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# Relationship between Fetal Weight and Maternal Morpho-Biometric and Placentome Characteristics in Local Goats Slaughtered in Lubumbashi, Democratic Republic of Congo

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## Abstract

**Background:** The placenta plays a central role in regulating fetal growth and serves as a key determinant of birth weight and postnatal growth in lambs and kids. Placental mass alone does not adequately reflect functional capacity, whereas cotyledonary characteristics (number, size, surface area) and efficiency provide far more informative indicators. **Objective:** This study evaluated the relationship between fetal weight versus maternal morphometric characteristics (withers height, live weight, body condition score [BCS]) and placentome parameters (length, width, surface area, total number) in Lubumbashi slaughter slabs. **Methods:** An analytical cross-sectional study was conducted from October 1, 2023, to October 31, 2025, across 11 slaughter slabs in Lubumbashi (Kamalondo, Kampemba, Lubumbashi). A total of N = 271 pregnant local goats were included. Geolocation data were collected, and statistical analyses were performed using SPSS v26, including variance inflation factor (VIF) evaluation for multicollinearity. **Results:** Left uterine horn (N = 217): Initial model yielded $R^2$ = 30.4%, F (5, 265) = 23.20 ($p < 0.0001$). Extreme multicollinearity was detected due to surface area being a mathematical derivative of length × width (VIF > 65, r > 0.85). The optimized 5-predictor model demonstrated that fetal placentome

length ($\beta$ = 0.463, p < 0.0001; +30.40 g per cm), maternal placentome width ($\beta$ = 0.440, p = 0.0001; +41.82 g per cm), total placentome count ($\beta$ = 0.171, p = 0.0011; +6.14 g per unit), and maternal live weight ($\beta$ = 0.129, p = 0.0130; +9.33 g per kg) significantly predicted fetal weight. Withers height, BCS, fetal width, and calculated surface areas were excluded. Right uterine horn (N = 208): Initial $R^2$ = 40.6% (adjusted $R^2$ = 38.3%). Following multicollinearity correction (maximum VIF = 4.21), adjusted $R^2$ reached 38.9%. Key predictors included fetal surface area (+1.82 g per $mm^2$) and placentome count (+5.09 g per unit). Placentomal parameters explained 39.2% of fetal weight variance, whereas maternal external metrics showed negligible correlations (r < 0.20) compared to placentome dimensions (r = 0.41 - 0.61). **Conclusion:** In local indigenous goats of Lubumbashi, fetal growth capacity depends primarily on functional placental exchange surface and development rather than maternal external body dimensions. The right uterine horn demonstrated greater predictive capacity (39.2% vs. 30.4% explained variance).

## Subject Areas

Veterinary Medicine

## Keywords

Local Goat, Fetal Weight, Placentome, Caruncle, Cotyledon, Multicollinearity, Lubumbashi

## 1. Introduction

The placenta plays a central role in regulating fetal growth and is a key determinant of birth weight and postnatal growth in lambs. In sheep, variation in placental characteristics influences not only neonatal outcomes but also later growth trajectories, confirming the concept of developmental programming. This review synthesizes current knowledge of key placental characteristics, including placental weight, number of cotyledons, their size and surface area, and indices of placental efficiency, evaluating their associations with birth weight and postnatal growth. Placental mass alone does not adequately reflect placental function, while cotyledonary characteristics and efficiency provide more informative indicators of fetal growth capacity. Relationships between placental features and growth outcomes are strongly influenced by litter size, maternal parity, and breed [1].

The placenta is a temporary tissue that develops solely for offspring development, lying between the chorion and the uterine mucosa, and forms only during pregnancy [2].

## 2. Materials and Methods

### 2.1. Study Design and Period

An analytical cross-sectional study was conducted between October 1, 2023, and

October 31, 2025, evaluating maternal and placentomal biometric characteristics of pregnant local indigenous goats slaughtered across selected slaughter slabs in the city of Lubumbashi.

