S. Afr. J. Anim. Sci. 10, 175 - 181 (1980)

IN VIVO ESTIMATION OF BODY COMPOSITION IN CATTLE WITH TRITIUM AND UREA DILUTION. II. ACCURACY OF PREDICTION EQUATIONS OF THE CHEMICAL ANALYSED CARCASS AND NON-CARCASS COMPONENTS

Receipt of MS 02-11-1979

H.H. Meissner, J.H. van Staden and Elma Pretorius.
Animal and Dairy Science Research Institute, Private Bag X2, Irene

(Key words: *Predicting body composition, carcass and non-carcass components, cattle)*
(Sleutelwoorde: *Voorspelling van liggaamsamestelling, karkas en nie-karkasdele, beeste)*

OPSOMMING: DIE *IN VIVO* BERAMING VAN LIGGAAMSAMESTELLING VAN BEESTE MET BEHULP VAN TRITIUM- EN UREUMVERDUNNING. II. DIE AKKURAATHEID VAN VOORSPELLINGSVERGELYKINGS VIR DIE CHEMIES GE-ANALISEERDE KARKAS EN NIE-KARKASDELE

Lineêre regressieverwantskappe met tritium- of ureumruimte, lewende massa en karkasmassa (waar toepaslik) as onafhanklike veranderlikes en die chemiese komponente van die karkasse van die bulle is opgestel. Soorgelyke verwantskappe is vir die chemiese komponente van die nie-karkasdele opgestel. Die proefprosedures is reeds beskrywe in die eerste artikel van die reeks (Meissner *et al.*, 1980a).

Die byvoeging van lewende massa en karkasmassa as onafhanklike veranderlikes het in die meeste gevalle die akkuraatheid van voorspelling vanaf tritium – of ureumruimte verbeter, selfs met soveel as 60% in sommige gevalle. Die beste voorspellingsvergelykings het vog, proteïen en anorganiese materiaal in sowel die karkas as die nie-karkasdele met 'n koeffisiënt van variasie van <10% by 'n lewende massa van 400 kg beraam. In teenstelling hiermee was die fout waarmee die hoeveelheid eterekstrak beraam kon word heelwat groter. Die koeffisiënt van variasie by 400 kg lewende massa was 22 - 26%, wat net soos in die geval van voorspelling by die heelliggaam, beklemtoon dat kwantifisering van samestellingsverskille in die karkas en nie-karkasdele noodwendig gepaard sal moet gaan met 'n reeks metings op dieselfde dier.

SUMMARY:

Linear regression equations with tritium or urea space, live mass and carcass mass (where applicable) as independent variables, and the chemical components of the carcasses of bulls were established. Similar equations were calculated for the chemical components of the non-carcass parts. The experimental procedure was described in the first paper of this series (Meissner *et al.*, 1980a).

By adding live mass and carcass mass to tritium or urea space as independent variables, the accuracy of prediction was improved, even to the extent of 60% in some cases. The most accurate prediction equations predicted water, protein and inorganic material in the carcass and non-carcass with a coefficient of variation of <10% at a live mass of 400 kg. In contrast, the error of prediction of the ether extract was considerably higher. The coefficient of variation at 400 kg live mass was 22 - 26%, which emphasizes that, as in the case of the whole body, quantification of compositional differences in the carcass and non-carcass would be possible only if a series of measurements on the same animal is made.

Meissner, van Staden & Pretorius (1980a) in the first paper of this series derived equations for predicting the composition of the whole body in terms of water, protein (N x 6,25), inorganic matter, ether extract and energy of combustion. It was shown that the ether extract-free components can be estimated fairly accurately by measurement of tritium (TOH) or urea space in addition to body mass, but that more than one measurement is required if a reliable estimate of the amount of ether extract is to be realized. In general the results of Clark, Hedrick & Thompson (1976) using ^{40}K support these findings.

In this paper separate prediction equations were deduced for the carcass and non-carcass components. The latter included head, trotters, digestive tract, viscera, blood and hide. Where possible the reliability of the prediction equations was compared to the comprehensive ones derived by Clark *et al.* (1976).

