Trop Anim Health Prod (2013) 45:781–789
DOI 10.1007/s11250-012-0289-8

REGULAR ARTICLES

Ultrasound measurements of live and carcass traits in Tswana goat kids raised under semi-intensive system in South-eastern Botswana

Phetogo Ineeleng Monau · Shalaulani James Nsoso · Esau Emmanuel Waugh · Surender Pal Sharma

Accepted: 5 October 2012 / Published online: 7 November 2012

Abstract The aim of this study was to characterise ultrasound measurements of live and carcass traits in intact males, females and castrated Tswana goat kids from birth to 12 months of age raised under semi-intensive system in South-eastern Botswana. Measurements were recorded in 15 castrates, 15 intact males and 15 female Tswana goat kids randomly selected at birth. Ultrasonic fat and muscle depths were measured at the first, third/fourth, sixth/seventh, ninth/tenth and 12th/13th thoracic; first, third and fifth lumbar and first, second/third and fourth/fifth sternal vertebrae, fortnightly for the first 6 months and then monthly for the remaining 6 months. The animals were stunned and humanely slaughtered at 12 months of age, and ultrasound and shatterproof ruler were used to measure fat and muscle depths on the carcasses at similar sites as on live animals. A real-time B-mode ultrasound scanner fitted with LV2-1 probe operating at 7.5 MHz (Explorer V5 Vet Laptop B-Ultrasonic Scanner UMC Technology Development Co., Ltd, China) was used to predict ultrasound measurements on live animals and their carcasses. Data were analysed using general linear model in statistical analysis system. Muscle depth measurements increased significantly ($p<0.05$) with age in all sites of measurements. However, there was no significant difference between the sexes at different sites of muscle depth measurements at the same age. Muscle depth at the sternal vertebrae was significantly deeper (almost 55 mm at 12 months of age) than 16 mm at thoracic and 16 mm at lumbar vertebrae at 12 and 8 months of age, respectively. No subcutaneous fat depth measurements were recorded in the lumbar vertebrae (0.00±0.00) and the thoracic (0.00±0.00) regions in all sex groups. However, fourth and fifth sternal vertebrae showed considerably deeper amount of subcutaneous fat suitable for taking fat measurements as age increases (2.07±0.23 mm females, 1.50±0.43 mm intact males and 1.80±0.38 mm castrates) at 12 months of age. All correlations between live and carcass ultrasound measurements and also between ultrasound carcass and ruler measurements were very high ($r^2=0.96$ to 1.00) for all the sexes indicating that live ultrasound measurements are suitable for use in this meat breed. More research is needed to evaluate the relationships between live ultrasonic measurements and carcass yield in the different sexes of Tswana goat kids.

Keywords Botswana · Carcass · Indigenous goat · Semi-intensive system · Ultrasound parameters

P. I. Monau (✉) · S. J. Nsoso · E. E. Waugh · S. P. Sharma
Department of Animal Science and Production,
Botswana College of Agriculture,
Private Bag 0027,
Gaborone, Botswana
e-mail: phet24@yahoo.com

Introduction

The importance of goats cannot be over emphasised; they provide income, employment, food security to poor farmers, main source of animal protein (milk and meat) and fulfil social functions (Aganga and Sera 2010; Yiga-Kibuuka 2010; Sebolai et al. 2012). Meat production is the most important function of goats in Africa (Držaić et al. 2011). In Botswana, goats contribute to the meat supply mostly in rural areas, where much of the marketed goat meat is sold at local markets, with little attention paid to quality. Meat quality is determined by different characteristics that also determine its relative market value. The main parameters of carcass quality are lean and fat proportions, lean to bone ratio and saleable meat yield (Oliván et al. 2001). Quality and quantity of meat produced are also generally a function of age, sex, genotype and management (feeding in particular) (Chowdhury and Faruque 2004). Knowledge of carcass composition and attempts to estimate the body composition

in live animals are essential for producers to programme the food supply needs, marketing and genetic selection (Teixeira et al. 2006). More importantly, scanning animals at an extended period before slaughter allows sufficient time to make crucial management decisions and decrease carcass discount (Wall et al. 2004). Real-time ultrasound devices are considered the method of choice for accurate measurement of both fat and muscle depths on live animals (Sahin et al. 2008). Ultrasound has been used for evaluating animal composition for over 40 years based on tissue depth and area measurements (Silva et al. 2007) on sheep and cattle, with scanty information on goats. Therefore, to determine optimal breeding strategies to increase the efficiency of Tswana goat production, knowledge of carcass traits of various sexes at different ages is needed. Generating such information can help in contributing to the characterisation of Tswana goat holistically and also aid in selection for their improved productivity. The aim of this study was to characterise fat and muscle depths using ultrasound and ruler measurements on live and carcass in intact males, females and castrates of Tswana goat kids from birth to 12 months of age raised under semi-intensive system in South-eastern Botswana.