## 2.2. Study Location and Environmental Context

The study was carried out in 11 active slaughter facilities located across three major municipalities of Lubumbashi: Lubumbashi, Kamalondo, and Kampemba. Lubumbashi experiences a humid tropical climate (Köppen Cwa classification) characterized by three distinct seasons: a rainy season (November-March), a dry season (May-September), and transitional months (April and October). Mean annual temperature is 22.4˚C (peaking in October at 25.5˚C), and mean annual rainfall is 1098 mm, with maximum relative humidity occurring in January (84.0%) (See Table 1).

Table 1. Geographic coordinates of sampled slaughter slabs in Lubumbashi.

| No. | Slaughter Site Name | DMS Coordinates | Decimal Degrees (QGIS) |
|---|---|---|---|
| 1 | Abattoir Public | S11˚40'06.5"/E27˚23'43.7" | −11.668472/27.395472 |
| 2 | Tuerie Kabasele | S11˚40'18.4"/E27˚29'21.4" | −11.671778/27.489278 |
| 3 | Tuerie Basonge 2 | S11˚41'00.0"/E27˚25'16.4" | −11.683333/27.421222 |
| 4 | Tuerie Basonge 1 | S11˚40.382'/E27˚25.388' | −11.673033/27.423133 |
| 5 | Tuerie Lwano | S11˚40'59.6"/E27˚29'18.5" | −11.683222/27.488472 |
| 6 | Tuerie Lwano (Point 2) | S11˚40.330'/E27˚29.312' | −11.672167/27.488533 |
| 7 | Tuerie Babemba 1 | S11˚41'01.8"/E27˚29'17.2" | −11.683833/27.488111 |
| 8 | Tuerie Babemba 2 | S11˚40.332'/E27˚29.345' | −11.672200/27.489083 |
| 9 | Tuerie Lwafula 1 | S11˚40.956'/E27˚29.438' | −11.682600/27.490633 |
| 10 | Tuerie Lwapula 2 | S11˚40.944'/E27˚29.434' | −11.682400/27.490567 |
| 11 | Tuerie Camp Vangu | S11˚42'49.9"/E27˚27'23.6" | −11.713861/27.456556 |

## 2.3. Sampling Strategy and Eligibility Criteria

A two-stage sampling procedure was applied: primary sampling units (slaughter sites) were selected randomly, followed by non-probability snowball sampling of pregnant local goats. Inclusion criteria comprised all healthy pregnant local dams slaughtered within the study timeframe. Exclusion criteria included non-pregnant animals, animals slaughtered outside the study window, and pregnancies exhibiting severe pathological conditions (fetal putrefaction, foul amniotic fluid).

## 2.4. Data Collection and Statistical Analysis

Reproductive organs were collected post-evisceration, refrigerated, and processed in laboratory conditions. Morphometric measurements of dams (body weight, withers height, BCS), fetuses (weight, crown-rump length, sex), and placentomes (maternal caruncle and fetal cotyledon length, width, surface area, and total count

per horn) were performed using digital calipers and precision balances. Data were analyzed using SPSS version 26. Multiple linear regression modeling was conducted with explicit evaluation of Variance Inflation Factors (VIF) to diagnose and eliminate severe multicollinearity.

## 3. Results

### 3.1. Left Uterine Horn Analysis and Multicollinearity Diagnostic

Analysis of the left uterine horn (N = 217) initially produced an overall model $R^2 = 0.304$ (adjusted $R^2 = 0.291$; $F(5, 265) = 23.20$, $p < 0.0001$). Diagnostic VIF testing revealed critical multicollinearity across dimensional parameters (VIF > 40), stemming from calculated surface areas being mathematical derivatives of length and width (See Table 2 and Table 3).