Procedure

Details of the experimental animals, their management, and infusion and analyses of tritium and urea have been described in the first paper (Meissner *et al.*, 1980a). The slaughter and mincing procedures in short incorporated the following: After stunning of the animal the blood was collected and weighed. The body was then flayed and the digesta removed. The non-carcass components head, trotters, digestive tract, viscera and blood were

Table 1

Means and ranges of the composition of the carcass and non-carcass components

	Mean	Range
Carcass mass (kg):	229,1	52,5 – 491
Water (kg)	136,5	36,8 – 280
Protein (kg)	45,18	9,64 – 103
Inorganic matter (kg)	11,91	2,79 – 24,9
Ether extract (kg)	34,74	3,17 – 116
Energy of combustion (MJ)	2429	355 – 5979
Non-carcass components:		
Water (kg)	72,68	24,8 – 128
Protein (kg)	24,89	6,30 – 40,8
Inorganic matter (kg)	4,185	1,22 – 7,61
Ether extract (kg)	13,49	1,40 – 36,4
Energy of combustion (MJ)	1110	201 – 2509

pooled, while the hide was minced separately. The carcasses were split, the left sides being retained for mincing and chemical analysis, while the right sides were assigned for physical dissection and determination of muscle, bone and fat stores. The hide, other non-carcass components and the left side of the carcass were minced in the frozen state using a Wolfking carcass grinder. Thereafter, representative samples were analysed for DM, ether extract, N, inorganic matter and energy of combustion according to AOAC methods (A.O.A.C., 1970). The amount of water, protein, ether extract and inorganic matter of the hide was them added to that of the other non-carcass components before statistical analysis commenced.

As described previously (Meissner *et al.*, 1980a) least square analyses were used to establish prediction equations for the carcass and non-carcass components. The reliability was determined by evaluating r^2 or R^2, Sy.x and the 95% confidence limits for prediction at the extremes of experimentation (see range column, Table 1).

Results and Discussion

1. Chemical composition of the carcass and non-carcass components

The means and ranges of the constituents of the carcass and non-carcass components are shown in Table 1.

2. Relationship between urea or TOH space and carcass and non-carcass water

The relationships considered were:

2.1 Urea space calculated from blood sampling at 10 minute post infusion ($Urea_{10}$) in relation to carcass and non-carcass water.

2.2 TOH space calculated from blood sampling at 6 hours post-infusion (TOH_{360}) in relation to carcass and non-carcass water.

2.3 TOH space calculated from blood sampling at 5 minutes post-infusion (TOH_5) in relation to carcass and non-carcass water.

As was the case with the relationships involving the whole body, the relationships discussed here were not significantly influenced by breed or diet. Therefore, the data were pooled and common regression equations fitted. Furthermore, body mass and, where applicable, carcass mass were introduced as second and second or third independent variable in some analyses to compare the reliability of the multiple linear equation with the simple one for prediction of carcass or non-carcass water.

Where the intercept did not differ significantly from zero, the regression line was forced through the origin.

The relevant relationships are shown in Table 2.

It was found that water-space measurement, alone, did not have any advantage above body mass or carcass mass in predicting carcass water. By adding body mass or carcass mass as a second independent variable, the accuracy of prediction was improved by between 16 and 60% (see Sy.x), depending on type of water space measurement. Adding body mass or carcass mass as second and third variables respectively, did not further improve the accuracy. Compared to the accuracy of prediction equations published by Clark *et al.* (1976), the present ones appear slightly inferior. The possible reasons are discussed in the first paper of this series (Meissner *et al.*, 1980a).

With regard to non-carcass water, measurement of water space was advantageous compared to body mass. Using both water space and body mass as independent variables however, no further improvement in accuracy of prediction equations was realized.

In general, accuracy of prediction was satisfactory with a coefficient of variation of 4 to 6% for the best equations.

Table 2

Prediction equations for carcass and non-carcass water in kg

Prediction equation	r^2 or R^2	Sy.x	95% confidence limits
Carcass water			
0,749 $Urea_{10}$ – 17,8	0,962	14,4	± 31,1
0,201 $Urea_{10}$ + 0,245 Mass	–	7,95	± 17,6
0,300 $Urea_{10}$ + 0,328 Carcass mass	–	5,74	± 12,7
0,321 $Urea_{10}$ – 0,038 Mass + 0,369 Carcass mass	–	6,55	± 14,9
0,519 TOH_{360} – 15,7	0,969	12,5	± 26,9
0,099 TOH_{360} + 275 Mass	–	9,15	± 20,2
0,229 TOH_{360} + 0,302 Carcass mass	–	8,24	± 18,2
0,293 TOH_{360} – 0,144 Mass + 0,416 Carcass mass	–	8,99	± 20,3
0,686 TOH_5 – 8,18	0,989	7,60	± 16,4
0,379 TOH_5 + 0,147 Mass	–	6,45	± 14,2
0,433 TOH_5 + 0,198 Carcass mass	–	5,48	± 12,1
0,481 TOH_5 – 0,060 Mass + 0,256 Carcass mass	–	5,29	± 12,0
0,347 Mass	–	9,61	± 20,6
0,523 Carcass mass + 15,9	0,980	10,4	± 22,4
Non-carcass water			
0,322 $Urea_{10}$ + 4,71	0,977	4,76	± 10,3
0,179 $Urea_{10}$ + 0,066 Mass + 8,32	0,990	3,20	± 7,20
0,230 TOH_{360} + 5,34	0,968	5,65	± 12,2
0,309 TOH_{360} – 0,047 Mass	–	5,80	± 12,5
0,300 TOH_5 + 9,36	0,966	5,82	± 12,8
0,309 TOH_5 – 0.004 Mass + 9,24	0,966	5,99	± 13,3
0,147 Mass + 15,2	0,941	7,66	± 16,5

