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Effects of bovine somatotropin on milk yield, mammary gland weight and histology in West African Dwarf goats

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Additional keywords

Lactation.
Histological parameters.
Growth hormone.

SUMMARY

Twenty-four lactating West African Dwarf (WAD) goats were used to study the effects of bovine somatotropin (bST) on total milk yield (TMY), mammary gland weight and histology. The goats were equally assigned into four treatment groups, comprised six does each. The first group (control, T0) received no bST while the other groups received bST (T1, 20 mg; T2, 40 mg; T3, 60 mg) injected at 2-week intervals commencing from the 7th week postpartum for 6 weeks. The does were milked-dry twice daily by 7:30 a.m. and 7:30 p.m. respectively for 42 days commencing from the 7th to the 12th week of lactation. The yields were added to determine the daily milk yield (DMY) and the TMY was determined by cumulative daily milk yields for 42 days. At the end of twelfth week, twelve does (three from each treatment) were milked-dry by hand, slaughtered and their udders were excised. Udder weight (UW), Mammary gland weight (MGW) and volume (MGV) were determined. The effects of bST on mammary gland histology were investigated. The analyzed parameters included number of alveoli lobules (ALN), lactating alveoli (LA), regressing alveoli (RA), total alveoli (TA), alveolar corpora amylacea (ACA), interstitial corpora amylacea (ICA), total corpora amylacea (TCA), alveolar ductular diameter (ALD), epithelial luminal diameter (ELD) and epithelial height (EH). TMY was higher in treated goats and significantly ($p<0.05$) increased with increased doses of bST. UW, MGW and MGV were higher in treated than control goats suggesting that with advance lactation, bST administration maintains milk secreting cells. Treatment of lactating goats with bST significantly ($p<0.05$) increased the number of LA and significantly ($p<0.05$) reduced the number of RA, ACA and ICA. ALD, ELD and EH increased with increased doses of bST. ALD and ELD were significantly ($p<0.05$) larger and EH was significantly ($p<0.05$) higher in treated than control goats. Therefore, our findings suggest that the administration of bST to lactating WAD goats after peak of lactation appears to change mammary gland activity increasing milk yield. This is related to the maintained mammary glandular tissue weight resulting from increased lactating alveoli.

Efecto de la somatotropina bovina sobre producción de leche, peso e histologia de la glándula mamaria en cabras Enana Africanas Occidentales

Palabras clave adicionales

Lactancia.
Parámetros histológicos.
Hormona del crecimiento.

RESUMEN

Se emplearon 24 cabras West African Dwarf (WAD) en lactación para estudiar los efectos de la somatropina bovina (bST) sobre el rendimiento total de leche (TMY) e histología y peso de la glándula mamaria. Las cabras fueron asignadas a cuatro tratamientos en grupos compuestos por 6 hembras. El primer grupo (control T0) no recibió bST mientras que los otros grupos si la recibieron (T1, 20 mg; T2 40 mg; T3 60 mg) mediante inyección durante seis semanas, a intervalos de 2 semanas, comenzando a partir de la 7ª semana postparto. Las hembras fueron ordeñadas totalmente 2 veces al día a las 7:30 a.m. y a las 7:30 p.m. durante 42 días, comenzando desde la 7ª semana de lactación. Los rendimientos fueron sumados para determinar el rendimiento diario de leche (DMY); el TMY fue determinado acumulando los rendimientos diarios de leche durante 42 días. Al final de la semana número 12, doce hembras (3 de cada tratamiento) fueron ordeñadas completamente a mano, sacrificadas y las ubres disecadas. Se determinó también el peso de la ubre (UW), el peso de la glándula mamaria (MGW) y su volumen (MGV). Los efectos de la bST sobre la histología de la glándula mamaria se estudiaron en relación al número de lóbulos alveolares (ALN), alveolos lactantes (LA), alveolos en regresión (RA), total de alveolos (TA), cuerpos amiláceos alveolares (ACA), cuerpos amiláceos intersticiales (ICA), total de cuerpos amiláceos (TCA), diámetro ductal del alveolo (ALD), diámetro luminal del epitelio (ELD) y la altura del epitelio (EH). El TMY fue mayor en las cabras tratadas y aumentó ($p<0,05$) al hacerlo las dosis de bST. UW, MGW y MGV fueron más altos en las cabras tratadas que en las controles,

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sugiriendo que con el avance de la lactación la administración de la bST mantiene las células en secreción. El tratamiento de las cabras lactantes con bST incrementó significativamente (p<0,05) el número de LA y redujo significativamente (p<0,05) el número de RA, ACA e ICA. Por el contrario, ALD, ELD y EH aumentaron al hacerlo las dosis de bST. Los ALD y ELD fueron significativamente mayores (p<0,05) y el EH fue significativamente más alto (p>0,05) en las cabras tratadas. Por eso, los hallazgos de esta investigación sugieren que la administración de bST a cabras WAD lactantes después del pico de la lactación, parece haber cambiado la actividad de la glándula mamaria incrementando el rendimiento lácteo. Esto está relacionado con el mantenimiento del peso de tejido glandular resultante del incremento de alveolos lactantes.

