The *in vivo* prediction of body composition in Boer goat does by means of the tritiated water space technique

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Twelve non-lactating Boer goat does with live masses ranging between 20 and 60 kg and of different body fatness were used to develop equations predicting body moisture, protein, ash and fat from tritiated water space. Calculated coefficients of variation, with the standard deviation obtained from deviations from regression showed that body moisture, protein, ash and fat could be predicted with an accuracy of 1,8%, 7,5%, 7,3% and 7,4% respectively. Combining body mass and tritium space in a multiple linear regression increased the accuracy of predicting body fat substantially. Applying prediction equations derived for sheep could underestimate body fat in Boer goat does.

Twaalf nie-lakterende Boerbokooie met liggaamsmassas tussen 20 en 60 kg en met groot variasie in liggaamsvetheid is gebruik om voorspellingsvergelykings vir die beraming van liggaamsvog, -proteïen, -as en -vet vanaf tritiumspasie te bereken. Koëffisiënte van variasie, bereken vanaf standaardafwykings vanaf regressies verkry, dui daarop dat die akkuraatheid van beraming van liggaamsvog, -proteïen, -as en -vet 1,8%, 7,5%, 7,3% en 7,4% respektiewelik was. Die kombinering van liggaamsmassa en tritiumspasie in 'n meervoudige lineêre regressievergelyking het die akkuraatheid van liggaamsvet-voorspelling aansienlik verhoog. Die toepassing van voorspellingsvergelykings vir skape kan lei tot die onderskatting van Boerbokooie se liggaamsvet.

Keywords: Body composition, tritiated water space, Boer goat

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Introduction

Slaughter analysis is an accurate method of determining the body composition of an animal. However, determining the degree of change in body composition, as effected by a given treatment, requires slaughtering a group of animals in the beginning and again at the end of a treatment period. An accurate, indirect method of estimating body composition in the living animal would provide greater control because it would allow the same animal to be studied throughout the treatment period (Reid, Bensadoun, Paladines, & van Niekerk, 1963). The tritiated water (TOH) space technique for estimating body composition of live animals with minimal interference has been applied succesfully and is preferred to other dilution techniques by some researchers (Panaretto, 1963; Panaretto & Till, 1963; Hansard, 1964; Meissner, 1976 and Meissner, van Staden & Pretorius, 1980). In South Africa, the technique has been used on various sheep breeds and species such as the Merino, SA Mutton Merino and Pedi (Hofmeyr, Olivier, Kroon & van Rensburg, 1971); on SA Mutton Merino and Karakul lambs (Meissner & Bieler, 1975); on pigs (Kemm, 1974); and on cattle (Meissner, *et al.*, 1980). The relationship between TOH space and body composition has not as yet been determined in the Boer goat. Equations derived for sheep are not necessarily applicable to Boer goats. This study was therefore aimed at describing body composition in the *ad lib.* fed Boer goat doe, and developing equations for predicting the different body components from TOH space.

Material and Methods

Twelve Boer goat does, varying in live mass between 20 and 60 kg and between 7 and 21 months old and visually of different body fatness, were used. Tritiated water space was determined according to a combination of the methods used by Hofmeyr, *et al.* (1971) and Meissner & Bieler (1975). In the study of Hofmeyr, *et al.* (1971), the animals were not fasted before administration of the tritium. Meissner & Bieler (1975), however, starved their animals for 24 h prior to the administration of tritium but slaughtered their animals approximately 6 h after the tritium was injected (as in the present study), whilst Hofmeyr, *et al.* (1971) starved their animals for an additional 12 – 16 h before slaughter. The method used in the present study was aimed at causing minimal interference in the *ad lib.* fed doe, so that this method may be used as such in follow-on studies. For this reason, the animals were not starved beforehand and were slaughtered 6 h after tritium was injected.