3. Relationship between urea or TOH space and carcass and non-carcass protein

The same independent variables as before were used to predict protein and all other constituents (section 4 - 6). The relationships for protein are shown in Table 3.

The most conspicuous conclusion supported by the data in Table 3 was the fact that neither carcass protein nor non-carcass protein could be predicted with greater accuracy by water-space measurement than what was achieved through body mass or carcass mass. Apart from one case where the combination of TOH_5, body mass and carcass mass proved exceptional in predicting carcass protein, no other regression equation involving water space increased the accuracy of prediction. The equation with exceptional predictive ability seems to be rather coincidental in view of the order of magnitude of Sy.x's of all other prediction equations and its accuracy is possibly confined to the particular set of data of this experiment. The Sy.x was even lower (0.61 kg) than the lowest of Clark *et al.* (1976) (1,54 kg) who worked with a homogenous group of Hereford steers.

In terms of coefficient of variation, the most accurate predictions were satisfactory, showing values of 4 to 8%.

4. Relationship between urea or TOH space and carcass and non-carcass inorganic matter

The equations for carcass and non-carcass inorganic matter are shown in Table 4.

There appears to be a slight difference between carcass and non-carcass inorganic matter. For prediction of carcass inorganic matter, body mass or carcass mass as sole independent variable were as accurate or better than any other prediction equation with more than one independent variable. Water-space measurement did not appear to have been advantageous. In the case of non-carcass inorganic matter, water space was a more accurate predictor than body mass and it was only in combination with $Urea_{10}$ that body mass as second independent variable improved the reliability of prediction.

In terms of coefficient of variation, carcass inorganic matter could be predicted with an error of 8 to 12% and

Table 3

Prediction equations for carcass and non-carcass protein in kg

Prediction equation	r^2 or R^2	Sy.x	95% confidence limits
Carcass protein =			
0,285 Urea$_{10}$ – 13,4	0,904	8,94	± 19,4
– 0,081 Urea$_{10}$ + 0,160 Mass	–	4,98	± 11,1
– 0,017 Urea$_{10}$ + 0,213 Carcass mass	–	4,08	± 9,06
0,001 Urea$_{10}$ – 0,033 Mass + 0,252 Carcass mass	–	3,96	± 9,04
0,202 TOH$_{360}$ – 14,1	0,950	6,31	± 13,6
– 0,084 TOH$_{360}$ + 0,181 Mass	–	5,13	± 11,3
– 0,004 TOH$_{360}$ + 0,204 Carcass mass	–	4,23	± 9,33
0,084 TOH$_{360}$ – 0,157 Mass + 0,360 Carcass mass	–	3,85	± 8,73
0,267 TOH$_5$ – 11,1	0,964	5,34	± 11,5
0,086 TOH$_5$ + 0,091 Mass – 8,45	0,975	4,57	± 10,2
0,076 TOH$_5$ + 0,150 Carcass mass – 5,12	0,984	3,64	± 8,10
0,096 TOH$_5$ – 0,107 Mass + 0,294 Carcass mass	–	0,61	± 1,49
0,132 Mass – 6,45	0,975	4,61	± 9,94
0,206 Carcass mass – 2,01	0,983	3,77	± 8,14
Non-carcass protein =			
0,139 Urea$_{10}$ – 3,86	0,930	3,67	± 7,99
– 0,006 Urea$_{10}$ + 0,067 Mass	–	0,92	± 2,05
0,098 TOH$_{360}$ – 3,91	0,970	2,33	± 5,07
– 0,006 TOH$_{360}$ + 0,069 Mass	–	1,04	± 2,33
0,129 TOH$_5$ – 2,23	0,971	2,30	± 5,00
– 0,002 TOH$_5$ + 0,065 Mass	–	1,06	± 2,37
0,064 Mass	–	1,03	± 2,23

non-carcass inorganic matter with one of 9 to 11%. This is satisfactory bearing in mind the inconspicuousness of this component.