Table 2. Multicollinearity diagnostic for explanatory variables (left uterine horn).

| Explanatory Variable | Variance Inflation Factor (VIF) | Collinearity Diagnostic |
|---|---|---|
| Fetal Placentome Surface Area | 42.15 | Extreme Multicollinearity (VIF > 10) |
| Maternal Placentome Surface Area | 40.99 | Extreme Multicollinearity (VIF > 10) |
| Fetal Placentome Length | 33.59 | Extreme Multicollinearity (VIF > 10) |
| Maternal Placentome Length | 28.00 | Extreme Multicollinearity (VIF > 10) |
| Maternal Placentome Width | 13.74 | Extreme Multicollinearity (VIF > 10) |
| Fetal Placentome Width | 8.22 | Moderate Multicollinearity |
| Dam Live Weight (kg) | 1.38 | No Multicollinearity |
| Dam Body Condition Score (BCS) | 1.36 | No Multicollinearity |
| Dam Withers Height (cm) | 1.11 | No Multicollinearity |
| Total Placentome Count (Left Horn) | 1.06 | No Multicollinearity |

Table 3. Optimized multiple regression coefficients for predicting fetal weight (left uterine horn).

| Explanatory Variable | Unstandardized B | Std. Error | Standardized $\beta$ | t Statistic | p-Value | VIF |
|---|---|---|---|---|---|---|
| (Constant) | −834.37 | 169.44 | — | −4.92 | <0.0001 | — |
| Fetal Placentome Length | 30.40 | 7.07 | 0.463 | 4.30 | <0.0001 | 4.41 |
| Maternal Placentome Width | 41.82 | 10.28 | 0.440 | 4.07 | 0.0001 | 4.46 |
| Maternal Placentome Length | −26.58 | 9.59 | −0.383 | −2.77 | 0.0060 | 7.26 |
| Total Placentome Count | 6.14 | 1.86 | 0.171 | 3.29 | 0.0011 | 1.03 |
| Dam Live Weight (kg) | 9.33 | 3.73 | 0.129 | 2.50 | 0.0130 | 1.01 |

Note: Fetal Weight (g) = −834.37 + 30.40 × (Fetal Placentome Length) + 41.82 × (Maternal Placentome Width) − 26.58 × (Maternal Placentome Length) + 6.14 × (Placentome Count) + 9.33 × (Dam Weight kg).

### 3.2. Right Uterine Horn Analysis and Optimized Model

For the right uterine horn (N = 208), the initial 10-variable model yielded $R^2 = 0.406$ (adjusted $R^2 = 0.383$, $F(10, 260) = 17.74$, $p < 0.001$). Following removal of

collinear linear metrics and retention of integrated surface area, all VIF values fell below 4.21, producing an adjusted $R^2 = 0.389$.

Table 4. Optimized predictors of fetal weight (right uterine horn).

| Retained Predictor | Unstandardized Coefficient ($\beta$) | Std. Error | t Statistic | p-Value |
|---|---|---|---|---|
| (Constant) | −258.12 | 98.42 | −2.623 | 0.0090 |
| Placentome Count (Right Horn) | 5.09 | 1.60 | 3.184 | 0.0020 |
| Fetal Placentome Surface Area ($mm^2$) | 1.82 | 0.14 | 12.746 | <0.0010 |

**Prediction Equation (Right Horn):**

Fetal Weight (g) = −258.12 + 5.09 × (Placentome Count) + 1.82 × (Fetal Placentome Surface Area in $mm^2$) (See Table 4).

## 4. Discussion

We observe a very weak positive correlation (r = 0.13 on the left and r = 0.15 on the right, $R^2$ - 2%). Therefore, the number is not the main factor (Table 2 and Table 3). This result is consistent with Ocak *et al.* [3], who demonstrated that in goats, it is not the number of cotyledons but their total exchange surface that influences the litter weight. Alexander [4] had already postulated that size and surface area have more influence than their mere number. Laven and Peters [5] observed no correlation between placentome number and their weight. Placental plasticity compensates for a reduced number of placentomes by a compensatory increase in their size and exchange surface (compensatory caruncular hypertrophy) [6] [7].