A pre-injection blood sample was collected from each goat before an accurately weighed amount of tritiated water (*ca* 400 μ Ci) was injected per *vena jugalaris*. Food and water were removed immediately after tritium administration. Six hours later a blood sample (post-injection sample) was collected from each goat. Duplicate samples of pre-injection and post-injection blood were freeze-distilled, prepared, and subsequently counted in a liquid scintillation spectrometer. The apparent tritiated water space (TOH) was calculated from the ratio of injected tritium to the concentration of diluted tritium after equillibrium with corrections for pre-injection activity (Searle, 1970). The efficiency with which the samples were counted was determined by comparison with a quench curve (United technologies, Quenched standards). All counts were adjusted to an efficiency of 100%. No correction was applied for losses of tritium through the faeces, urine or skin during the 6 h following administration.

Immediately after the second blood sample was taken, the goats were shorn, weighed and slaughtered. The gut contents of the goats were removed, weighed and a dry matter (DM) analysis was performed. The carcasses, blood and intestines were stored at -10°C overnight. After mincing the carcasses the following morning, thoroughly homogenized samples were analysed for DM, nitrogen (N), ether extract and ash using the procedures described by Hofmeyr, Kroon, van Rensburg & van der Merwe (1972). The moisture content of the does used in this study refers to the moisture content of the whole animal and was calculated by adding the moisture content of the gut contents to that of the carcass.

The relationship between TOH space and respectively moisture, protein and ash was analysed using simple linear regression techniques. Linear relationships were shown by Panaretto (1963); Searle (1970); Hofmeyr, *et al.* (1971); and Meissner & Bieler (1975) to be satisfactorily accurate predictors. Simple and multiple linear regression equations between fat as dependent variable and TOH space, live mass and age as independent variables were also calculated to determine the best possible prediction of fat. Hofmeyr, *et al.* (1971) suggested that the inclusion of factors such as age and live mass as independent variables might improve the accuracy of fat prediction. A sample standard deviation from the regresssion ($Sy.x$) was calculated for each regression equation.

Results and Discussion

Age, live mass and body composition (determined by proximate analysis) of the 12 Boer goat does used in the study are shown in Table 1. The moisture content of the does varied between 53% and 72% of live mass, whilst the fat content varied between 8% and 29% of live mass. Little variation occurred in the protein content (13 – 15%). These differences indicate the applicability of this study to Boer goat does over a wide range of age, live mass and body fatness. Full details of carcass analysis, TOH space and gut contents are given in Appendix 1.

Simple linear regression equations between TOH space and respectively moisture, protein and ash are presented in Table 2.

The good fit obtained for these regression lines between TOH space and respectively moisture and protein (r^2 = 0,997 and 0,963) are of the same order as those obtained by Panaretto (1963); Searle (1970); Hofmeyr, *et al.* (1971); and Meissner & Bieler (1975).

The relationship between TOH space and moisture is illustrated in Figure 1, which shows a close fit of the data. The slope in the equation (0,872) for the determination of moisture is slightly lower than the value of about 0,93 found by authors working on sheep (Searle, 1970 and Hofmeyr, *et al.*, 1971). Since Hofmeyr, *et al.* (1971) starved their animals for an additional period of 12 –16 h prior to slaughter, it would be expected that an additional loss of gut moisture during this period would lead to a lower slope than that of the present study. This, however, was not the case. Working on cattle (following the same experimantal procedures as in the present study), Meissner, *et al.* (1980) calculated a slope value of 0,86 which

Table 1 Means and ranges of age, live mass and body components of the 12 Boer goat does

	Age (months)	Live mass (kg)	Moisture (kg)	Protein (kg)	Fat (kg)	Ash (kg)
Mean	20,5	36,7	23,0	5,1	6,7	1,3
Range	7,4–43,6	17,9–59,0	12,8–31,6	2,5–8,0	1,5–17,1	0,6–2,0

Table 2 Equations to predict body moisture, protein and ash from TOH space (kg)

Equations		r^2	$Sy.x$
Moisture (kg)	= 0,736 (± 0,418) + 0,872 (± 0,016) TOH (kg)	0,997	0,423
Protein (kg)	= -0,698 (± 0,374) + 0,227 (± 0,014) TOH (kg)	0,963	0,379
Ash (kg)	= -0,261 (± 0,091) + 0,060 (± 0,003) TOH (kg)	0,968	0,093

