Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v39i2.33215

Methods of body composition estimative of growing goats

Kleber Tomas Resende[1*], Marcia Helena Machado da Rocha Fernandes[1], Fernanda Hentz[1], Izabelle Auxiliadora Molina de Almeida Teixeira[1] and José Américo Garcia[2]

[1]*Universidade Estadual Paulista, Via de acesso Professor Paulo Donato Castellane, s/n., 14884-900, Jaboticabal, São Paulo, Brazil.*
[2]*Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil. *Author for correspondence. E-mail: kresende@fcav.unesp.br*

ABSTRACT. The objective of this study was to compare methods for estimative of body composition of goats based on tritiated water space technique (TOH), specific gravity (SG) of carcass and 9-11th ribs. Ten Toggenburg x Alpine intact male goat kids, from 5.3±0.4 to 25.9±1.3 kg of body weight (BW), were used to estimate body composition by: 1) direct method, 2) TOH method, 3) SG of the carcass and 4) SG of the 9-11th whole ribs. In addition, update linear equations for predicting body composition were developed using data from direct method. The TOH space overestimated water body composition on average 31%. The SG of the carcass and 9-11th ribs underestimated water empty body composition (%) on average 21 and 12%, respectively. In spite of its overestimate, the determination of TOH space can be used as a reliable field technique to study relative changes in body composition of growing goats. Specific gravity is practicable in most circumstances and does not require expensive equipment. However, the SG of the carcass and 9-11th ribs has not a valid equation to predict body composition of growing goats.

Keywords: direct method, *in vivo* determination, specific gravity, tritiated water space.

Métodos de estimativa da composição corporal de caprinos em crescimento

RESUMO. O objetivo deste estudo foi comparar métodos para estimar a composição corporal de caprinos, baseando-se em água tritiada (AT) e gravidade específica (GE) da carcaça e da 9 à 11ª costela. Dez cabritos Toggenburg x Alpine machos não castrados, de 5,3 ± 0,4 para 25,9 ± 1,3 kg de peso corporal (PC), foram utilizados para estimar a composição corporal por: 1) método direto; 2) espaço de AT; 3) GE da carcaça e 4) GE da 9 à 11ª costela. Além disso, equações lineares para predizer a composição corporal foram desenvolvidas, usando dados do método direto. O espaço AT superestimou a composição corporal em água em 31%, em média. A GE da carcaça e a da 9 à 11ª costela subestimaram a composição corporal percentual de água (%), em média, em 21 e 12%, respectivamente. Apesar da sua superestimativa, a determinação do espaço AT pode ser usado como uma técnica de campo viável para estudar alterações relativas na composição corporal de caprinos em crescimento. O uso da GE é possível na maioria das circunstâncias e não requer equipamentos caros. No entanto, a GE da carcaça e a da 9 à 11ª costela ainda não possuem uma equação de predição válida para estimar adequadamente a composição corporal de caprinos em crescimento.

Palavras-chave: método direto, determinação *in vivo*, gravidade específica, água tritiada.

Introduction

Reliable estimation of chemical body composition in ruminants is of primary importance to the animal production and meat industry. Nutritionists desire the knowledge of body composition to properly estimate nutrient requirements and to understand body functions; breeders desire an estimate of body composition to elicit the desirable changes through selection programs; and the traders need a reliable method for the classification of carcasses for industry (Maeno, Oishi, & Hirooka, 2013).

The gold standard method is the chemical analysis of the whole body (Fernandes et al., 2008). However, this procedure is unsuitable to be adopted as a routine because it is expensive, time consuming and the carcass is devalued in obtaining the information. Consequently, indirect methods to obtain readily body and carcass composition would benefit both animal production and meat research. The tritiated water space technique (TOH) for determining body composition has been successfully applied in ruminants (Viljoen, Coetzee, & Meissner, 1988, Benjamin, Koenig, & Becker, 1993). This methodology has the advantage of being an *in vivo* procedure, allowing repeated measurements in the same animal. Other indirect methods that require post-mortem of the farm animal have also received considerable attention, such as the specific gravity (SG), which results from the density of body or carcass components, and the variation in fat content was reported to be the principal determinant of the success of body SG. Previous studies supported the use of carcass density as an approach of estimating body composition of mature cattle or those in a later stage of growth and development (Johnson, Miller, Haydon, & Reagan, 1990, Owens, Gill, Secrist, & Coleman, 1995).