Materials and methods

Animals and management

Forty-five Tswana goat kids born at the same time were randomly selected and tagged immediately after birth. The goats were divided into three groups according to sex: 15 castrates, 15 intact males and 15 females. Castration of 15 animals was done at 4 months of age using rubber ring. The kids at 0–4 months of age remained in an enclosed paddock whereby they freely nibbled available feed, while their dams went out to graze natural pasture. At the age of 4 months, the kids were allowed to graze natural pasture together with their mothers. The animals were released for grazing at 0800 hours and remained outside until 1400 hours. The animals were also supplemented with feed when there was a need. Animals received routine inspection, dipping and drenching. Vaccination was done for flock health maintenance. Water was provided ad libitum in the kraals.

Pre-slaughter measurements

Measurements of fat and muscle depths were obtained from each kid using real-time B-mode ultrasound scanner fitted with a LV2-1 linear probe operating at 7.5 MHz (Explorer V5 Vet Laptop B-Ultrasonic Scanner UMC Technology Development Co., Ltd., China). The animals were shaved, and ultrasonic gel was applied as the couplant before the probe was placed. The probe was then placed perpendicular to the backbone; fat and muscle depth measurements were recorded on the first, third/fourth, sixth/seventh, ninth/tenth and 12th/13th thoracic; first, third and fifth lumbar and first, second/third and fourth/fifth sternal vertebrae.

Carcass measurements

Following measurements at 12 months of age, the animals were transported to Lobatse Meat Inspection Training Centre abattoir and slaughtered by standard abattoir practices. Immediately after slaughter, the head, feet including metacarpals and metatarsals, skin, digestive tract, liver, lungs, heart, kidneys, pelvic fat, spleen, diaphragm and genital organs were removed. The carcasses were then cooled at 4 °C for 24 h. After the cooling period, chilled carcass was cut along the midline. Ultrasound and shatterproof ruler were used to measure fat and muscle depths on the left side of the carcass, on the first, third/fourth, sixth/seventh, ninth/tenth and 12th/13th thoracic; first, third and fifth lumbar and first, second/third and fourth/fifth sternal vertebrae.

Statistical analysis

The data were analysed using general linear model procedure in statistical analysis system (SAS Institute 2002–2008) by fitting the following model:

$$Y_{ijk} = \mu + \mathrm{Sex_i} \times \mathrm{Age_j} + \varepsilon_{\mathrm{ijk}}$$

where

Y_{ijk}	observation of individual
μ	population mean
Sex_i	sex (i=1, 2, 3)
Age_j	($_j$=0 to 12 months, age at measurements)
$\varepsilon_{\mathrm{ijk}}$	random error.

The reported least squares means were separated using t test in SAS (SAS Institute 2002–2008). Correlations between live and carcass ultrasound measurements were calculated using Minitab 15 (Minitab 2006).

Results

The mean slaughter weights were 14.87±0.69, 14.00±0.17 and 13.80±1.14 kg for females, intact males and castrates at 12 months of age, respectively.

Ultrasound muscle depth measurements

Generally, muscle depth increased significantly ($p<0.05$) with age on all sites of the thoracic, lumbar and sternal regions.

However, there was no significant difference ($p>0.05$) between the sexes at the same age on all the same sites. The ultrasonic muscle depth measurements over thoracic vertebrae reached almost 16 mm at 12 months of age (Fig. 1). However, muscle depth measurements reached almost 16 mm in lumbar vertebrae for all the sexes between 28 and 30 weeks (Fig. 2).