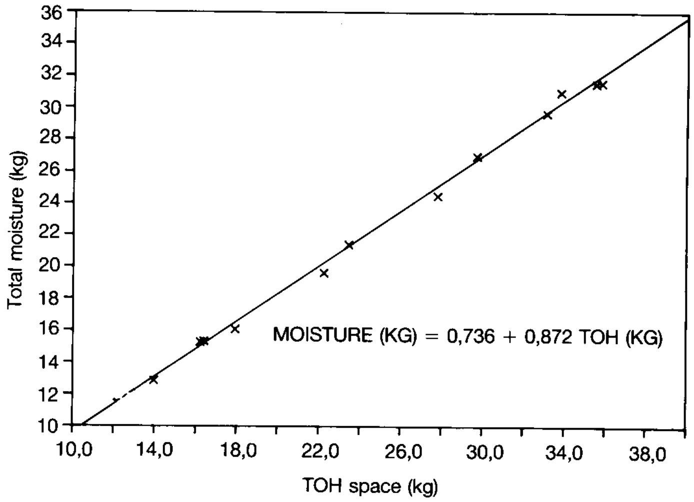

Figure 1 The relationship between TOH space and total moisture

corresponds well with the value in the present study. Species difference could be the reason for the lower slope value in comparison to values found by other authors. The reciprocal of the slope of the regression equation (1,15) shows agreement with the values of Meissner *et al.* (1980) and Carnegie & Tulloh (1968). This indicates that if ruminants are not fsted beforehand, moisture may be overestimated by 14 – 16%.

In the prediction of body protein from TOH space, the slope of 0,227 agrees with the values of 0,22 and 0,23 found by Hofmeyr, *et al.* (1971) and Meissner & Bieler (1975). It was not suspected that any difference in experimental procedure between Hofmeyr, *et al.* (1971) and the present study would influence the relationship, because the animals were not starved beforehand. The starvation of animals prior to tritium injections as performed by Meissner & Bieler (1975) could have resulted in a higher slope value because of a potentially lower TOH space value. The degeee of gut fill before starvation, and moisture lost from the gut during starvation, would however, have determined the extent of potential differences. Panaretto (1963) quoted Berendsen (1960) and Klotz (1962) who postulated that water is intimately involved in the stabilization of protein configuration. According to Reid, *et al.* (1963), protein, moisture and ash are deposited simultaneously. They stated that the rate of both moisture and protein deposition in the body was essentially a linear function for animals containing less than *ca.* 30% of fat. The close association between protein and moisture could thus be the reason for the close fit and high accuracy of relationships between TOH space and protein as well as ash. It could also be the reason for the close association between body protein and ash.

The correlation coefficient for ash (0,984) found in this study is higher than the value of 0,942 found by Searle (1970). By including both age and body mass in the prediction equation, Searle (1970) realized a correlation coefficient of 0,981 which corresponds to the value found in this study.

A relationship between ash and protein was also calculated. Results showed that the ash content may be calculated satisfactorily as 0,25 ± 0,02 × crude protein content of the body. This corresponds with the value of 0,25 × crude protein content of the body found by Panaretto & Till (1963). According to Reid *et al.* (1963), the percentages of protein and ash in the fat-free dry matter of the empty body are relatively constant. This was confirmed in the presenrt study.

According to Hofmeyr, *et al.* (1971) the inclusion of live mass and age could improve the accuracy with which body fat may be predicted. This was done for the relationship between TOH space and fat. From the prediction equations shown in Table 3, it is evident that the accuracy of prediction was substantially increased by the multiple linear regression equations as indicated by the *Sy.x* and R^2 values. Cowan, Robinson, McHattie & Fraser (1980) and Reid, *et al.* (1963) found a close negative relationship between the proportions of water

Table 3 Simple and multiple linear regression equations for the prediction of fat from TOH space (kg), live mass (kg) and age (months)