Although the TOH space and SG techniques has been used for predicting body composition in sheep and cattle (Benjamin et al., 1993, Schröder & Staufenbiel, 2006), there are only few and not conclusive reports in the literature on goats (Viljoen et al., 1988, Benjamin et al., 1993). In addition, the equations derived from sheep are not necessarily applicable to goats due to differences in body composition. Therefore, the objective of this study was to compare equations to estimate body and carcass composition of goats based on TOH space, SG of carcass and 9-11th ribs.

Material and methods

Animals, feeding and management

Ten Toggenburg x Alpine intact male goat kids (5.9±0.65 kg of initial body weight (BW) and 19±3 days old of initial age) were used, housed in indoor individual pens. After the kids were born, they received *colostrum* for two days and thereafter 1.5 L day^{-1} goat milk until weaning at 50 days of age. The experimental diet consisted of 58.6 oat hay and 41.4% concentrate (29.2 ground corn, 10.3 soybean meal, 0.98 mineral supplement, and 0.75% limestone). The mineral supplement contained (per kg): NaCl: 98.4, $FeSO_4$: 0.593, $ZnSO_4$: 0.593, $CuSO_4$: 0.273, $CoSO_4$: 0.071 and KIO_3: 0.018%. The chemical composition of the diet was: 83.8% DM (%), 4.6 ash (% DM), 14.4 protein (% DM), 2.63 Mcal kg^{-1} DM (ME). Diets were offered *ad libitum* and water was freely available. The entire experimental period lasted 242 days. The animals were slaughtered as they reached 5, 10, 15, 20 and 25 kg of body weight (BW) in order to embrace different body compositions.

Four methods to estimate body composition were tested: 1) direct method through total body grinding and analysis, 2) TOH method, 3) SG of the carcass and 4) SG of the 9-11th whole ribs.

Tritiated water space

The animals were fasted for 18 hours before administration of the tritium solution. A pre injection blood sample was collected from each goat before starting the isotope administration. Thereafter, a tritiated water solution averaging 4 μCi kg^{-1} BW was infused into the right jugular vein of the goats using an indwelling catheter and a sterilized disposable syringe attached to the catheter. Six hours following tritium administration, a post injection equilibrium blood sample (10 mL) was collected from the left jugular vein of each goat into tubes containing sodium heparin. Plasma was obtained by centrifugation of the blood samples at 1800 × g for 20 min. and stored at –10°C for further analysis. Immediately after, the goats were slaughtered. Plasma tritium activity was determined according to Springel and Wright (1976). The apparent TOH space was calculated from the ratio of injected tritium to the concentration of diluted tritium after equilibrium, with corrections for pre-injection values.

Direct method

At slaughter, the animals were sedated (1.0 mL kg^{-1} BW of xylazine hydrochloride) and killed by exsanguination using conventional humane procedures. At slaughter, the gut content of the gastrointestinal tract was removed and weighed to determine the empty body weight (EBW). The whole empty body of the goats was ground and homogenized. Representative samples (500 g) were taken, oven dried at 65°C for 72 hours, ball milled and stored for further laboratory analysis. Gross energy was determined using a calorimeter (Parr Instruments Co., Moline, Ilinois, USA). Total nitrogen was determined using a Kjeldhal procedure (Association of Official Analytical Chemists [AOAC], 2007; method number 984.13) and crude protein (CP) content was calculated as: CP = N × 6.25. Ether extract was obtained upon extraction with petroleum ether in a Soxhlet extraction apparatus for 6 h (AOAC, 2007; method number 920.39) and ash with complete combustion in a muffle furnace at 600°C for 6 hours (AOAC, 2007; method number 942.05).

Specific gravity of the carcass and 9-11th whole ribs

Hot carcass weight was obtained at slaughter. Following slaughter, the carcass was kept at a cold room (4°C) for 48 hours before SG was determined in chilled water at 4°C, according to the procedure described by Harris (1970). Specific gravity measurements were obtained for the intact right side of the carcass and the 9-11th whole ribs of the left side of the carcass. The whole 9-10-11th ribs were obtained by a straight cut between the 8-9th thoracic vertebrae and another cut between the 11-12th thoracic vertebrae. Water losses from the right half carcass and 9-11th ribs were calculated for correction of the body's water content, determined by the direct method. Specific gravity of the carcass was calculated as Equation 1:

$$Carcass\ SG = \frac{\text{Hot carcass in air(kg)}}{(\text{Hot carcass in air(kg)} - \text{Carcass submerged in water(kg)})} \quad (1)$$

