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Time-related and sequential developmental horizons of Sahel goat foetuses

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Abstract

The aim of the present study was to follow the time related developmental changes of caprine foetuses to aid in their age determination. Certain gross external features along with body size changes were studied. Twenty five pregnant Sahel does of known gestational age managed under controlled conditions were used for the study. Absolute changes in the body weight, crown-rump length and height at withers and their relative growth changes compared to body size had similar and significant growth relationships. All the parameters showed high positive significant correlation with the foetal age and with each other with *r*- values ranging from 0.975 to 0.998. A chronological guide on age estimation of caprine foetuses at 28 day gestational interval, evolved from observations based on developmental horizons. The present study has provided a baseline data which could be applied for age estimation of Sahel goat foetuses. It has also indicated that, it is necessary to employ many criteria involving physiological horizons to estimate the age of a foetus age within narrow limits.

Keywords: developmental horizons, foetuses, gestation, Sahel goats, sequential.

Introduction

The goat is fast gaining recognition as a meat and milk source, especially in the developing tropical countries, because of its efficient feed utilization and disease tolerance compared to other domestic ruminants (Devendra & McLeroy, 1988). Goats are emerging as important research animals. They reproduce very fast. Most tropical breeds cycle all year round and produce twins and sometimes triplets (Peacock, 1996). In Nigeria, there are about 34.5 million goats consisting of Sahel, Sokoto Red (Maradi), and the West African Dwarf breeds (Bourn *et al.,* 1994). The breeds are recognised by their physical appearance and grouped according to geographical distribution. Sahel goats are found in the Sahel belt of northern Nigeria, where arid and semi-arid weather conditions prevail. They are long-legged with short fine coat hairs and principal coat colours of plain white, black, brown, or the combinations of these colours in patches or spots (Gall, 1996; Kwari, 2004).

While relatively more studies were conducted on sheep and other livestock (Jainudeen & Hafez, 1993; Sivachelvan *et al*., 1996; Hennessy *et al*.,2001), there is dearth of information on goats (Osuagwuh & Aire, 1986; Osuagwuh & Aire, 1991).

The size of the foetus, measured as length or weight, at different stages of development gives an approximate assessment of foetal age but, is affected by individual variation and by breed differences within a species (Greenwood *et al*.,2005). The accuracy of using the crown-rump length measurements is limited by the fact that, the long neck of some animals precludes accurate measurement, and a further serious variation is introduced by the practice of the crown-rump length along the vertebral column.

The objective of the study was therefore, to determine a time related sequential developmental horizons using several physical characteristics of Sahel goat foetuses of known ages so that they could

be used to estimate the ages of foetuses within a range of 28 day interval, in circumstances where their actual ages could not be obtained.

Materials and methods

Twenty-five adult Sahel does and one Sahel buck were used within the limits of the International guiding principles for biomedical research involving animals. The ethics committee of the faculty of Veterinary Medicine University of Maiduguri, Nigeria approved the study. Strict compliance with EC Directive 86/609/EEC for animal experimentation was observed. Their live-weights ranged from 14 to 25kg and the parity was not known. The animals (does) were synchronised with Cloprostenol, (Estrumate® a synthetic analogue of Prostaglandins ($PGF_{2\alpha}$) at 250µg/ml) and those that came into heat were mated with a healthy and sexually active Sahel buck. The service was repeated if the doe still remained on heat the following day. The service dates were recorded. Non-return to service was considered as an indication for conception. The foetuses were harvested through salvage by exsanguination under barbiturate anaesthesia on days 28, 56, 84, 112 and 140 of gestation. Each group in the above five stages consisted of five does. The parameters considered for the developmental horizons were based on earlier studies (Jainudeen & Hafez, 1993; Sivachelvan *et al.*, 1996). These included foetal weight, the crown-rump length (CRL), height at withers (HW) as well as developmental horizons listed below:

(1) The state and transparency of the integument.
(2) Visibility and prominence of some named blood vessels underlying the integument.
(3) Developmental changes in external genitalia.
(4) Consistency of the segments of *calvarium* (skull-roof), whether soft, pliable or hard, and the presence or absence of *anterior fontanelle.*
(5) Regional appearance of hairs.
(6) State of teeth eruption.

These parameters were recorded and analysed statistically as appropriate by ANOVA and regression analysis using a computer statistical software package (GraphPad InStat, 2000).

Results

Developmental horizons

Foetuses of days 28, 56, 84, 112, 140, as well as, one newborn kid were used to observe the developmental horizons. The chronological pattern of the foetal developmental horizons was as follows.