Equations	r^2	*Sy.x*
Simple linear regressions		
1. Fat (kg) = -8,306(± 3,045) + 0,588(± 0,114) TOH (kg)	0,726	3,085
2. Fat (%) = 92,023(± 5,768) - 1,065(± 0,080) TOH (%)	0,947	1,849
Multiple linear regressions	R^2	*Sy.x*
3. Fat (kg) =-1,118(± 0,607) - 0,943(± 0,080) TOH (kg) + 0,869(± 0,044) live mass (kg)	0,994	0,491
4. Fat (kg) =-1,335(± 0,685) - 0,905(± 0,096) TOH (kg) + 0,856(± 0,048) live mass (kg) - 0,004(± 0,005) age (months)[a]	0,994	0,503

[a] No statistical significant effect on the accuracy of prediction of fat ($P > 0,05$)

and fat in live mass. However, inclusion of live mass with body moisture in an equation to predict fat, significantly reduced the residual error in the study of Cowan, *et al.* (1980). Including age in the present study as an additional independent variable to live mass did not have a statistically significant effect. In fact, including age slightly diminished the accuracy with which fat could be estimated. Searle (1970), however, found a small increase in the correlation coefficient when he included age as an independent variable. Searle (1970) mentioned that the fat content of an animal can vary substantially at a particular age which makes the inclusion of a parameter like age irrelevant. This might be the reason why age did not have an effect in this study (Table 1). The *Sy.x* value of 0,419 kg for the estimation of fat in this study was better than the values of 1,996 kg and 1,859 kg found by Hofmeyr, *et al.* (1971) and Meissner & Bieler (1975) respectively.

The coefficients of variation for moisture, protein, ash and fat, with standard deviations from regression, were 1,84%; 7,45%; 7,33%; and 7,35% respectively. These values indicate that the magnitude of the accuracy of determinig protein, ash and fat was of the same order whilst that of moisture was substantially better.

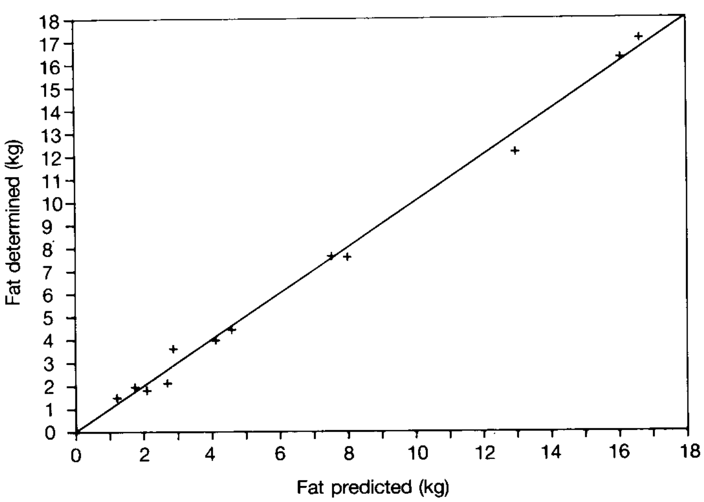

Figure 2 The relationship between predicted and determined values of fat

Because fat is the most variable component of the body the relationship between determined and predicted fat is shown in Figure 2. This relationship and the relationships between determined and predicted values for moisture, protein and ash had respective correlation coefficients of 0,997; 0,998; 0,982; and 0,984. The slopes of the different linear relationships were not significantly different from one and the intercepts were not significantly different from zero. These relationships were thus unbiased and of sufficient accuracy to warrant confident prediction of the different body components.

As in the study of Hofmeyr, *et al.* (1971), the animals were not fasted before tritium treatment. According to Meissner & Bieler (1975) not fasting beforehand may have the effect that the intercept values of the prediction equations may differ from equations where animals were fasted beforehand (usual procedure; Panaretto & Till (1963); Searle (1970) and Meissner & Bieler (1975)).

The prediction equations of Hofmeyr, *et al.* (1971), using three divergent breeds, were used to compare body composition values of the Boer goat determined and predicted in this study with values obtained by using prediction equations for sheep. The values thus obtained are compared with determined and predicted body composition values of the present study as shown in Table 4. Hofmeyr, *et al.* (1971), however, did not calculate a prediction equation for ash. Therefore ash comparisons are not included in Table 4.