Specific gravity of the whole 9-11th ribs was calculated according to Harris (1970) as Equation 2:

$$9 - 11^{th}\ SG = \frac{9 - 11^{\text{th}} \text{ in air(g)}}{(9 - 11^{\text{th}} \text{ in air(g)} - 9 - 11^{\text{th}} \text{ submerged in water(g)})} \quad (2)$$

The water, protein and fat content in the empty body were predicted from SG of the carcass and 9-11th ribs using the Equations proposed by Harris (1970).

Statistical analyses

The experimental design adopted was completely randomized. Simple and multiple regression analyses were performed using the PROC REG of SAS v9.2 (SAS, 2008), to develop equations for prediction of empty body composition from TOH space and SG of the carcass and 9-11th ribs. Independent variables in the model were TOH space, SG of the carcass and 9-11th ribs, empty body weight (EBW) and EB water. Dependent variables studied were carcass protein, fat, water and mineral content, expressed both as a percentage of EBW and in kilograms.

Results and discussion

The animals were slaughtered as they reached 5.3±0.4, 11.8 ±0.8, 15.1 ±0.7, 20.4 ±0.9 and 25.9±1.3 kg of BW. The water body composition of goats decreased from 71.6 to 61.4% of EBW, whereas the fat and ash percentage increased from 5.0 to 12.7% and 3.8 to 6.4% of EBW, respectively, as BW increased (Table 1). Despite the variations in water and fat body composition, the protein body composition (%) did not differ greatly (18 to 20.5%), although the goat weight varied from 5.3 to 25.9 kg of BW.

TOH space

The TOH space overestimated water empty body composition and total body water (water empty body composition plus water in the gastrointestinal tract content) by in average 31 and 25%, respectively (Table 2). This overestimate might be related to losses of hydrogen tritium (^3H) in urine, during sample processing and to losses of water by transpiration which the animals underwent between the 6 hours after tritium infusion and blood collections. Previous studies also reported an overestimate of total body water (TBw) by TOH space, however, the overestimate reported in this study was greater than those previously reported (between 14 and 15%; Meissner et al., 1976; Viljoen et al., 1988). These variable results are due to experimental procedure, mainly regarding time of fasting, administration and sampling techniques (Schröder & Staufenbiel, 2006).

Table 1. Summary of body weight, empty body weight, age and chemical composition of the goats.

Parameter[1]	Mean	SD	Min	Max
Body weight, kg	16.2	7.81	5.30	25.9
Empty body weight, kg	13.0	6.16	4.55	23.3
Age, days	126	87.6	16.0	262
Empty body composition (from direct method)				
Dry matter, % EBW	33.3	3.57	28.4	38.6
Ash, % EBW	4.40	0.75	3.80	6.40
Fat, % EBW	8.40	3.07	5.03	12.7
Protein, % EBW	19.3	1.11	17.9	20.6
Energy, kcal kg^{-1} EBW	5651	464	4837	6262

[1]EBW = empty body weight; SD = standard deviation; Min = minimum value; Max = maximum value.

Table 2. Total and empty body water composition of growing goats obtained from the direct method and tritiated water space (TOH).

Parameter	Mean	SD	Min	Max
Direct method				
Total body water[1], kg	8.90	3.95	3.31	15.5
Water empty body composition, kg	8.49	3.70	3.25	14.9
TOH space				
TOH space, kg	11.2	5.02	3.91	18.4

[1]water empty body composition plus water in the gastrointestinal tract content.

Using TOH space, linear equations were developed to predict the chemical composition of the empty body of growing goats (Table 3). The TOH space predicted the water (Equation 4; Table 3) and protein (Equation 7) composition of the empty body with high precision (R^2 of 0.97), whereas the determinant coefficients (R^2) were slightly lower for ash, fat and energy (Equations 5, 6 and 8, respectively). The inclusion of the EBW as a second independent variable significantly improved the precision of the equations for predicting the empty body water and protein content (Equations 10 and 13), however, did not alter the predictive value for ash, fat and energy. The fit obtained for the regression lines between TOH space and TBw (R^2 = 0.98), EBwater (R^2 = 0.97) and empty body protein (R^2 = 0.97) were similar to those obtained by Meissner et al. (1976) and Viljoen, Coetzee, and Meissner (1988), in studies with sheep and goats, respectively.