I. Integument - The integument was pinkish and transparent. At day 28 of gestation the abdominal wall was not closed. By 56th day the abdominal wall was closed. The integument became progressively thicker and whitish and by the 112th day, it lost its transparency.
II. Superficial blood vessels - The external jugular vein, facial vein, scrotal vessels and ear vein were easily seen by the 84th day of gestation. All of them completely disappeared from view by the 112th day.
III. External genitalia - The labium and clitoris and mammary buds in the female, and the penile sheath and an empty scrotum in the male were visible at 56th day of gestation. The testes were palpable in the scrotal sacs by day 84 of gestation.
IV. Calvarium - At day 28 the calvarium was soft, membranous and transparent and the developing brain was visible from the exterior. By day 56, the calvarium was still soft and membranous in the middle marking the anterior fontanelle, but was hard and pliable peripherally in the frontal and parietal regions. As the process of ossification continued, the calvarium became hard and the anterior fontanelle was obliterated by day 84 of gestation. However, the sutures and inter bony clefts could still be palpated. By day 112 of gestation, the whole calvarium was hard to palpation without inter-bony clefts or anterior fontanelle.
V. Appearance of hairs and teeth eruption - The chronological sequence of appearance of hairs on the body was in the following order: eyelid, muzzle, horn pit, poll and forehead; dorsum of the neck; chest; sparsely on the body wall; on limbs; and densely all over the body. Hairs were first observed on the eyelids and muzzle at 84th day of gestation and by day 140, dense hair covered the entire body of the foetuses. Teeth eruption was not recorded in any of the foetuses examined. However, the teeth buds were increasingly prominent particularly by the 112th day of gestation. The one kid which was born after 154 days of gestation weighed 1.4 kg and had 33.2 cm of crown-rump length. It also had three temporary incisors erupted in its lower jaw.

Table 1: Chronological development of the Sahel goat foetuses based on developmental Horizons[a] at known ages

Gestational Age (days)	Developmental features
28	Embryo has the head with optic placodes and limb buds are seen. The skull roof (calvarium) is membranous and transparent. The abdominal wall is partially closed.
56	The calvarium has a membranous middle portion marking the anterior fontanelle which is surrounded by hard and pliable areas of frontal and parietal bones. The mouth, nostrils and ears were seen. The eyes were closed and the ear canals were open. Limb segments and digits with dew claws are seen. Mammary buds and the vulva (labium & clitoris) are seen in females while, the penile sheath and an empty scrotal sac were apparent in the male. There were no hairs on the skin. The external jugular vein is seen through the skin.
84	The calvarium has hardened and the anterior fontanelle was obliterated but inter bony suture or cleft is prominent. The jugular vein, facial vein, scrotal vessels and ear vein are easily seen. Nostrils have opened and the scrotal contents palpable. Fine hairs were seen on the eye lids and the muzzle. The horn pits can be seen. There are canty patches of hair present around the horn pits and the forehead.
112	The calvarium is now hard. Hairs sparsely covered the whole body except the limbs. The hairs are more densely seen around the forehead, eyes, muzzle, chest, poll and dorsum of the foetus. Eye lids are separable and teeth buds are apparent.
140	Dense hairs cover the entire body including the limbs. 1-3 incisors are very prominent at the gum line; the teeth are barely erupted.
At birth (154)	Incisors erupt.

[a] Developmental horizons in the present study included visible and palpable features relating to integument, blood vessels, genitalia, skull-roof, hairs and teeth eruption. This was based on guidelines provided by previous reports of Osuagwuh & Aire (1986) and Sivachelvan *et al.* (1996).

The above features are given in table 1 and Plate 1-5 as a chronological guide to estimate foetal ages of Sahel goats at 28 day intervals from 28 day gestation to birth.

Body measurements

Thirty three foetuses were obtained from twenty five does. However, five foetuses of 28 days old were not used to obtain other measurements as their body weights were too small (mean weight (g) of 1.21 $\pm$ 0.032) only. The offspring obtained from the doe that kidded was also not used in the analysis. The data used were therefore, obtained from 27 foetuses comprising of 14 males and 13 females.

The data on mean ($\pm$SE) of the foetal body weight (g), crown-rump length (cm) and height at withers (cm) for the developing Sahel goat foetuses at days 56, 84, 112 and 140 of gestation are presented in Table 2.