From Table 4 it is evident that protein and moisture predicted from the equations used by Hofmeyr, *et al.* (1971) did not differ substantially from those predicted from the equatioins in the present study. A tendency to overestimate moisture by approximately 3 – 5% and protein by approximately 2% was found. This could be regarded as sufficiently accurate and in the range of experimental error. The prediction of fat is

Table 4 Comparison of body composition of the goats, determined by analysing slaughter data, predicted using equations from this study and using equations determined for sheep by Hofmeyr, *et al.* (1971)

		Live mass (kg)	Moisture (kg)	%	Protein (kg)	%	Fat (kg)	%
Goat with	Determined	59,00	31,55	(100)	8,00	(100)	17,09	(100)
the highest	Predicted[a]		31,72	(100,5)	7,37	(92,1)	16,65	(97,4)
live mass	Predicted[b]		33,24	(105,4)	7,39	(92,4)	13,53	(79,2)
Goat with	Determined	17,85	12,83	(100)	2,50	(100)	1,50	(100)
the lowest	Predicted[a]		12,92	(100,7)	2,48	(99,2)	1,21	(80,7)
live mass	Predicted[b]		13,16	(102,6)	2,67	(106,8)	1,15	(76,7)
Average of	Determined	36,69	22,98	(100)	5,09	(100)	6,68	(100)
all 12	Predicted[a]		22,98	(100)	5,09	(100)	6,71	(100,4)
goats	Predicted[b]		23,91	(104,1)	5,20	(102,2)	5,31	(79,5)

[a] Predicted by using the equations of this study

[b] Predicted by using the equations determined with sheep (Hofmeyr, *et al.*, 1971)

underestimated by the equation used for sheep by as much as 20,5%, which indicates that the equation would not be suitable for the prediction of body fat in the Boer goat. It is doubted whether experimental procedure could be responsible for such differences.

In conclusion, the determined prediction equations for the Boer goat doe show that moisture, protein, ash and fat may be satisfactorily predicted using the tritiated water technique. Coefficients of variation, with the standard deviation obtained from deviations from regression were 1,84%; 7,45%; 7,33%; and 7,35%. this is sufficiently accurate for the TOH space technique to be used for future estimation of body composition in the Boer goat doe, using the prediction equations developed in this study.

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Appendix 1 Age live mass, TOH space, carcass analysis and gut contents of the 12 Boer goat does

Goat no.	Age (months)	Live mass (kg)	TOH space (kg)	Moisture (kg)	Protein (kg)	Fat (kg)	Ash (kg)	Gut moisture (kg)	Gut DM (kg)
84,1	7,4	17,9	14,0	12,8	2,50	1,50	0,64	3,04	0,66
84,3	7,4	21,3	16,2	15,3	3,13	1,81	0,78	3,22	0,68
3,55	16,8	22,2	16,4	15,3	3,16	2,12	0,81	3,39	0,62
3,3	16,9	22,8	17,9	16,1	3,35	1,96	0,81	2,86	0,54
3,41	10,3	28,8	22,3	19,6	4,15	3,61	0,98	4,38	0,72
2	9,9	31,5	23,5	21,4	4,62	3,99	0,97	4,13	0,47
3,5	16,9	36,8	27,8	24,5	5,37	4,44	1,33	5,62	0,98
1,7	43,5	42,8	29,7	27,0	5,58	7,59	1,49	5,68	1,33
1,5	43,6	48,8	35,8	31,6	6,82	7,65	1,92	5,73	1,07
40	24,0	52,9	33,8	31,0	7,00	12,16	1,74	6,78	0,82
29	24,2	55,8	33,1	29,7	7,37	16,26	1,76	6,30	1,00
30	24,5	59,0	35,5	31,5	8,00	17,09	2,00	5,70	0,45
Mean	20,4	36,7	25,5	23,0	5,09	6,68	1,27	4,74	0,78