INTRODUCTION

The mammary gland is one of a few tissues in mammals, which can repeatedly undergo cycles of growth, functional differentiation, and regression. Major dynamic changes in the population and function of the mammary gland cells (alveoli) occur during the progress of lactation (Knight, 1997; Capuco and Akers, 1999). These changes are characterized by changes in the weight of the mammary gland. However, Hurley, 2007 attributed these changes to the influence of a complex of mammogenic hormones including prolactin, oestrogen, progesterone, relaxin and growth hormones. Growth hormone, also known as somatotropin, is a protein hormone of about 190 amino acids that is synthesized and secreted by cells called somatotrophs in the anterior pituitary (Hafez *et al.*, 2000). It controls and regulates many physiological processes, such as growth, metabolism and lactation.

Mammogenic effect of bovine somatotropin (bST) is well documented in heifers (Stelwagen *et al.*, 1992), lactating cows (Capuco *et al.*, 2001), sheep (Stelwagen *et al.*, 1993; Leibovich *et al.*, 2001) and dairy goats (Knight *et al.*, 1990). In goats, after peak of lactation, the mammary gland undergoes involution such that at drying-off; after 36 to 40 week of lactation, secretory cell numbers have decreased by 40 to 50 % (Wilde *et al.*, 1999). The involuted mammary gland is characterized by decreased alveolar lumen area, increased interalveolar connective tissue, regressing alveoli (RA) and increased corpora amylacea (CA) (Gonzalez-Romano *et al.*, 2000). The overall effect being reduction in mammary cell numbers and decline in milk production and tissue DNA have correlated with cell death by apoptosis (Wilde *et al.*, 1997). Though, it is an established fact that administration of bST enhances milk production in dairy goats (Baldi *et al.*, 2002; Boutinaud *et al.*, 2003), it has also been reported that it increases mammary gland weight and total DNA during lactation with significant increase in number of lactating alveoli (LA) and decrease in number of RA and CA, both within and outside the alveolar lumen (Baldi *et al.*, 2002), thereby delaying mammary involution and improving lactation persistency by slowing down post peak rate of decline (Gallo *et al.*, 1997; Baldi, 1999; Chiofalo *et al.*, 1999). Administration of growth hormone in mid-lactation seemed to cause an increase in the quantity of mammary parenchyma (Sejrsen *et al.*, 1999) leading to increase in udder size which is positively correlated with milk yield (James and Osinowo, 2004).

In view of the facts that mammary regression occurs after peak of lactation which is accompanied with decline in milk yield and deterioration in milk quality in advanced stages of lactation. Therefore, bST administration could be beneficial in modulating the rate of mammary gland involution in West African Dwarf (WAD) goat that is one among the most widely distributed dairy goat breed (FAO, 2016) but has low selection intensity, with fairly short lactation period where little information is available on the effects of bST treatment and improvement for dairying. In order to have a better understanding of how bST exerts its effects on mammary gland, we studied the effects of bST on total milk yield, mammary gland weight and histology in lactating WAD goats.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted at the goat unit of the College of Animal Science and Livestock Production Teaching and Research Farm, Federal University of Agriculture, Abeokuta. It falls within the Rain Forest Vegetation zone of South-Western Nigeria at latitude $7^0$13′ 49.46″N, longitude $3^0$26′ 11.98″E (Google Earth, 2015) and altitude of 76 meters above sea level. The climate is humid with a mean annual rainfall of 1037 mm. The annual mean temperature and humidity are 34.7 ºC and 82 % respectively.

Experimental animals and their management

All experimental procedures including use of animals were performed according to approval granted by the Research Supervisory Committee of Department of Animal Physiology, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta, Nigeria.

Twenty four lactating West African Dwarf lactating does of first and second parity with ages between 1.5 and 3 years and whose body weights ranged from 11 – 16 kg, were selected from existing flock on the farm and used for the experiment. The goats were housed in cross-ventilated pens with slatted floors and water given *ad libitum.* The goats were under intensive management system with zero grazing (‘cut and feed’) and 0.3 kg per animal day concentrate feed supplement, consisting of about 17 % crude protein, 11.56 % crude fibre, 4.68 % ether extract and 8.69 MJ/kg metabolisable energy was fed to the animals. *Panicum maximum* grass was chopped and 1.0 kg per animal per day was fed to the goats. The proximate composition of the grass consisted of 5.37% of crude protein, 33.35% of crude fibre, 66.31% of neutral deteregent fibre, 42.79% acid detergent fibre and 19.71 % of acid detergent lignin respectively.