The results from the regression analysis of the parameters studied are shown in Figures 1 to 5. Absolute growth changes parameters showed high positive significant ($P<0.01$) correlation with the foetal age as well as in their relative growth with each other with *r*- values ranging from 0.975 to 0.998. The variables showed a very strong linear relationship in the growth pattern i.e. $y=13.745x-749.41$, $r=0.9988$; $y=0.2817x-3.712$, $r=0.9764$; $y=0.2126x-4.594$, $r=0.9824$; $y=47.658x-541.02$, $r=0.9557$ and $y=0.7446x-1.5461$, $r=0.9789$ for the relationship of the age to foetal body weight (Fig. 1), age to crown-rump length (Fig. 2), age to foetal height at the withers (Fig. 3), foetal body weight to crown-rump length (Fig. 4) and the crown-rump length to the foetal height at the withers (Fig. 5), respectively.

At day 28 of gestation, the foetal mean body weight (BW) was 1.2g ± 0.03; n = 5 and at day 56 of gestation, the mean foetal BW was 28.37g ± 2.23; n = 7; the C-R length was 10.79 cm ± 0.67 and height at withers (HW) was 7.36 cm ± 0.12 (Table 2). These dimensions increased to BW 1169.79 g ± 45.25; C-R 34.28 cm ± 0.47 and HW 24.48 cm ± 0.93 at day 140 respectively (Table 2). This would mean that all the above parameters had same pace in their absolute growth changes during the gestation period under consideration. Also, relative growth changes of other parameters relative to body weight showed isometric proportionate growth relationships. When the 28 day interval periods between 28-56, 56-84 days, 84-112 days and 112-140 days are considered, the absolute weight gain was very low between day 28 and day 56 (0.97g/d) while it remained almost same from day 56 to day140 (12.70g/d; 15.15g/d & 12.91g/d). The percentile increase on the other hand were much higher between 28 to 56 days (2244%) and between 56-84 days (1253%) than the other two periods (111% and 44.71%, respectively) involved.

Table 2: Mean values ± standard error of mean of some parameters of the Sahel goat at different stages of gestation

Foetal age (days)	Foetal weight (g)	Crown-Rump length (cm)	Height at withers (cm)
8	1.21 ± 0.03 (5)	-	-
6	28.37 ± 2.23 (7)	10.79 ± 0.67 (7)	7.36 ± 0.12 (7)
84	383.98 ± 83.47 (6)	21.05 ± 0.79 (6)	12.48 ± 0.15 (6)
12	808.45 ± 57.23 (7)	29.45 ± 0.80 (7)	20.66 ± 0.17 (7)
40	1169.79 ± 45.25 (7)	34.28 ± 0.47 (7)	24.48 ± 0.93 (7)

Figures in parenthesis represents the sample size.