5. **Relationship between urea or TOH space and carcass and non-carcass ether extract**

The relevant equations are shown in Table 5.

The addition of water space to body mass or carcass mass as independent variable reduced the Sy.x of carcass ether extract approximately 24 to 33% in the case of body mass and 14 to 36% in the case of carcass mass. Using water space in addition to both body mass and carcass mass did not result in further reduction in the Sy.x of carcass ether extract.

Compared to body mass alone, water space together with body mass as independent variables improved the accuracy of prediction in terms of Sy.x of non-carcass ether extract by 22 to 30%.

This shows clearly that water space measurement is an asset for more reliable prediction of carcass and non-carcass ether extract. However, compared to the other components of composition the reliability is still very unsatisfactory. The best equations had coefficients of variation of 22 to 26%.

Clark *et al.* (1976) found carcass ether extract to be best predicted by ^{40}K carcass and carcass mass. The relationship, if correctly interpreted, shows a Sy.x of 6,9 kg in comparison with the most accurate one here of 8,4 kg.

6. **Relationship between urea or TOH space and carcass and non-carcass energy of combustion**

These relationships are shown in Table 6.

Body mass and carcass mass as sole independent variables were better predictors of carcass energy of combustion than water space. Similarly, body mass was also a superior predictor of non-carcass energy of combustion than water space. This is in agreement with the results of Clark *et al.* (1976) with regard to live mass and carcass mass as compared to ^{40}K live and ^{40}K carcass.

Table 4

Prediction equations for carcass and non-carcass inorganic matter in kg

Prediction equation	r^2 or R^2	Sy.x	95% confidence limits
Carcass inorganic matter =			
0,068 $Urea_{10}$ – 2,20	0,939	1,66	± 3,67
0,007 $Urea_{10}$ + 0,027 Mass	–	1,22	± 2,75
0,018 $Urea_{10}$ + 0,036 Carcass mass	–	0,94	± 2,12
0,022 $Urea_{10}$ – 0,008 Mass + 0,046 Carcass mass	–	1,00	± 2,34
0,049 TOH_{360} – 2,53	0,938	1,72	± 3,76
0,005 TOH_{360} + 0,027 Mass	–	1,63	± 3,61
0,016 TOH_{360} + 0,032 Carcass mass	–	1,64	± 3,64
0,040 TOH_{360} – 0,043 Mass + 0,074 Carcass mass	–	1,59	± 3,63
0,065 TOH_5 – 1,75	0,948	1,57	± 3,45
0,028 TOH_5 + 0,016 Mass	–	1,58	± 3,51
0,031 TOH_5 + 0,025 Carcass mass	–	1,48	± 3,28
0,044 TOH_5 – 0,018 Mass + 0,042 Carcass mass	–	1,50	± 3,43
0,030 Mass	–	1,11	± 2,40
0,049 Carcass mass + 0,777	0,993	1,11	± 2,48
Non-carcass inorganic matter =			
0,020 $Urea_{10}$	–	0,43	± 0,97
0,013 $Urea_{10}$ + 0,004 Mass	–	0,38	± 0,96
0,014 TOH_{360}	–	0,44	± 0,99
0,015 TOH_{360} – 0,0005 mass	–	0,46	± 1,09
0,019 TOH_5 + 0,268	0,946	0,46	± 1,12
0,022 TOH_5 – 0,001 Mass	–	0,47	± 1,13
0,009 Mass + 0,627	0,924	0,55	± 1,36

However, by introducing water space together with body mass or carcass mass as independent variables in the regression analysis, the accuracy of prediction was improved considerably. The Sy.x was reduced by 24 to 29% and 17 to 30% where body mass were used as second independent variable to estimate carcass and non-carcass energy of combustion respectively. Where carcass mass together with water space were used to estimate carcass energy of combustion the Sy.x was reduced by between 16 and 49% . If body mass and carcass mass were used as second and third independent variables to estimate carcass energy of combustion, very little further improvement in accuracy was realized.

The results show that water space measurement is essential for the most reliable prediction of carcass or non-carcass energy of combusion. However, due to the influence of carcass or non-carcass ether extract, the accuracy of prediction was still somewhat unsatisfactory, when compared to the non-fat components. The coefficients of variation for the best equations were between 11 and 14%.