Experimental procedure

Twenty four lactating does were divided equally into four treatment groups, each group comprising of six does with first and second parity with liveweight and daily milk yield equalized among treatment groups. The first group, which was the control (T_0) received no bovine somatotropin injection while the remaining three groups received bovine somatotropin injections at different doses: 20 mg (T_1), 40 mg (T_2) and 60 mg (T_3). The bovine somatotropin, Lactotropina MR, division Sanidad Animal, Eli Lilly CO., Mexico is in a sustained-release formulation for 14 days interval.

The does were given three injections of bST spaced 2 weeks apart, i.e. at the onset of weeks 7, 9 and 11 of lactation. The doses of bST were selected based on the preliminary results obtained on the study on milk yield and composition of goats treated with bovine somatotropin in Egypt by Sallam *et al.* (2005).

Data collection

Total milk yield

The animals were milked-dry twice daily in the morning and evening at 7:30 a.m. and 7:30 p.m. respectively. The a.m. and p.m. yields were added to determine the daily milk yield (DMY). The does were milked for 42 days commencing from the 7th to the 12th week of lactation. The total milk yield was determined by cumulative daily milk yields for 42 days.

Mammary gland weight and volume and histological parameters

At the end of 12th week of lactation, 12 does consisting of 3 does per treatment were selected from the 24 does, milked-dry and subsequently slaughtered and their udders excised for the study on mammary gland traits and histological parameters. The udders excised were weighed to get udder weight (UDW) and there after trimmed of extra-parenchymal tissue (skin, teat and subcutaneous fat) and weighed by a sensitive electronic weighing scale with maximum capacity of 210 g and readability of 0.0001 g (Adventurer™,OHAUS Corp, Pime Brook NJ, USA.) to get mammary gland weight (MGW). Mammary gland volume (MGV) was determined by Archimedes's principle (Linzell, 1966). The udders were separated into right and left halves and mammary tissue samples taken medially from each half for histological analysis. The permanent histological slide of mammary tissue samples were produced following hematoxylin and eosin-staining technique as reported by Baldi *et al.* (2002).

The histological parameters evaluated through the permanent histological slide included number of alveolar lobules (ALN), number of lactating alveoli (LA), number of regressing alveoli (RA), total alveoli (TA), alveolar corpora amylacea (ACA), interstitial corpora amylacea (ICA), total corpora amylacea (TCA), alveolar ductular diameter (ADD), epithelial luminal diameter (ELD) and epithelial height (EH). The TA was counted on hematoxylin and eosin-stained sections. Alveoli were classified as LA or RA based on the following criteria. The LA epithelial cells were columnar, with well-differentiated cells containing rounded basally displaced nuclei, abundant apical secretory vacuoles, and evidence of secretion; the cells were well polarized with large cytoplasm-to-nucleus ratio. The RA epithelial cells were non-columnar; the cytoplasm-to-nucleus ratio was smaller; secretory vesicles were absent; but large lipid droplets were present, and frequently, nuclei were located apically. Some collapsed alveoli were found.

The numbers and positions of CA were estimated on sections stained with Congo red (Highman technique). The CA within the lumen of the alveolus was classified as ACA, and those in interalveolar connective tissue were classified as ICA. Alveoli and CA were quantified with the aid of a grid placed in the eyepiece. For each animal, 2 independent tissue blocks per doe were examined: a block from each gland (left and right). Two sections per block and five random fields per section were examined and evaluated at × 250 magnification. Therefore, 20 fields per doe, 60 fields per treatment group and 240 fields for the entire 12 does were evaluated and examined. The numbers of TA, LA, and RA were counted in each field, selecting alveolar sections in which most secretory cells presented sagittal section. The CA was counted in the same fields; for each field the number of TCA, ACA, and ICA were counted. Two independent observers performed counts.

ADD, ELD and EH were also evaluated using the same number of sections and fields stated for alveoli and CA. The permanent slides were examined under the microscope with calibrated eyepiece micrometer (Graticule Ltd., Tonbridge, Kent, England).