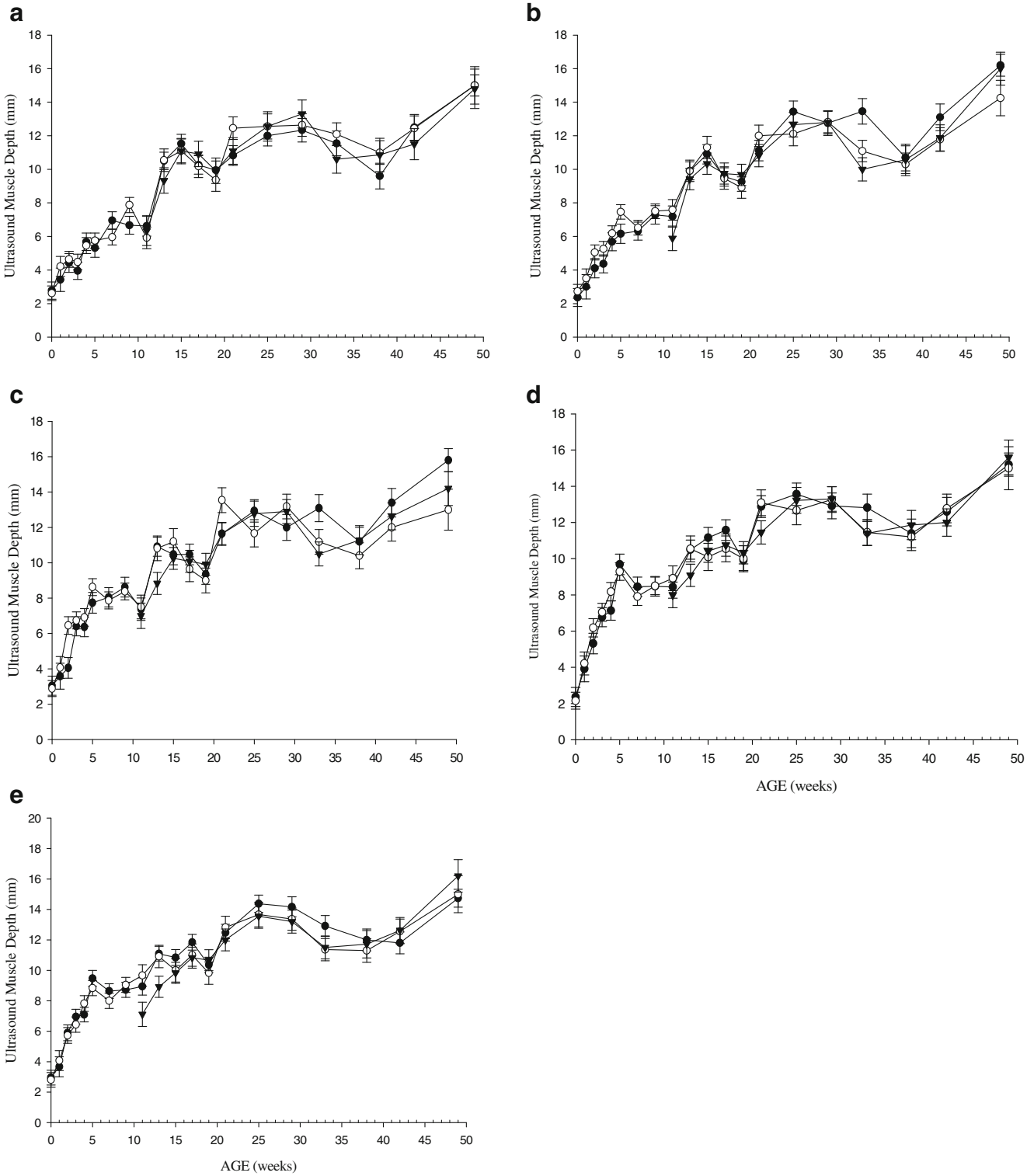

Fig. 1 Ultrasound measurements of muscle depth at the (**a**) first, (**b**) between third and fourth, (**c**) between sixth and seventh, (**d**) between ninth and tenth and (**e**) between 12th and 13th rib for female (*filled circle*), intact male (*empty circle*) and castrated (*inverted triangle*) Tswana kids from birth to 48 weeks of age kept under semi-intensive system in South-eastern Botswana