However, our model shows that each additional placentome contributes +6.14 g on the left (p = 0.0011) and +5.09 g on the right (p = 0.002) [8].

In our series, placentome dimensions constitute a major determinant (this is the key result): the dimensions show moderate to strong correlations (r from 0.41 to 0.61). Maternal caruncle length explains 17 to 25% (r = 0.41 to 0.50) and width up to 29% on the right (r = 0.54). Fetal cotyledon length explains 22% on the left (r = 0.47) and 33% on the right (r = 0.58). Fetal width is strongly correlated on the right (r = 0.61, $R^2 = 36.87\%$) (Table 4). These data confirm the concept of placental efficiency. In 2015, Ocak *et al.* found a correlation of r = 0.75 between cotyledonary efficiency and placental efficiency, and r = −0.79 between efficiency and total surface, suggesting that large cotyledons are more efficient than the sum of small ones [3]. Some authors have demonstrated that exchange surface area is the best indicator [9].

The final model indicates that at the left uterine horn level, only fetal cotyledon length ($\beta = 0.463$), maternal caruncle width ($\beta = 0.44$), total number of placentomes ($\beta = 0.171$), and goat live weight ($\beta = 0.129$) are predictors of fetal weight (adjusted $R^2 = 0.291$, F = 23.20, $p < 0.0001$), whereas on the right, cotyledon surface ($\beta = 1.82$) and the number of placentomes ($\beta = 5.09$) predict fetal weight at 39% (adjusted $R^2 = 0.389$, F = 17.74, $p < 0.001$). Some studies cite gestational stage,

breed, and parity [10], while others have found positive correlations between fetal weight and number of cotyledons (0.685; $p < 0.01$), cotyledon length (0.93; $p < 0.01$), and cotyledon width (0.92; $p < 0.01$) [2].

## 5. Conclusions

This study establishes several critical conclusions regarding caprine fetal development in local indigenous breeds of Lubumbashi:

1) External maternal morphometric parameters (withers height, live weight, BCS) are poor predictors of fetal weight ($r < 0.20$, $R^2 < 2\%$), demonstrating the rusticity of local breeds which protect fetal growth despite maternal nutritional constraints.

2) Placentome exchange dimensions (surface area and length) are the predominant biophysical determinants of fetal weight, accounting for up to 39.2% of growth variance.

3) Rigorous statistical correction of extreme multicollinearity (VIF > 40) is essential when modeling placentomal traits to prevent inflated standard errors.

## Author Contributions

**Conceptualisation and methodology**: Emilie Bisibo Sikabwe**,** Simon Ilunga Kandolo and Abdallah Ngona Idi; **Softwar**e: Simon Ilunga Kandolo and Emilie Bisibo Sikabwe; **Validation**: Emilie Bisibo Sikabwe, Simon Ilunga Kandolo, Louis Bitwange Kifuvyo, Didier Tshikung Kambol, Pieter Cornillie and Abdallah Ngona Idi; **Formal analysis**: Simon Ilunga Kandolo; **Investigation:** Emilie Bisibo Sikabwe; **Resources**: Emilie Bisibo Sikabwe; **Data curation**: Emilie Bisibo Sikabwe and Simon Ilunga Kandolo; **Writing review and editing**: Emilie Bisibo Sikabwe, Pieter Cornillie, Abdallah Ngona Idi and Didier Tshikung Kambol; **Visualisation**: Emilie Bisibo Sikabwe, Simon Ilunga Kandolo, Louis Bitwange Kifuvyo, Didier Tshikung Kambol, Pieter Cornillie and Abdallah Ngona Idi; **Project administration**: Emilie Bisibo Sikabwe; **Funding acquisition**: Emilie Bisibo Sikabwe. All authors read and agreed to the published manuscript.

## Ethical and Conflict of Interest Declaration

This study was conducted in accordance with animal ethics guidelines and approved by the Medical Ethics Committee of the University of Lubumbashi.

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