Statistical analysis

Data generated on total milk yield, mammary gland weight and volume and histological parameters were subjected to analysis of variance (ANOVA) in 4 × 2 factorial design using the Systat Analytical Computer Package, version 5.02 (SYSTAT, 1992). The statistical model used was:

$$Y_{ijk} = \mu + A_i + B_j + A^*B_{ij} + \varepsilon_{ijk}$$

Where:

Y_{ijk}= Trait of interest;

A_i= Fixed effect of ith bST dose (i = 0, 20, 40 & 60 mg);

B_j= Fixed effect of kth parity (k = 1st & 2nd);

A^*B_{ij} =Interaction between ith bST dose and jth parity of does;

ε_{ijk} = Random error associated with each record.

The package analyzed the main effects of bST treatment and parity on mammary gland traits and histological parameters examined but failed for their interaction. This could be due to the small number of does per group (n= 3) in the experiment. Tukey's Honest Significant Difference (HSD) was used to separate means where significant differences exist.

RESULTS AND DISCUSSION

Total milk yield, udder weight and mammary gland weight were significantly ($p<0.05$) influenced by bovine somatotropin administration and parity except for mammary gland volume that was not significantly ($p>0.05$) affected by bovine somatotropin administration and parity. Total milk yield increased with increased dose of bovine somatotropin and T_1, T_2 and T_3 exceeded T_0 by 50.36, 68.00 and 71.16% respectively **(table I)**. The result of the present study could be attributed to the galactogenic activity of the growth hormone used resulting to proliferation of milk secreting cells for milk production which was earlier reported by James *et al.* (2010). Udder weight and mammary gland weight significantly ($p<0.05$) increased inconsistently with increasing doses of bovine somatotropin and increasing parity **(table I)**. West African Dwarf does administered bovine somatotropin and those with second parity have heavier udder and mammary glands compared with the control. The heavier udder weight and mammary gland weight observed in bovine somatotropin -treated does compared with the control showed the mammogenic and galactopoietic ability of bovine somatotropin. Sejrsen *et al.* (1999) asserted that administration of growth hormone in mid-lactation caused an increase in the quantity of mammary parenchyma. Dijkstra *et al.* (1997) and Hurley (2006) attributed the increase to the activities of a complex of mammogenic hormones including prolactin, oestrogen and relaxin. These hormones are responsible for proliferation of milk secreting cells resulting to increased mass of mammary tissue for galactopoiesis (Hurley, 2006). James and Osinowo (2004) and Bemji *et al.* (2007) reported that increase in mammary tissue was positively correlated with milk yield.

The increase in total milk yield and mammary gland traits with increased parity is expected since goats with multiples lactation cycles must have laid down more mammary structures including milk-secreting cells (alveoli) for milk production (Knight and Wilde, 1993; James, 2009).

Histological parameters including number of alveolar lobules, lactating alveoli, regressing alveoli, total alveoli, alveolar corpora amylacea, interstitial corpora amylacea, total corpora amylacea, alveolar ductular diameter, epithelial luminal diameter and epithelial height were significantly ($p<0.05$) influenced by bovine somatotropin dose but not by parity ($p>0.05$).

All histological parameters significantly ($p<0.05$) increased correspondingly with increased levels of bovine somatotropin doses except , regressing alveoli, alveolar corpora amylacea, interstitial corpora amylacea and total corpora amylacea where the reverse hold **(tables I, II)**. West African Dwarf does administered bovine somatotropin have larger alveolar ductular diameter, epithelial luminal diameter and taller epithelial height **(table II)**; more number of alveolar lobules, lactating alveoli **(table I)** and total alveoli and fewer alveolar corpora amylacea, interstitial corpora amylacea and total corpora amylacea **(tables I, II)** vis-à-vis the control.

The increased number of alveolar lobules, lactating alveoli and total alveoli and the decreased number of regressing alveoli, alveolar corpora amylacea, interstitial corpora amylacea and total corpora amylacea with increased levels of bovine somatotropin doses in WAD does treated with bovine somatotropin than in the control corroborates the findings of Baldi *et al.* (2002) who reported that bovine somatotropin administration to Saanen goats significantly increased the number of lactating alveoli and significantly reduced the number of regressing alveoli and corpora amylacea, both within and outside the alveolar lumen. Similar effects were

Table I. Effects of bovine somatotropin (bST) dose and parity on total milk yield, udder weight, mammary weight and volume and some mammary histological parameters in *West African Dwarf* goats. (Efectos de la dosis de somatotropina bovina (bST) y del número del parto sobre el rendimiento lechero total, peso de la ubre, peso y volumen de la glándula mamaria y algunos parámetros histológicos en cabras Enanas de Africa occidental).