The slope of the Equation 4 (0.729, Table 3) for the determination of water was slightly lower than the value of 0.872 reported for Boer goats (Viljoen et al., 1988), presumably as a consequence of time of fasting. In this study, the animals were fasted for a period of 18 hours prior to slaughter, while in the previous study (Viljoen et al., 1988), the animals were not fasted beforehand, and therefore, an additional loss of gut water during the fast in this study resulted in a lower slope.

Table 3. Regression equations to predict the chemical composition of the empty body of growing goats from TOH space and EBW.

Equation	Parameter	α value	α SE	α *P*	β1 (TOH space) value	β1 SE	β1 *P*	β2 (EBW) value	β2 SE	β2 *P*	Model *P*	Model RMSE	Model R^2
3	TBw, kg	0.158	0.39	0.69	0.780	0.03	< 0.0001	-	-	-	< 0.0001	0.48	0.98
4	EBw, kg	0.328	0.48	0.51	0.729	0.03	< 0.0001	-	-	-	< 0.0001	0.59	0.97
5	Ash, kg	-0.057	0.006	0.41	0.057	0.005	< 0.0001	-	-	-	< 0.0001	0.08	0.93
6	Fat, kg	-0.455	0.29	0.15	0.147	0.02	< 0.001	-	-	-	< 0.001	0.36	0.82
7	Protein, kg	-0.352	0.18	0.08	0.260	0.01	< 0.0001	-	-	-	< 0.0001	0.22	0.97
8	Energy, kcal	-5773	3278	0.11	2804	269	< 0.0001	-	-	-	< 0.0001	4059	0.93
Using the EBW as second independent variable:													
9	TBw, kg	0.499	0.16	0.01	0.124	0.09	0.24	0.539	0.08	< 0.001	< 0.0001	0.19	0.99
10	EBw, kg	0.733	0.23	0.01	-0.05	0.14	0.72	0.640	0.11	< 0.001	< 0.0001	0.27	0.99
11	Ash, kg	-0.050	0.07	0.51	0.044	0.04	0.35	0.010	0.03	0.78	< 0.0001	0.08	0.93
12	Fat, kg	-0.457	0.32	0.20	0.149	0.19	0.47	-0.02	0.16	0.98	0.002	0.38	0.82
13	Protein, kg	-0.196	0.07	0.03	-0.04	0.04	0.41	0.246	0.03	< 0.001	< 0.0001	0.09	0.99
14	Energy, kcal	-4995	3567	0.20	1307	1762	0.56	1230	1762	0.50	< 0.0001	4196	0.93

TOH, tritiated water space; EBW, empty body weight; RMSE, residual mean square error; TBw, total body water; EBw, empty body water.

On the other hand, the fasting of goats in this study resulted in a higher slope (0.260, Table 4) of prediction of body protein than that of Boer goats (0.227; Viljoen et al., 1988), probably due to a potentially lower TOH space value herein.

Table 4. Chemical composition of water, fat and protein in the empty body of growing goats obtained from the direct method and specific gravity of the carcass or 9-11th ribs.

Parameter	Mean	SD	Min	Max
Direct method				
Empty body water, %	66.6	3.57	61.3	71.5
Fat, %	8.40	3.07	5.03	12.7
Protein, %	19.3	1.11	17.9	20.6
Carcass specific gravity				
Empty body water, %[1]	52.6	4.86	45.8	59.9
Fat, %[2]	25.5	6.40	16.5	35.0
Protein, %[3]	17.4	1.26	15.4	19.0
9-11th ribs specific gravity				
Empty body water, %[1]	58.5	5.9	47.6	66.2
Fat, %	18.3	7.12	9.83	32.3
Protein, %	18.5	1.02	16.1	19.3

[1]Calculated as: empty body (EB) water (%) = [(100×(4.008-(3.62/(0.995×carcass specific gravity)))]. [2]Calculated as: EB fat (%) = [(337.8+ (0.240×EB water)-(188.9×Log EB water))]. [3]Calculated as: EB protein (%) = [(80.8-(0.00078×animal age)/100)]. All calculations were according to Harris, (1970).