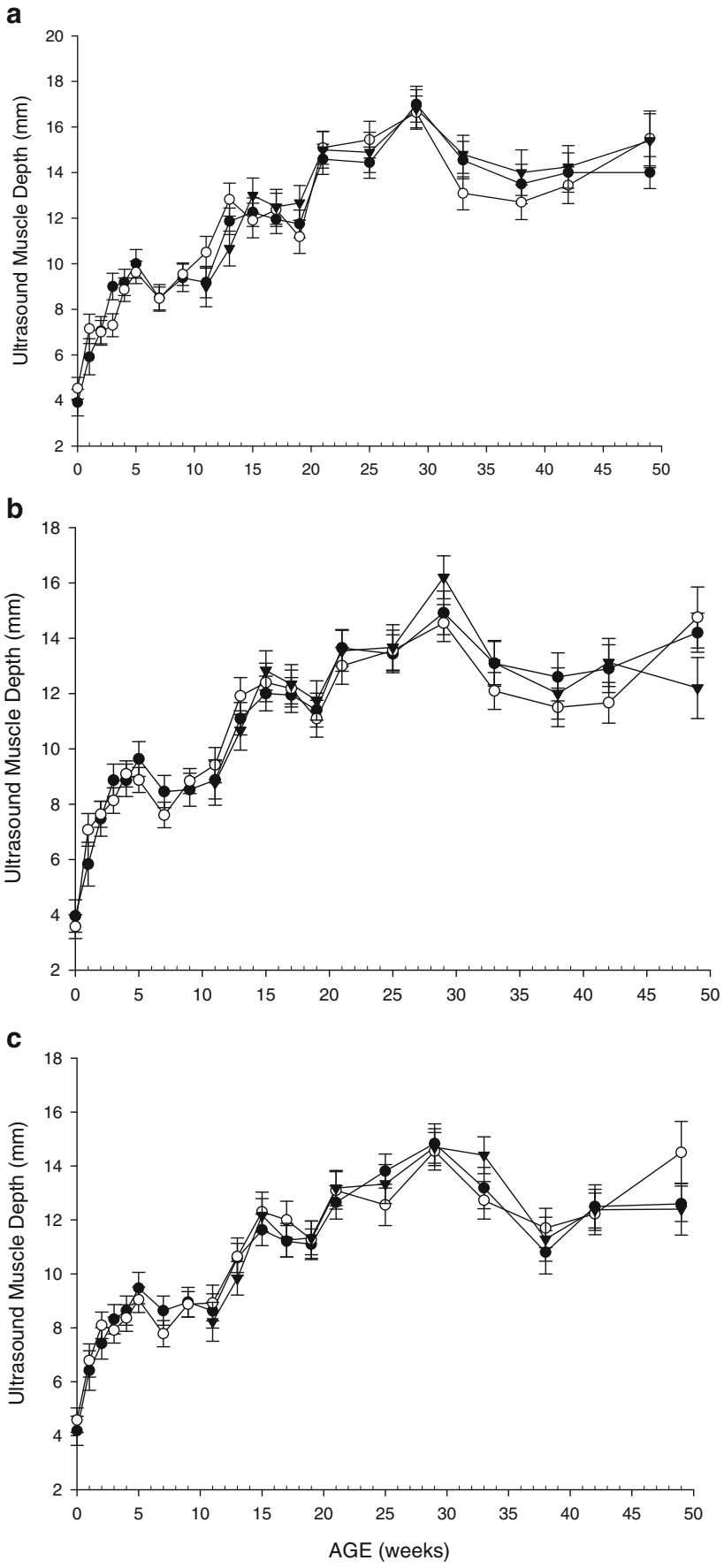

Fig. 2 Ultrasound measurements of muscle depth at the (**a**) first, (**b**) third and fifth lumbar vertebrae for female (*filled circle*), intact male (*empty circle*) and castrated (*inverted triangle*) Tswana kids from birth to 48 weeks of age kept under semi-intensive system in South-eastern Botswana