Parameters evaluated	Bovine somatotropin (bST) dose				p values	Parity		p values
	Control (T_0) (n=3)	20 mg (T_1) (n=3)	40 mg (T_2) (n=3)	60 mg (T_3) (n=3)		First (n=5)	Second (n=7)	
[1]Total milk yield (TMY, g)	5881.75 ± 763.96^b	8843.83 ± 763.96^{ab}	9881.17 ± 763.96^a	10067.17 ± 763.96^a	0.0049	7538.42 ± 540.20^b	9798.54 ± 540.20^a	0.0091
Udder weight (UDW, g)	103.33 ± 2.38^d	112.56 ± 2.07^c	132.44 ± 2.07^b	145.11 ± 2.07^a	0.0231	120.03 ± 1.77^b	126.69 ± 1.45^a	0.0342
Mammary gland weight (MGW, g)	73.92 ± 2.17^c	85.97 ± 1.89^b	102.36 ± 1.89^a	107.36 ± 1.89^a	0.0292	90.32 ± 1.62^b	94.49 ± 1.32^a	0.0371
Mammary gland volume (MGV, ml)	63.17 ± 2.55^b	65.72 ± 2.22^b	67.61 ± 2.22^b	77.61 ± 2.22^a	0.1201	65.36 ± 1.56^b	71.69 ± 1.90^a	0.1053
[*]Number of Alveolar lobules (ALN)	65.12 ± 0.96^d	107.83 ± 0.84^c	134.44 ± 0.84^b	182.14 ± 0.84^a	0.0000	121.96 ± 0.72	122.80 ± 0.59	0.4086
[*]Lactating alveoli (LA)	117.02 ± 0.98^d	196.13 ± 0.86^c	218.04 ± 0.86^b	304.14 ± 0.86^a	0.0000	208.42 ± 0.73	209.25 ± 0.60	0.4178
[*]Regressing alveoli (RA)	56.81 ± 0.33^a	12.49 ± 0.29^b	7.27 ± 0.29^c	4.01 ± 0.29^d	0.0000	20.43 ± 0.24	19.87 ± 0.20	0.1053
[*]Total alveoli (TA)	173.83 ± 1.03^d	208.62 ± 0.89^c	225.31 ± 0.89^b	308.15 ± 0.89^a	0.0000	228.84 ± 0.76	229.12 ± 0.63	0.7976

[a-d]Means in the same row having different superscript differ significantly ($p<0.05$).
[*]Data represent means ± SE of values observed in 5 fields at magnification of ×250.
[1]Numbers of animals used for evaluating total milk yield (7-12 weeks of lactation) were 24. Six per treatment and 12 in each parity group.

Table II. Effects of bovine somatotropin (bST) dose and parity on some mammary histological parameters in *West African Dwarf* goats (Efecto de la dosis de somatotropina bovina (bST) y del número de parto sobre algunos parámetros histológicos en cabras Enanas de África Occidental).

*Parameters evaluated	Bovine somatotropin (bST) dose				p values	Parity		p values
	Control (T_0) (n=3)	20 mg (T_1) (n=3)	40 mg (T_2) (n=3)	60 mg (T_3) (n=3)		First (n=5)	Second (n=7)	
Alveolar corpora amylacea (ACA)	7.80 ± 0.16[a]	3.67 ± 0.14[b]	2.81 ± 0.14[c]	1.15 ± 0.14[d]	0.0000	3.82 ± 0.12	3.89 ± 0.10	0.6547
Interstitial corpora amylacea (ICA)	3.54 ± 0.13[a]	1.49 ± 0.12[b]	0.88 ± 0.12[c]	0.43 ± 0.12[d]	0.0000	1.59 ± 0.10	1.58 ± 0.08	0.9039
Total corpora amylacea (TCA)	11.34 ± 0.25[a]	5.16 ± 0.22[b]	3.69 ± 0.22[c]	1.58 ± 0.22[d]	0.0000	5.41 ± 0.19	5.47 ± 0.16	0.8259
Alveolar ductular diameter (ADD) (μm)	88.87 ± 1.99[c]	101.87 ± 1.72[b]	102.48 ± 1.72[b]	117.04 ± 1.72[b]	0.0000	102.18 ± 1.48	102.95 ± 1.21	0.7122
Epithelial luminal diameter (ELD) (μm)	78.30 ± 1.97[c]	90.27 ± 1.71[b]	90.67 ± 1.71[b]	106.25 ± 1.71[a]	0.0000	91.28 ± 1.46	91.46 ± 1.20	0.9289
*Epithelial height (EH) (μm)	9.78 ± 0.30[d]	11.12 ± 0.26[c]	11.98 ± 0.26[b]	13.76 ± 0.26[a]	0.0000	11.49 ± 0.23	11.83 ± 0.18	0.2927

[a-d]Means in the same row having different superscript differ significantly ($p<0.05$).
*Data represent means ± SE of values observed in 5 fields at magnification of ×250.

observed by Baldi *et al.* (2002) in Saanen goats, but lower values were observed in this study. The disparity could be due to differences in breed and doses of bovine somatotropin administered. In the present study, WAD goats, a light breed not yet selected for dairy production was used as against heavy breed Saanen goats selected for dairying. The authors used a dose of 120 mg per 2 weeks whereas a maximum dose of 60 mg per 2 weeks was used in the present study.