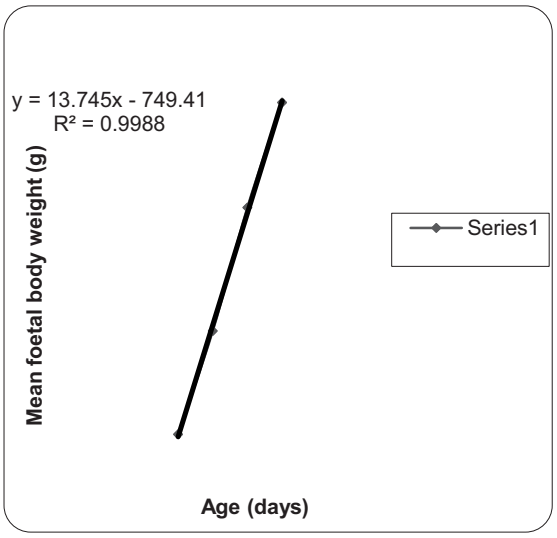

Figure 1: Age-weight relationship in Sahel goat foetal development

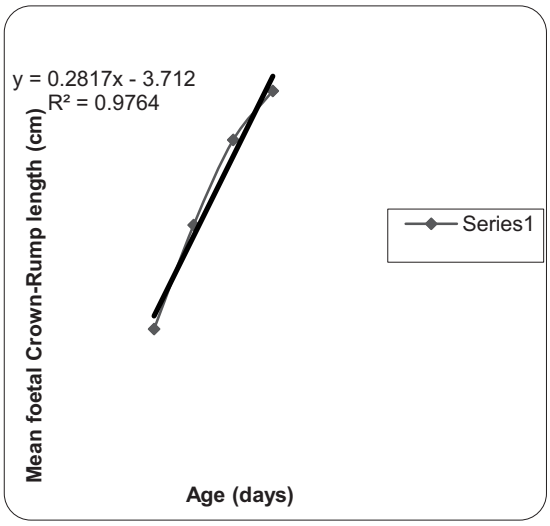

Figure 2: Age-Crown-Rump length relationship in Sahel goat foetal development

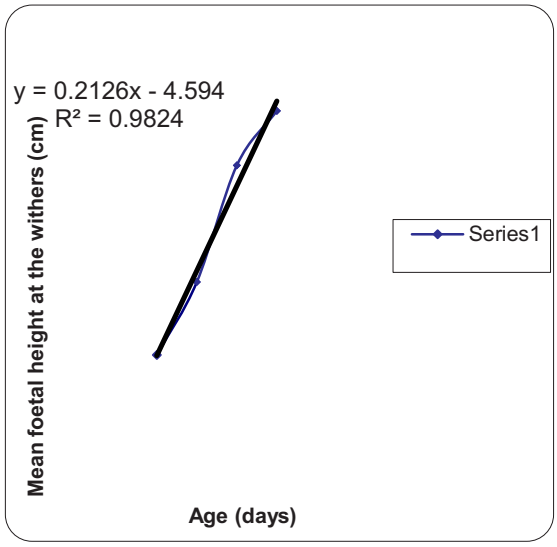

Figure 3: Age-height at the withers relationship in Sahel goat foetal development

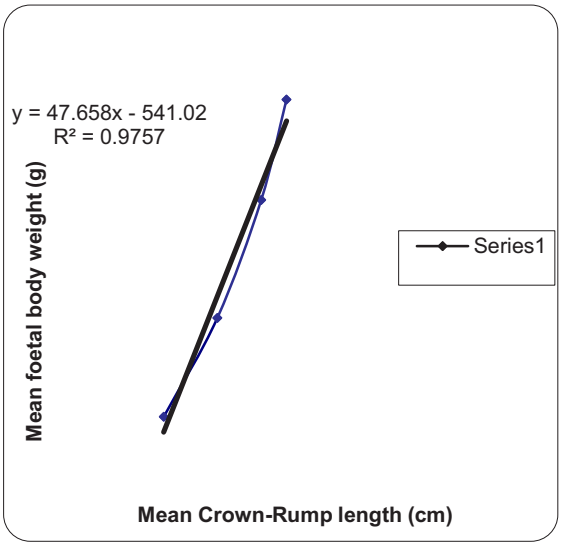

Figure 4: Mean foetal body weight- mean Crown-Rump length relationship in the Sahel goat

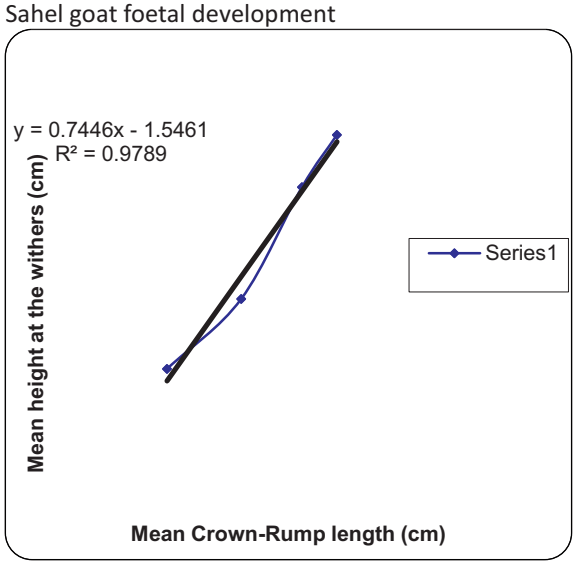

Figure 5: Relationship between Crown-Rump length and height at the withers in Sahel goat foetal development

Plate 1: Embryo of a Sahel goat at day 28 of gestation. Note: The size of the embryo, the optic placodes (long arrow), the Calvarium (short arrows) is membranous and transparent.

Plate 2 :Foetus of a Sahel goat at day 56 of gestation
Note: The mouth, nostrils and ears are seen; eyelids are fused; the limb segments and digits with dew claws are seen. No hair on the skin and the external jugular vein is seen through the skin.