The fat-free composition of the empty body is relatively constant as protein, water and ash are deposited simultaneously. In addition, water is intimately involved in the stabilization of protein configuration. Consequently, the high precision of the relationship between TOH space and protein might be a consequence of their close association in the body composition. Contrary to protein, fat is inversely related to water and is the most variable component in the body. Due to its high variability between animals, the use of equations to predict fat from other species or breed could result in under or overestimate as much as 20.5% (Viljoen et al., 1988).

Specific gravity

The SG of the carcass and 9-11th ribs underestimated water empty body composition (%) percentage by in average 21 and 12%, respectively, whereas the prediction of fat empty body composition was overestimated by in average 223 and 142%, respectively (Table 4). Probably, the EB water and fat content have not been accurately predicted due to the fact that the equations proposed by Harris (1970), used in our calculations, were obtained from sheep, which were also older and probably fatter than the goats used in our study. In addition, the protein percentage was overestimated by as much as 9% using the carcass SG and by 4% from 9-11th ribs SG.

The density of specific gravity of the body is a biological parameter determined by the body volume to body weight ratio and it is inversely related to the percentage of body fat in animals (Hohl, Oliveira, Macedo, & Brenzikofer, 2007). Then, the poor relationships of SG with body composition found in this study are in agreement with earlier reports (Gonçalves, Silva, Gomes, & Castro, 1991, Alleoni et al., 1997), which could be addressed to the fact that carcass density may not be critical enough to measure low quantities of fat. Additionally, a previous report suggested that SG was a poor indicator of carcass composition of steers when carcass fat percentage was less than 12% (Fortin et al., 1981). In our study, the highest fat percentage observed was approximately 12%, which could have contributed greatly for such differences. A further source of error, which could have a considerable influence on SG values, is the amount of air entrapped between the muscles when carcass is immersed in water. The method of obtaining submerged carcass weights in our study (i.e. submerging the whole half carcass instead of parts of the carcass) may have increased the risk of entrapping air between the tissues.

Using the body composition obtained from the direct method, we developed equations for estimating the water and fat composition of growing goats from SG of the carcass and 9-11th ribs (Table 5). In fact, the percentage of water in the empty body of the goats explained a high proportion of the

Table 5. Regression equations to predict empty body water and fat from specific gravity of the carcass or 9-11th ribs and EBW.

Equation	Parameter	SG	α			β1 (SG)			β2 (EBW)			Model		
			value	SE	*P*	value	SE	*P*	value	SE	*P*	*P*	RMSE	R^2
15	Water, %	Carcass	-49.3	81.0	0.55	110.8	77.4	0.19	-	-	-	0.19	3.37	0.20
16	Water, %	9-11th ribs	77.4	73.5	0.32	-10.1	69.0	0.88	-	-	-	0.88	3.78	0.002
17	Fat, %[1]	-	58.4	9.87	< 0.001	-	-	-	-0.75	0.14	0.001	0.001	1.58	0.76
Using the EBW as second independent variable:														
18	Water, %	Carcass	25.2	50.8	0.63	45.2	48.1	0.37	-0.45	0.11	0.004	0.005	1.97	0.76
19	Water, %	9-11th ribs	91.3	40.3	0.05	-17.1	37.8	0.66	-0.49	0.11	0.003	0.009	2.06	0.73

SG, specific gravity; EBW, empty body weight; RMSE, residual mean square error. [1]Regression equation to predict empty body fat from empty body water percentage.

measured body fat variation (R^2 = 0.80) in our study (Equation 17). The water fraction (Equations 15 and 16) however, was significantly less satisfactorily explained by the carcass (R^2 = 0.26) or 9-11th ribs (R^2 = 0.09) SG, indicating that SG alone is a poor estimator of body water.

An important factor influencing body composition is the weight. Thus, EBW was included in the model as a second independent variable together with SG of the carcass or 9-11th ribs, which significantly improved the precision of EB water prediction (Equations 18 and 19). This is expected since the muscular tissue, which varies greatly with changes in the body weight, is composed mainly by water (i.e. ca. 75%). Calculating a linear regression between empty body protein and water resulted in a highly significant regression line (EB protein (kg) = [(-0.45 ±0.12) + 0. 0.355 ± 0.01) × EB water (kg), RMSE = 0.15)], explaining nearly all the variation in body protein content (98.9%). Protein, ash and water are deposited simultaneously in the body and the rate of both protein and water deposition is essentially a linear function for animals containing less than 30% fat (Reid, Bensadoun, Paladines, & Van Niekerk, 1963). The close association of water and protein could be the reason of the high precision of the prediction equation of body protein from water.