The larger alveolar ductular diameter and epithelial luminal diameter and taller and epithelial height observed in goats treated with bovine somatotropin than in the control explains the higher secretory activity of alveolar cells. Samuelson (2007) stated that the alveoli and associated secretory tubules that comprise the secretory units of the mammary gland consist of cuboidal epithelial cells that vary in height according to their state of activity. The author further explained that each alveolar lobe undergoes a secretary cycle whereby the secretory cells increased in their height while milk is being released into the lumen and as the lumen becomes full, the secretory cells wind down in activity and decrease in height.

The effect of bovine somatotropin treatment on features of mammary gland structure in WAD does is illustrated in **figures 1 and 2**. T_1, T_2, and T_3 reveal lactating alveoli with various degrees of dilation of alveolar lumina with slightly thickened alveolar wall, well-differentiated and numerous cuboidal epithelial cells with abundant secretory vesicles (arrow E in T_3), rounded basically displaced vesicular nuclei (arrow in T_2) and increased cytoplasmic-nuclear ratio. There was relatively little or no corpora amylacea. These observa-

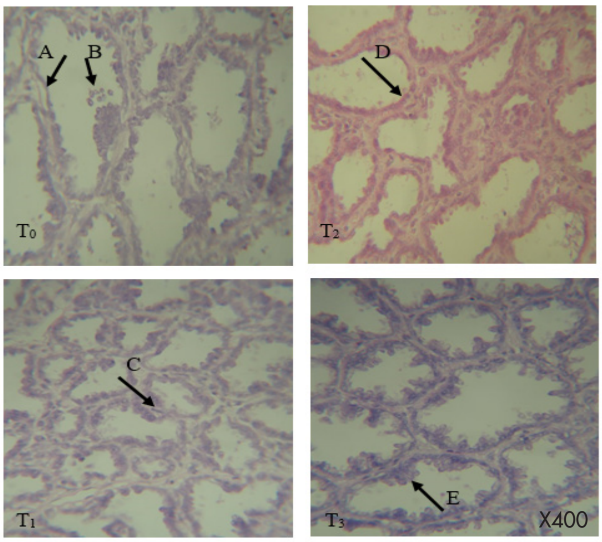

Figure 1. Representative of examples of alveolar structures in the mammary glands of West African Dwarf goats which were not treated with bST (T_0, control group) or belonged to a group injected with 20mg bST (T_1), 40mg bST (T_2) or 60mg bST (T_3) (Representación de ejemplos de las estructuras alveolares de las glandulas mamarias de Cabras Enanas de Africa Occidental sin tratamiento (T_0; grupo control) o sometidas a inyecciones de 20 mg de bST (T_1); 40 mg de bST (72) o 60 mg de bST (T_3)).
Arrow A shows sloughed-off secretory vesicles from the alveolar wall. Arrow B shows detached secretory vesicles from the alveolar wall. Arrow C shows fewer number of secretory vesicles. Arrow D shows few number of secretory vesicles and arrow E shows numerous cuboidal epithelial cells with abundant secretory vesicles.

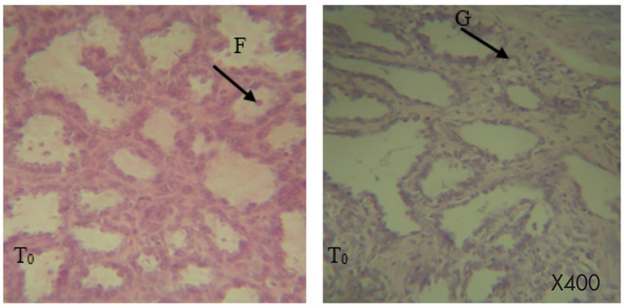

Figure 2. Representative of examples of corpora amylacea within the alveolar lumen arrow F in T_0, control) and in the interstitial tissue of West African Dwarf goats (arrow G in T_0, control) (Ejemplos representatiivos de cuerpos amiláceos dentro del lumen alveolar de cabras Enanas de África Occidental: F en T0 grupo control y en el tejido intersticial (G en T_0, grupo control)).