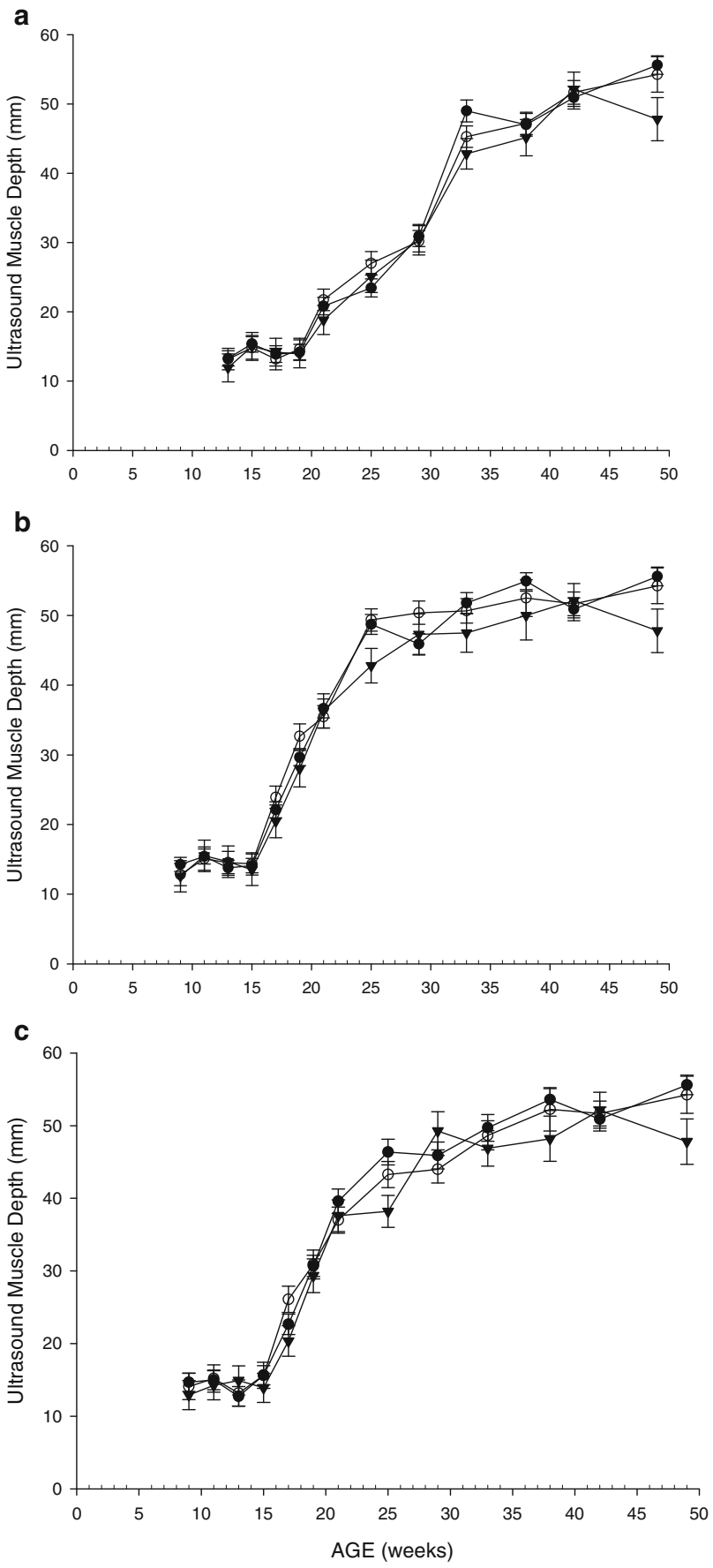

Fig. 3 Ultrasound measurements of muscle depth at the (**a**) first, (**b**) between second and third and (**c**) between fourth and fifth sternal vertebrae for female (*filled circle*), intact male (*empty circle*) and castrated (*inverted triangle*) Tswana kids from 10 to 48 weeks of age kept under semi-intensive system in South-eastern Botswana

The ultrasonic muscle depth measurement was significantly deeper reaching almost 55 mm at 12 months of age for all the sexes over the sternal vertebrae compared to that over the thoracic and lumbar vertebrae (Fig. 3).

Ultrasound fat depth measurements

Ultrasonic fat depth measurements across all the sites of measurements in the thoracic and lumbar vertebrae were not detectable (0.00±0.00). However, on the sternal region, there was an increase on fat depth as the animal aged, which was generally significant from week 38 onwards. Furthermore, there was no significant variation between the sexes as age increased on this trait measured at various sites (Table 1).

Carcass measurements

Slaughter at 48 weeks revealed no significant differences between ultrasound and ruler measurements of fat and muscle depths, although the ruler measurements were slightly higher. Muscle depth measurements from the sternal vertebrae were significantly deeper than those from thoracic and lumbar regions. However, measurements of fat and muscle depths at thoracic and lumbar regions showed no significant difference (Table 2). All correlations between ultrasound and ruler measurements were very high (r^2=0.962 to 1.00).

There were no significant differences between ultrasound and ruler measurements on fat depth among the sexes. However, ultrasound measurements within a sex group were significantly higher in females and castrates than in intact males (Table 3). There were no fat depths detected in the thoracic and lumbar vertebrae either in ultrasound or ruler carcass measurements.

Table 1 Least square means (±SE) of ultrasound measurements of fat depths between the fourth and fifth sternal vertebrae of live Tswana goats from 15 to 48 weeks of age kept under semi-intensive system

Age (weeks)	Fat depth (mm)		
	Females	Intact males	Castrates
15	1.95±0.15 a	1.67±0.19 a	1.67±0.19 a
17	1.84±0.06 a	1.91±0.09 a	2.00±0.09 a
19	2.40±0.18 a	2.72±0.24 a, b	2.25±0.23 a
21	3.24±0.13 b	3.09±0.17 b	3.09±0.17 b
25	2.00±0.00 a	2.00±0.00 a	2.00±0.00 a
29	2.00±0.00 a	2.00±0.00 a	2.00±0.00 a
33	2.25±0.09 a	2.00±0.10 a	2.11±0.10 a
38	3.00±0.00 b	3.00±0.00 b	3.00±0.00 b
42	3.00±0.00 b	3.00±0.00 b	3.00±0.00 b
48	3.00±0.00 b	3.00±0.00 b	3.00±0.00 b

Means with different small letters within rows and columns differ significantly (p<0.05)

Discussion

The significant increase of muscle depth as measured by ultrasound in the three vertebrae regions as the age of the goats increased is consistent with the findings of Nsoso and Macheng (2009). Butterfield (1988) explained that this represents growth and development of farm animals. The similarities in muscle and fat depths among the different groups of goats in the thoracic, lumbar and sternal regions are consistent with Mahgoub et al. (2004) who also found that differences in muscle distribution in goats due to sex were small and unlikely to have a commercial impact on meat production. However, Nsoso and Macheng (2009) reported significantly higher muscle parameters in males than females. The non-significant differences between males and females on muscle and fat parameters in this study could be due to lack of selection for meat production in this breed.