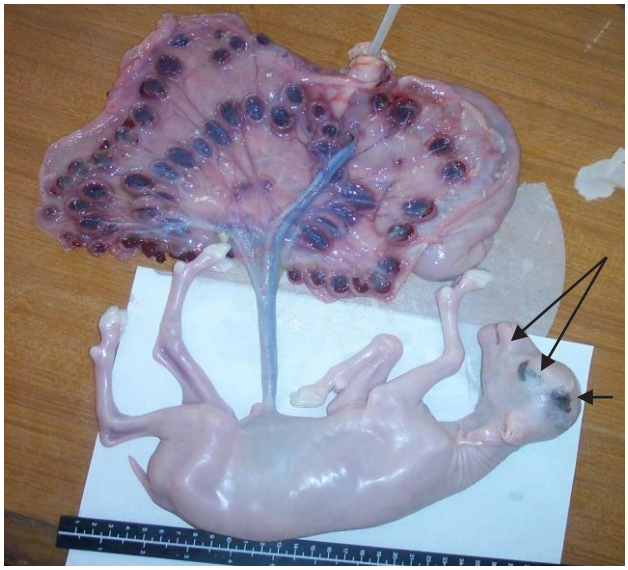

Plate 3 :Foetus of a Sahel goat at day 84 of gestation
Note: Fine hairs are seen on the eyelids and the muzzle (long arrows). Jugular vein, facial veins, scrotal vessels and ear veins can be seen. The horn pit can be seen and there are scanty patches of hair present around the horn pit (short arrow).

Plate 4: Foetus of a Sahel goat at day 112 of gestation.
Note: Hairs sparsely covered the whole body except the limbs. The hairs are more densely seen around the forehead, eyelid, muzzle and poll. The eyelids are separable.

Plate 5: Twin foetuses of Sahel goat at day 140 of gestation.
Note: Dense hairs cover the entire body including the limbs. Full term twin foetuses with colour variation (Black and White) as a manifestation of ecotypes of Sahel goats.

Discussion

The present study used foetuses of known gestational ages so as to correlate certain grossly recognisable external features. The results obtained in this study represent a general chronological guide to estimate ages of caprine foetuses within time interval of four weeks. In the previous studies, foetal age estimation based on developmental horizons

has not been adequately covered for farm animals (Jainudeen & Hafez, 1993). The only work that has followed sequential changes on some features as has been done in the present study is that of Sivachelvan *et al.* (1996). However, they used specimens of unknown ages in their study. The previous data available for sheep (Jainudeen & Hafez, 1993), goats (Osuagwuh & Aire, 1986; Ahemen *et al.*, 2010, and cow Greenwood *et al*.,2005), using specimens with known ages collectively formed a useful basis in formulating the chronological guide. To narrow down the time interval for foetal age determination in a study like the present one, a larger number of pregnant does may have to be sacrificed within shorter intervals during the period of gestation.

Foetal development is influenced by both genetic and environmental factors (Jainudeen & Hafez, 1993; Sivachelvan *et al.*, 1996; Greenwood *et al*; 2005). Those structural features which are essential for life processes and functions of the body are primarily genetically controlled and those involved in secondary adaptory functions such as storage, movement and protection are influenced greatly by environmental factors (Sivachelvan *et al*., 1996). It could be inferred, therefore, that features which are influenced by environmental factors, including nutrition, show variations especially in time-event either within or between species, while genetically biased features are expected to follow the same time-event and sequence in both sheep (148 days) and goats (150 days) with almost the same average length of gestation (Jainudeen & Hafez, 1993; Smith, 1997).

The present data on the crown-rump lengths (CRL), body weight (BW) and heights at withers (HW) of the foetuses were found to positively correlate with the advancing age of gestation. This is consistent with the earlier reports (Osuagwuh & Aire, 1986; Sivachelvan *et al.*, 1996). However, possible variations are expected due to breeds and strains, multiple foetuses are expected to be smaller than single ones and males to be larger than females (Osuagwuh & Aire, 1986; Jainudeen & Hafez, 1993; Sivachelvan *et al.*, 1996, Gregory *et al*; 1996, Cooper *et al*., 1998). Consequently, there are conflicting reports on the acceptability of CRL, BW and HW, on their own, as reliable indices for foetal age estimation because of wide variations due to genetic and environmental factors (Osuagwuh & Aire, 1986; Jainudeen & Hafez, 1993, Gatford *et al.,* 2002). As such, it is not advisable to use any chronological guide with CRL, BW and HW changes as the sole criteria to estimate foetal age within narrow limits, even if it is for a particular breed.

In conclusion, the present study has provided a baseline data (reference points) for age determination of Sahel goat foetuses. It has also indicated that, it is necessary to employ many criteria relating to time event and sequence of changes involving physiological horizons to approximate the age of a foetus within narrow limits.

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