Conclusion

The determination of TOH space can be used as a reliable field technique to study relative changes in body composition of growing goats.

Specific gravity determinations are practicable in most circumstances and do not require expensive equipment. However, the SG of the carcass and 9-11th ribs has not a valid equation to predict body composition of growing goats.

References

Alleoni, G. F., Boin, C., Leme, P. R., Vieira, P. F., Nardon, R. F., Demarchi, J. J. A. A., & Otsuk, I. P. (1997). Avaliação da gravidade específica e de outras medidas corporais e da carcaça para estimar a composição corporal de novilhos Nelore. *Revista Brasileira de Zootecnia, 26*(2), 375-381.

Association of Official Analytical Chemists [AOAC]. (2007). *Official methods of analysis* (15th ed.). Arlington, VA: AOAC.

Benjamin, R. W., Koenig, R., & Becker, K. (1993). Body composition of young sheep and goats determined by the tritium dilution technique. *The Journal of Agricultural Science, 121*, 399-408.

Fernandes, M. H. M. R., Resende, K. T., Tedeschi, L. O., Fernandes, J. S., Teixeira, I. A. M. A., Carstens, G. E., & Berchielli, T. T. (2008). Predicting the chemical composition of the body and the carcass of 3/4Boer×1/4Saanen kids using body components. *Small Ruminant Research, 75*(1), 90-98.

Fortin, A., Reid, J. T., Simpfendorfer, S., Ayala, H. J., Anrique, R., Kertz, A. F., … Wellington, G. H. (1981). Chemical composition and carcass specific gravity in cattle : effect of level of energy intake and influence of breed and sex. *Canadian Journal of Animal Science, 61* (4), 871-882.

Gonçalves, L. C., Silva, J. F. C., Gomes, A. I., & Castro, A. C. G. (1991). Métodos para determinação da composição corporal e estudo da área corporal de novilhos. *Revista da Sociedade Brasileira de Zootecnia, 20*(4), 405-412.

Harris, L. F. (1970). *Nutrition research techniques for domestics and wild animals*. Logan, UT: Logan State University.

Hohl, R., Oliveira, R. B., Macedo, D. V., & Brenzikofer, R. (2007). Apparatus for measuring rat body volume: a methodological proposition. *Journal of Applied Physiology, 102*(3), 1229-1234.

Johnson, L. P., Miller, M. F., Haydon, K. D., & Reagan, J. O. (1990). The prediction of percentage of fat in pork carcasses. *Journal of Animal Science, 68*(12), 4185-4192.

Maeno, H., Oishi, K., & Hirooka, H. (2013). Interspecies differences in the empty body chemical composition of domestic animals. *Animal: an International Journal of Animal Bioscience, 7*(7), 1148-1157.

Meissner, H. H. (1976). Urea space versus tritiated water space as an *in vivo* preditctor of body water and body fat. *South African Journal of Animal Science, 6*(3), 171-178.

Owens, F. N., Gill, D. R., Secrist, D. S., & Coleman, S. W. (1995). Review of some aspects of growth and development of feedlot cattle. *Journal of Animal Science, 73*(10), 3152-3172.

Reid, J. T., Bensadoun, A., Paladines, O. L., & Van Niekerk, B. D. H. (1963). Body water estimations in relation to body composition and indirect calorimetry in ruminants. *Annals of the New York Academy of Sciences, 110*(Part I), 327-342.

Statistical Analysis System [SAS]. (2008). *SAS/STAT user's guide*. *Version 9.2.* Cary, NC: SAS Inst. Inc.

Schröder, U. J., & Staufenbiel, R. (2006). Invited review: Methods to determine body fat reserves in the dairy cow with special regard to ultrasonographic measurement of backfat thickness. *Journal of Dairy Science, 89*(1), 1-14.

Springel, P. H., & Wright, D. E. (1976). Liquid cintillation counting of tritiated water in plasma following dioxane precipitation. *International Journal Applied Radiation and Isotopes, 27*(2), 85-88.

Viljoen, J., Coetzee, S. E., & Meissner, H. H. (1988). The *in vivo* prediction of body composition in Boer goat does by means of the tritiated water space technique. *South African Journal of Animal Science, 18*(2), 63-67.

Received on August 23, 2016.
Accepted on January 17, 2017.