tions were more prominent in T_3 than in T_1 and T_2. T_0 reveal regressing alveoli showing irregularly shaped low cuboidal or flattened epithelial cells with few secretory vesicles detached and sloughed-off (arrows in T_0, **figure 1**) and reduced cytoplasmic-nuclear ratio. There was decreased alveolar lumen with thickened interalveolar or interlobular connective tissues and presence of more corpora amylacea found within (alveolar corpora amylacea) and between alveolar cells (interstitial corpora amylacea). This is because bovine somatotropin administration to goats has been shown severally to enhance proliferation of milk secretory vesicles, maintain alveolar number and secretory activity after peak of lactation (Baldi *et al.*, 2002; Boutinaud *et al.*, 2003; Annen *et al.*, 2004) with resultant effect of maintaining total mammary parenchyma weight and lactating alveoli. The reverse holds for the control where mammary apoptosis was facilitated leading to regression of the secretory epithelial cells to non-productive state (Li *et al.*, 1999; Wilde *et al.*, 1999).

Morphological damage of the secretory vesicles and reduction in cell number and the associated decline in milk production and tissue DNA after peak of lactation in the mammary gland of WAD does have been correlated with cell death by apoptosis (Wilde *et al.*, 1997).

CONCLUSION

The administration of bovine somatotropin (bST) in a slow-release formulation to lactating WAD does at the onset of weeks 7, 9 and 11 of lactation increased post-slaughter udder and mammary gland weights and some histological parameters culminating to 50-71 % increase in TMY of bST treated does over the control. This resulted from increased metabolic activity of the mammary cells which slow down involution, thereby allowing more secretory cells to persist over time for milk synthesis and secretion.

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BIBLIOGRAPHY

Annen, E.L.; Collier, R.J.; McGuire, M.A.; Vicini, J.L.; Ballam, J.M. and Lormore, M.J. 2004. Effect of modified dry period lengths and bovine somatotropin on yield and composition of milk from dairy cows. *J Dairy Sci*, 87: 3746-3761.

Baldi, A. 1999. Manipulating of milk production and quality by use of somatotropin in dairy ruminants other than cow. *Domest Anim Endocrinol*, 17: 131-137.

Baldi, A.; Modina, S.; Chelli, F.; Gandolfi, F.; Pinotti, L.; Baraldi-Scesi, L.; Fantuz, F. and Dell`Orto, V. 2002. Bovine somatoptropin administration to dairy goats in late lactation: Effects on mammary function, composition and morphology. *J Dairy Sci*, 85: 1093-1102.

Bemji, M.N.; Osinowo, O.A.; Ozoje, M.O.; Adebambo, O.A. and Aina, A.B.J. 2007. A comparative study on milk yield and pre-weaning growth of West African Dwarf and Red Sokoto goats intensively managed in South-Western Nigeria. *Ghanian J Anim Sci*, 2-3: 81-88.

Boutinaud, M.; Rousseau, C.; Keisler, D.H. and James, H. 2003. Growth hormone and milking frequency act differently on goat mammary gland in late lactation. *J Dairy Sci*, 86: 509-520.

Capuco, A.V. and Akers, R.M. 1999. Mammary involution in dairy animals. *J Mammary Gland Biol Neoplasia*, 4: 137-144.

Capuco, A.V.; Wood, D.L.; Baldwin, R.; McLeod, K. and Paape, M.J. 2001. Mammary cell number, proliferation and apoptosis during a bovine lactation: relation to milk production and effect of bST. *J Dairy Sci*, 84: 2177-2187.

Chiofalo, V.; Baldi, A.; Savoini, G.; Polidori, F.; Dell`Orto, V. and Politis, I. 1999. Response of dairy ewes in late lactation to recombinant bovine somatotropin (rbST). *Small Rumin Res*, 34: 119-125.

Dijkstra, J.; France.; Dhanoe, M.S.; Maas, J.A.; Hanigan, M.D.; Rook, A.J. and Beaver, D.E. 1997. A model to describe growth patterns of the mammary gland during pregnancy and lactation. *J Dairy Sci*, 80: 2340-2354.

Food and Agricultural Organisation (FAO). 2016. Small Ruminants. Dairy production and products. http://www.fao.org/agriculture/dairy-gateway/milk-production/dairy-animals/small-ruminants/en/#.V9rXJslVEtc

Gallo, L.; Bailoni, L.; Schiavon, S.; Carnier, P.; Ramanzin, M.; Andrighetto, I. and Bittante, G. 1997. Effect of slow-release somatotropin on the pattern of milk yield between and within injection intervals. *J Dairy Sci*, 80: 46-51.

