsi.asso.fr/sites/www.cfsi.asso.fr/files/20-etude-lait-cameroun.pdf> (accessed 04.10.19).
- Adamou K.I., Boubacar A., Issa M., Mouloul H., Abdou H., Malam B. S., Marichatou H., 2017a. Modèle de régression optimale des traits de conformation et de la production laitière des troupeaux bovins de race kouri élevés à la station de Sayam du Niger. *Journal of Applied Biosciences*.113, 11192-11200.
- Adamou K.I., Moumouni I., Harouna A., Malam B.S., Hamani M., 2017b. Pratiques d'élevage et indicateurs morphométriques de performance laitière chez les éleveurs de bovins Kouri au Niger. *Revue d'Élevage et de Médecine Vétérinaire des Pays tropicaux*.70,51-58.
- Alkoiret T., Gbangboche A., 2005. Fécondité de la vache Lagunaire au Bénin: Age au premier vêlage et intervalle entre vêlages. *Revue d'Élevage et de Médecine Vétérinaire des Pays tropicaux*.58,61-68.
- Atkins G., Shannon J., Muir B., 2008. Using conformational anatomy to identify functionality and economics of dairy cows. *WCDS Adv. Dairy Technol*.20, 279–295.
- Bayemi P.H, Bryant M., Perera B., Mbanya J. N., 2005. Milk production in Cameroon: A review. *Livestock Research for Rural Development*, 17(6).
- Boujenane I., Aïssa H., 2008. Performances de reproduction et de production laitière des vaches de race Holstein et Montbéliarde au Maroc. *Revue d'Élevage et de Médecine Vétérinaire des Pays tropicaux*.61,191-196.
- Byishimo J., 2012. Contribution à l'évaluation des performances de reproduction et de production des bovins Girolando dans la ferme agro-pastorale de pout au Sénégal. Thèse Médecine Vétérinaire EISMV Dakar, Sénégal, p. 120.
- Djoko T.D., Mbah D.A., Mban J.N., Kamga P., Awah N.R., Bopelet M., 2003. Crossbreeding Cattle for Milk Production in the Tropics: Effects of Genetic and Environmental Factors on the Performance of Improved Genotypes on the Cameroon Western High Plateau. *Revue d'Élevage et de Médecine Vétérinaire des Pays tropicaux*.56, 63-72.
- FAO, 2015. Production laitière au Cameroun: Croissance, développement, problèmes et solutions. [In English] Disponible sur: www.fao.org [Accessed le 24. 08. 18].
- Hanzen C., Houtain J., Laurent Y., Ectors F., 1996. Influence des facteurs individuels et de troupeau sur les performances de reproduction bovine. *Annales de Médecine Vétérinaire*. 140, 195–210.
- INS (Institut National de la statistique), 2015. *Annuaire Statistique du Cameroun*.p. 15
- Kamga P., Mbanya J.N., Awah N.R., Mbohou Y., Manjeli Y., Nguemdjo A., Kamga Pamela B., Njwe R.M., Bayemi P.H., Ndi C., Imélé H., Kameni A., 2001. Effets de la saison de vêlage et de quelques paramètres zootechniques sur la production laitière dans les hauts plateaux de l'ouest du Cameroun. *Revue d'Élevage et de Médecine Vétérinaire des Pays Tropicaux*. 54, 55-61.
- Kouamo J., Pa-ana P., 2017. Typology of cattle farms in the northern regions of Cameroon. *Revue d'Élevage et de Médecine Vétérinaire des Pays tropicaux*.70, 73-80.
- Kouamo J., Zangué T., Nono F. S., Mfopit Y., 2018. Performances de reproduction et de production laitière des femelles White Fulani et Red Fulani dans les petits élevages traditionnels de la région du Nord (Cameroun). *Rev. Mar. Sci. Agron. Vét.* 3, 294-299.
- Labonne M., Magrong P., Oustalet Y., 2002. Le secteur de l'élevage au Cameroun et dans les provinces du grand Nord: situation actuelle, contraintes, enjeux et défis, Garoua, Cameroun: Actes du colloque, 27-31 Mai. 8p.