Failure to detect fat depths in the thoracic and lumbar regions in Tswana goats is consistent with the conclusions of several authors: Colomer-Rocher et al. (1992), Teixeira et al. (1995) and Dhanda et al. (1999) who found that a typical feature of goat carcasses is the thin subcutaneous fat cover which increases with age, especially on the sternal region. This is because kids have a slow development of subcutaneous fat (Delfa et al. 2000; Teixeira et al. 1995). Owen et al. (1978) also concluded that indigenous goats generally mature later and have leaner carcasses than sheep. Consistent with previous studies of Delfa et al. (2000) and Teixeira et al. (1995), the sternal vertebrae showed slightly deeper subcutaneous fat layer that is suitable for taking fat measurements as age increases in the goat. The sternal region can therefore be the most useful part of the body to assess subcutaneous fat during growth and development in Tswana goat kids. The higher proportion of muscle and lower proportion of subcutaneous fat in the present study indicate the potential of the Tswana breed as a source of lean meat. Fat deposition is not desirable, and today's health conscious consumer demands leaner meat products (Nsoso et al. 1999). Tswana goats could be genetically superior for lean tissue deposition and inferior for fat deposition and therefore suitable for exportation to various countries and selection programmes. Excess fat deposition is a waste of energy and money (Nsoso et al. 2003). Although Tswana goat growth may not be as rapid as other improved breeds, with modest care and minimum investment, they can produce good yields of meat and improve income for rural communities who keep this indigenous breed.

The values of the ultrasound and ruler measurements on live and carcass traits of Tswana goats in this study were

Table 2 Least squares means (±SE) of ultrasound and ruler measurements of muscle depths on carcass of Tswana kids slaughtered at 48 weeks of age raised under semi-intensive system in South-eastern Botswana

Muscle depth (mm)	Intact male		Female		Castrates	
	Ultrasound	Ruler	Ultrasound	Ruler	Ultrasound	Ruler
At first rib	26.50±2.5 a, b, x	30.60±1.53 a, x	24.79±1.3 a, b, x	26.46±0.95 a, b, x	23.00±2.26 b, x	22.60±1.53 a, b, x
Between third and fourth ribs	26.00±3.23 a, x	27.00±1.68 a, x, y	23.86 ±1.73 a, x	26.69±1.04 a, x	20.60±2.90 a, x	25.00±1.68 a, x
Between sixth and seventh ribs	21.50±2.97 a, x	28.80±3.80 a, x, y	22.43±1.59 a, x	25.69±2.36 a, x	22.80±2.66 a, x	27.80±3.80 a, x
Between ninth and tenth ribs	23.00±2.84 a, x	24.20±2.61 a, x, y	22.14±1.52 a, x	28.23±1.62 a, x	23.00±2.54 a, x	26.00±2.61 a, x
Between 12th and 13th ribs	21.25±2.65 a, x	23.80±2.25 a, x, y	22.21±1.42 a, x	26.77±1.40 a, x	22.80±2.37 a, x	25.20±2.25 a, x
At first lumbar vertebrae	21.75±1.89 a, x	23.20±1.52 a, y	21.79±1.01 a, x	25.31±0.94 a, x	19.20±1.69 a, x	25.20±1.52 a, x
At third lumbar vertebrae	23.00±1.88 a, x	23.00±1.51 a, y	22.79±1.01 a, x	23.23±0.94 a, x	21.80±1.68 a, x	25.60±1.51 a, x
At fifth lumbar vertebrae	23.50±2.18 a, x	24.00±2.26 a, x, y	21.71±1.16 a, x	24.46±1.40 a, x	28.60±0.95 a, y	24.40±2.26 a, x
At first sternal vertebrae	48.50±3.52 a, y	54.00±3.44 a, z	51.14±1.88 a, y	56.23±2.14 a, y	42.40±3.15 a, z	51.60±3.44 a, y
Between second and third sternal vertebrae	52.50±3.40 a, b, y	62.00±4.31 b, z	52.71±1.82 a, b, y	54.53±2.67 a, b, y	45.00±3.04 a, z	51.00±4.31 a, b, y
Between fourth and sternal vertebrae	51.00±4.39 a, y	53.60±4.20 a, z	55.50±2.35 a, y	52.15±2.60 a, y	47.40±3.93 a, z	51.20±4.20 a, y

Means with different small letters a, b and c within a row differ significantly ($p<0.05$). Means with different small letters x, y and z within a column differ significantly ($p<0.05$)

similar to those observed by Teixeira et al. (2008) on Celtiberica goats. The deeper ultrasonic fat depth measurements in live animals could have been due to overestimation. It is possible to overestimate fat depth in live animals due to small space between the ribs in relation to the probe width. This was also reported by Corral de Mesta et al. (2004) on crossbred Spanish goats. Stanford et al. (1995) also reported difficulty in obtaining distortion-free ultrasound images due to closeness of the 12th and 13th ribs in Alpine goats. Corral de Mesta et al. (2004) mentioned that the lumbar vertebrae could be a possible alternative site of measurements to remedy the overestimation problem in goats. However, correlation between ultrasound measurements in live animals and their carcasses and between ultrasound carcass and ruler measurements was nearly unity ($r^2=0.96$ to 1.00). Therefore, if there was overestimation, it was relatively low in the present study. Moreover, research has shown that accuracy is highly dependent on the technician and the level of experience (Realini et al. 2001). The high correlations for live and carcass traits obtained in the present study indicate high accuracy.