Gonzalez-Romano, N.A.; Arencibia, A.; Espinosa de los Monteros, A.; Rodriguez, E.; Rivero, M.; Vazquez, J.M.; Capote, J and Jaber, J.R. 2000. Anatomical evaluation of the caprine mammary gland by computer tomography, radiology and histology. *Anatomia Histologia Embryologia*, 29: 25-30.

Google Earth. 2015. http://www.google.earth

Hafez, E.S.E.; Jainudeen, M.R. and Rosnina, Y. 2000. Hormones, growth factors, and reproduction. In: E.S.E. Hafez and B. Hafez (Eds). Reproduction in farm animals. 7th edition. Lippincott Williams and Wilkins Publishers. USA. pp. 33-54.

Hurley, W.L. 2006. Mammary gland involution and dry period. http://classes.aces.uiuc.edu/AnSci308/involution.html

Hurley, W.L. 2007. Mother and neonate: lactogenesis. http://classes.ansci.uiuc.edu/ansc438/Motherneonate/lactogenesis.html

James, I.J. 2009. Effects of bovine somatotropin on milk yield and mammary gland histology in West African Dwarf goats. P.hD Thesis. Department of Animal Physiology. University of Agriculture. Abeokuta. Nigeria. 136 pp.

James, I.J., Osinowo, O.A., Smith, O.F., Bemji, M.N. and Rekwot, P.I. 2010. Effects of bovine somatotropin on the pattern of milk yield within and between injection intervals in West African Dwarf goats. *J Agricul Sci Environ,* 10: 86-97.

James, I.J. and Osinowo, O.A. 2004. Changes in udder size and liveweight of West African Dwarf, Red Sokoto and Sahel goats during lactation and their phenotypic relationship with partial daily milk yield. *Nig J Anim Prod,* 31: 119-129.

Knight, C.H. 1997. Biological control of lactation length. *Livest Prod Sci,* 50: 1-3.

Knight, C.H. and Wilde, C.J. 1993. Mammary cell changes during pregnancy and lactation. *Livest Prod Sci,* 35: 3-19.

Knight, C.H.; Fowler, P.A. and Wilde, C.J. 1990. Galactopoeitic and mammogenic effects of long-term treatment with bovine growth hormone and thrice daily milking in goats. *J Endocrinol,* 127: 129-138.

Leibovich, H.; Gertler, A.; Bazer, F. and Gootwine, E. 2001. Effects of recombinant ovine placental lactogen and recombinant ovine growth hormone on growth of lambs and milk production of ewes. *Livest Prod Sci,* 68: 79-86.

Li, P.; Rudland, P.S.; Fernig, D.G.; Finch, L.M.B. and Wilde, C.J. 1999. Modulation of mammary development and programmed cell death by the frequency of milk removal in lactating goats. *J Physiol,* 519: 885-900.

Linzell, J.L. 1966. Measurement of udder volumein live goats as an index of mammary growth and function. *J Dairy Sci,* 49: 307-311.

Sallam, S.M.A.; Nasser, M.E.A. and Yousef, M.I. 2005. Effect of recombinant bovine somatotropin administration on milk production, composition and some haemato-biochemical parameters of lactating goats. http://net.shams.edu.eg/esap/12005issue/4.pdf

Samuelson, D.A. 2007. Textbook of Veterinary Histology. Female reproductive system, mammary gland. 1st edition. Saunders Elsevier. St. Luis. Missouri. USA. pp. 474-478.

Sejrsen, K.; Purup, S.; Vestergaard, M.; Weber, M.S. and Knight, C.H. 1999. Growth hormone and mammary development. *Domest Anim Endocrinol,* 17: 117-129.

Stelwagen, K., Grieve, D.G., McBride, B.W. and Reyman, J.D. 1992. Growth and subsequent latation in primigravid Holstein heifer after post-partum bovine somatotrpin treatment. *J Dairy Sci,* 75: 463-471.

Stelwagen, K.; Grieve, D.G.; Walton, J.S.; Ball, J.L. and McBride, B.W. 1993. Effect of prepartum bovine somatotropin in primigravid ewes on mammogenesis, milk production and hormone concentrations. *J Dairy Sci,* 76: 992-1001.

SYSTAT. 1992. SYSTAT Computer Package. Version 5.02 SYSTAT, Inc. Evanston, IL. USA.

Wilde, C.J., Knight, C.H. and Flint, D.J. 1999. Control of milk secretion and apoptosis during mammary involution. *J Mamm Gland Biol Neopl,* 4: 129-136.

Wilde, C.J.; Quarrie, L.H.; Tonner, E.; Flint, D.J. and Peaker, M. 1997. Mammary apoptosis. *Livest Prod Sci,* 50: 29-37.