17. Marian K., Edward P., Wojciech K., Jerzy A., 2000. Relations between body frame and milk performance of black-white cows imported from Holland. *Electronic Journal of Polish Agricultural Universities, Animal Husbandry*. 3, 1075-1082.
18. Messine O., 2003. Certain aspects of the reproductive performance of Zebu cattle in Cameroon. Phd Thesis. Faculty of Natural and Agricultural Sciences, Department of Animal, Wildlife and Grassland Sciences, University of the Free State, Republic of South Africa. p. 215.
19. Messine O., Tanya V., Mbah D., Tawah C., 1995. Resources génétiques animales du Cameroun. Passé, présent et avenir: le cas de Cameroun. *Animal Genetic Resources Information*. 16, 51-69.
20. MINEPIA, 2015. Elevage et pêche, Rapport annuel. p. 32.
21. Misganaw G., Wuletaw Z., Ayalew W., 2013. Relationships between conformation traits and milk off-take of indigenous cattle breeds in north-western Ethiopia. *Animal Genetic Resources*. 53, 27–32.
22. Misganaw M., Alemayehu K., Tassew A., 2017. Conformation traits of dairy cattle populations in selected Districts of Northwestern Amhara, Ethiopia. *Biodiversitas*. 18, 1669-1679.
23. Sepchat B., D'hour P., Agabriel J., 2018. Production laitière des vaches allaitantes: Caractérisation et étude des principaux facteurs de variation. *INRA Productions Animales*, 30, 139-152.
24. Sokouri D.P., Yapi-Gnaore C.V., N'guetta A.S.P, Loukou N.E., Kouao B.J., Toure G., 2010. Performances de reproduction des races bovines locales de Côte d'Ivoire. *Journal of Applied Biosciences*. 36, 2353- 2359.
25. Tapki I., Guzey Y.Z., 2013. Genetic and Phenotypic Correlations between Linear Type Traits and Milk Production Yields of Turkish Holstein Dairy Cows. *Greener Journal of Agricultural Sciences*. 3, 755-761.
26. Tchoumboué J., Manjeli Y., 1990. Situation et problématique de l'élevage bovin au Cameroun. Centre universitaire de Dschang. p. 18.
27. WHFF, 2003. Evaluation internationale de la morphologie des bovins laitiers. p. 13.
28. Yakubu A., 2011. Path analysis of conformation traits and milk yield of bunaji cows in smallholder's herds in Nigeria. *Agricultura Tropica and Subtropica*. 44, 152–157.

Morfobiometrijska evaluacija reproduktivnih i proizvodnih performansi goveda Gudali, Holstein i križanaca na tradicionalnim malim farmama u Ngaoundereu, regija Adamawa u Kamerunu

Sažetak

Ovo istraživanje je provedeno na 27 tradicionalnih malih farmi u Ngaoundereu. Podaci su prikupljeni na 247 krava. Glavne pasmine za proizvodnju mlijeka su Gudali (55.47%), Holstein (5.26%) i križane pasmine Holstein x Gudali (HxG) F1 (20.24%), Montbeliard x Gudali (MxG) F1 (2.02%), Simmental x Gudali (SIMGOUD) F1 (5.67%), Charolais x Gudali (ChxG) F1 (2.83%) i Holstein x Gudali (HxG) F2 (3.64%). Morfobiometrijske osobine koje se mogu izdvojiti za bolju reprodukciju i proizvodnju mlijeka kod pasmine Gudali su: visina grebena krava između 131 i 138 cm ($r=0.31$, $P=0.01$), ugao karlice između 4/9 i 5/9 ($r=0.36$, $P=0.00$), dužina sisa između 4 i 5 cm ($r=-0.38$, $P=0.00$), paralelne zadnje noge ($r=-0.31$, $P=0.01$), centralni ligament od -2 do -4 cm ($r=-0.44$, $P=0.00$) i ugao skočnog zgloba ($149-155^\circ$) ($r=0.43$, $P=0.00$); za Holstein: visina grebena krava između 136-145cm ($r=0.66$, $P=0.02$) i voluminozno vime (10-16cm) ($r=-0.771$, $P=0.005$); za HxG F₁: otvoren ugao stopala između 36° and 43° ($r=-0.47$, $P=0.03$) i veće vime (13-19cm) ($r=-0.51$, $P=0.01$), širina grudi od 29 do 33 cm ($r=0.48$, $P=0.02$), otvorenija rebra sa ravnijom koštanom strukturom (ugaonost između 6-8) ($r=0.44$, $P=0.04$); za MxG F₁ krave: dubina trupa između 5 i 7 ($r=0.99$, $P=0.00$); i za HxG F₂: visina grebena (131-140cm) ($r=-0.99$, $P=0.04$) i ugaono (6-8) ($r=-1.00$, $P=0.00$).

Ključne riječi: krave, tradicionalno stočarstvo, konformacijske osobine, mlijeko, Kamerun