Lack of significant influence of sex on ultrasound and ruler measurements of carcass muscle and fat depths is inconsistent with findings of Owen et al. (1978) who found that the dissectible carcass fat levels were higher in the indigenous Tswana castrates than in the Boer goats. The lower values could be associated with inadequate nutrition or late maturity in goats. Level of intake and diet composition have been shown to be major factors influencing carcass yield and composition (Wood et al. 2008), especially in different sexes of goats. Pasture alone, specifically tropical

Table 3 Least squares means (±SE) of ultrasound and ruler measurements of fat depths on carcass of Tswana kids slaughtered at 48 weeks of age raised under semi-intensive system in South-eastern Botswana

Fat depth (mm)	Intact male		Female		Castrates	
	Ultrasound	Ruler	Ultrasound	Ruler	Ultrasound	Ruler
At first sternal vertebrae	1.25±0.32 a	0.52±0.11 a	1.79±0.17 a	0.28±0.07 b	1.40±0.28 a	0.24±0.11 b
Between second and third sternal vertebrae	1.25±0.35 a	0.48±0.09 a	1.86±0.19 a	0.28±0.06 b	1.60±0.31 a	0.22±0.10 b
Between fourth and fifth sternal vertebrae	1.50±0.43 a	0.58±0.12 a	2.07±0.23 a	0.32±0.07 b	1.80±0.38 a	0.18±0.12 b

Means with different small letters within a row within a sex group differ significantly ($p<0.05$)

grass, does not ensure that growing animals get sufficient energy to attain appropriate growth rates for high slaughter weight, heavy and well-conformed carcass (Alexandre et al. 2009). The level of fatness influences the general body composition of meat animals more than differences in any other tissue. However, fat depth measurement is the most variable component of the body in relation to varying genetic and environmental factors (Owen et al. 1978; Alexandre et al. 2009).

Conclusions

Due to lack of subcutaneous fat development and shallower muscle depths, both in thoracic and lumbar regions in both the live animals and carcasses using either ultrasound or ruler measurements in Tswana goats kids during growth and development under semi-intensive system, these sites were deemed not suitable for use in this meat breed. However, because of the deeper muscle depth and detectable fat depth, the sternum region proved to be the most useful part of the body to assess subcutaneous fat and muscle depths in the live animals and carcass of Tswana goat kids raised under semi-intensive system in Botswana during growth and development. Due to lack of significant differences among the sexes at the same site of measurement for muscle and fat depths at the same age in Tswana goat kids raised under semi-intensive system in Botswana during growth and development, farmers can select any sex for meat production. Further studies are required to evaluate the relationships between live ultrasonic measurements and carcass yield in the different sexes of Tswana goat kids to help in the selection and marketing of this breed.

Acknowledgments The authors wish to acknowledge the assistance of M. John Phuthego who assisted patiently during data collection. This research was fully funded by the Botswana College of Agriculture.

References

Aganga, A.A., and Sera, S.K., 2010. Performance of Tswana weaner goats under semi-intensive management in Gaborone Botswana. Botswana Journal of Agriculture and Applied Sciences, Special Issue, 6, (3), 111–113.

Alexandre G., Limèa L., Fanchonne A., Coppry O., Mandonnet N. and Boval M., 2009. Effect of forage feeding on goat meat production: Carcass characteristics and composition of Creole kids reared either at pasture or indoors in the humid tropics, Asian-Australian Journal of Animal Sciences, 22, (8), 1140–1150.

Butterfield, R.M., 1988. New concepts of sheep growth. University of Sidney Press, Sydney, Australia, pp 168.

Chowdhury, S.A. & Faruque, S., 2004. Meat Production Characteristics of Black Bengal Goat, Asian-Australian Journal of Animal Science, 17, 848–856.

Colomer-Rocher, F., Kirton, A.H., Mercer, G.J.K., Duganzich, D.M., 1992. Carcass composition of New Zealand Saanen goats slaughtered at different weights, Small Ruminant Research, 7, 161–173.

Corral de Mesta G., Will P.A. and Gonzalez, J. M., 2004. The Measurement of Carcass Characteristics of Goat using the Ultrasound Method. The Texas Journal of Agriculture and Natural Resource, 17, 46–52.

Delfa, R., Teixeira, A., Cadavez, V., González, C., Sierra, I. (2000): Use of ultrasound measurements for predicting body fat depots in live goats. Proceedings of the 7th International Conference on Goats, Vol. II: 835–836.

Dhanda, J.S., Taylor, D.G., McCosker, J.E. and Murray, P.J., 1999. The influence of goat genotype on the production of Capretto and Chevon carcasses. 1. Growth and carcass characteristics. Meat Science 52, (4), 355–361.

Držaić, V., Mioč, B., Pavić, V., Prpić, Z., Vnučec, I., 2011. The effect of slaughter weight and sex on carcass traits of Croatian Spotted goat kids. XVII World Veterinary Poultry Association Congress, Cancun, Mexico, August, 14–18.

SAS Institute, 2002–2008. Release 8.01 Window version 4.10.2222.SAS Institute Inc., Cary, NC. USA.

Mahgoub, O., Kadim, I.T., Al-Saqry, N.M. and Al-Busaidi R.M., 2004. Effects of body weight and sex on carcass tissue distribution in goats. Meat Science 67, (4), 577–585.

MINITAB. 2006. Meet Minitab 15 for Windows®. Minitab Inc., 3081Enterprise Drive State College, PA, USA.

Nsoso, S.J., and Macheng, M.K., 2009. Ultrasound parameters and body weight in Tswana goat kids during growth and development kept under semi-intensive in Botswana. Botswana Journal of Agriculture and Applied Sciences, 5 (2), 46–55.

Nsoso, S.J., Young M.J. & Beatson, P.R., 1999. The genetic control and manipulation of lean tissue growth and body composition in sheep. Animal Breeding Abstracts, 67(6), 433–443.

Nsoso, S. J., Aganga, A. A., Moganetsi, B. P., and Tshwenyane, S.O., 2003, Body weight, body condition score and heart girth in indigenous Tswana goats during the dry and wet seasons in southeast Botswana. Livestock Research for Rural Development, (15), 4, http://www.lrrd.org/lrrd15/4/nsos154.htm

Oliván, M., Martínez, A., García, P., Noval, G. and Osoro, K., 2001. Estimation of the carcass composition of yearling bulls of "Asturiana de los Valles" breed from the dissection of a rib joint. Meat Science, 57(2), 185–190.

Owen, J.E., Norman, G.A., Philbrooks, C.A. and Jones, N.S.D., 1978. Studies on the meat production characteristics of Botswana goats and sheep—Part III: Carcase composition and distribution. Meat Science, 1 (4), 283–306.

Realini, C.E., Willams, R.E., Pringles, T.D. and Bertrand, J.K., 2001. Gluteus medius and rump fat depths as additional live animal ultrasound measurements for predicting retail product and trimmable fat in beef carcasses. Journal of Animal Science, 79(6), 1378–1385.

Sahin, E.H., Yardimci, M., Cetingul, I.S., Bayram, I. and Sengor, E., 2008. The use of ultrasound to predict the carcass composition of live Akkaraman lambs. Meat Science, 79(4), 716–721.

Sebolai, B., Nsoso, S.J., Podisi, B. and Mokhutshwane, B. S., 2012. The estimation of live weight based on linear traits in indigenous Tswana goats at various ages in Botswana, Tropical Animal Health and production, 44, 899–904.

Silva, S.R., Guedes, C.M., Santos, V.A., Lourenco, A.L., Azevedo, J.M.T. and Dias-da- Silva, A., 2007. Sheep carcass composition estimated form Longissimus thoracis et lumborum muscle volume measured by in vivo real-time ultrasonography, Meat Science, 76 (4), 708–714.

Stanford, K., McAllister, T.A., MacDougall, M. and Bailey, D.R.C., 1995. Use of ultrasound for the prediction of carcass characteristics in Alpine goats, Small Ruminant Research, 15 (2), 195–201.

Teixeira, A., Azevedo, J., Delfa, R., Morand-Fehr, P and Costa, C., 1995. Growth and development of Serrano kids from Montesinho Natural Park (NE of Portugal), Small Ruminant Research, 16, 263–269.

Teixeira, A., Matos, S., Rodrigues, S., Delfa, R. and Cadavez, V., 2006. In vivo estimation of lamb carcass composition by real-time ultrasonography, Meat Science 74 (2), 289–295.

Teixeira, A., Joy, M. and Delfa, R., 2008. In vivo estimation of goat carcass composition and body fat partition by real-time ultrasonography, Journal of Animal Science, 86, 2369–2376.

Wall P.B., Rouse G.H., Wilson D.E., Tait R.G. and Busby W.D., 2004. Use of ultrasound to predict body composition changes in steers at 100 and 65 days before slaughter, Journal of Animal Science, 84, 1621–1629.

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., Hughes, S. I. and Whittington, F. M., 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Science, 78, 343–358.

Yiga-Kibuuka, J., 2010. Present state and future prospects of the small ruminant sub-sector in Botswana. Botswana Journal of Agriculture and Applied Sciences, Special Issue, 6 (3), 82–90.