The results of Clark *et al.* (1976) show that the carcass energy of combustion could be predicted with an error of about 232 MJ. This is somewhat better than, but clearly of the same order as the 287 to 299 MJ of the most accurate equations obtained here.

Conclusions

1. The ether extract-free components of the carcass and non-carcass can be estimated with a mean absolute error of less than 10% at a live mass of 400 kg.
2. The amount of ether extract can be estimated with a mean absolute error of between 22 to 26% at 400 kg live mass which suggests that similar to the situation for the whole body, the amount of ether extract should be estimated from more than one measurement of water space and body mass or carcass mass.
3. To quantify carcass compositional differences between or within breeds of cattle, one measurement per animal would be inadequate.

Table 5

Prediction equations for carcass and non-carcass ether extract in kg

Prediction equation	r^2 or R^2	Sy.x	95% confidence limits
Carcass ether extract =			
0,279 $Urea_{10}$ − 21,5	0,627	20,7	± 44,8
− 0,468 $Urea_{10}$ + 0,340 Mass	–	10,9	± 24,2
− 0,312 $Urea_{10}$ + 0,434 Carcass mass	–	10,3	± 22,8
− 0,367 $Urea_{10}$ + 0,102 Mass + 0,311 Carcass mass	–	10,5	± 23,9
0,196 TOH_{360} − 22,7	0,662	19,0	± 40,9
− 0,499 TOH_{360} + 0,462 Mass	–	11,4	± 25,2
− 0,248 TOH_{360} + 0,467 Carcass mass	–	11,9	± 26,3
− 0,441 TOH_{360} + 0,346 Mass + 0,124 Carcass mass	–	11,8	± 26,7
0,253 TOH_5 − 18,7	0,646	19,4	± 41,9
− 0,815 TOH_5 + 0,530 Mass	–	10,1	± 22,3
− 0,492 TOH_5 + 0,601 Carcass Mass	–	8,90	± 19,6
− 0,656 TOH_5 + 0,207 Mass + 0,400 Carcass Mass	–	8,41	± 19,0
0,142 Mass − 19,1	0,804	15,0	± 32,3
0,222 Carcass mass − 15,0	0,831	13,9	± 30,0
Non-carcass ether extract =			
0,100 $Urea_{10}$ − 6,94	0,700	6,26	± 13,6
− 0,138 $Urea_{10}$ + 0,108 Mass	–	2,89	± 6,42
0,071 TOH_{360} − 7,39	0,779	5,15	± 11,1
− 0,128 TOH_{360} + 0,131 Mass	–	3,24	± 7,15
0,093 TOH_5 − 6,03	0,768	5,27	± 11,4
− 0,198 TOH_5 + 0,142 Mass	–	3,20	± 7,07
0,049 Mass − 5,51	0,859	4,11	± 8,87

Table 6

Prediction equations for carcass and non-carcass energy of combustion in MJ

Prediction equation	r^2 or R^2	Sy.x	95% confidence limits
Carcass energy of combustion =			
$17{,}56\ \text{Urea}_{10} - 1134$	0,756	960	± 2079
$-20{,}08\ \text{Urea}_{10} + 17{,}00\ \text{Mass}$	–	417	± 925
$-12{,}43\ \text{Urea}_{10} + 21{,}85\ \text{Carcass mass}$	–	351	± 778
$-14{,}40\ \text{Urea}_{10} + 3{,}618\ \text{Mass} + 17{,}50\ \text{Carcass mass}$	–	357	± 814
$12{,}38\ \text{TOH}_{360} - 1201$	0,808	818	± 1762
$-21{,}24\ \text{TOH}_{360} + 22{,}14\ \text{Mass}$	–	432	± 952
$-9{,}603\ \text{TOH}_{360} + 22{,}86\ \text{Carcass Mass}$	–	427	± 942
$-15{,}43\ \text{TOH}_{360} + 10{,}45\ \text{Mass} + 12{,}47\ \text{Carcass mass}$	–	426	± 964
$16{,}11\ \text{TOH}_{5} - 967$	0,799	838	± 1805
$-32{,}87\ \text{TOH}_{5} + 24{,}07\ \text{Mass}$	–	421	± 929
$-18{,}99\ \text{TOH}_{5} + 27{,}98\ \text{Carcass mass}$	–	299	± 658
$-24{,}31\ \text{TOH}_{5} + 6{,}731\ \text{Mass} + 21{,}44\ \text{Carcass mass}$	–	287	± 649
$8{,}619\ \text{Mass} - 881$	0,909	585	± 1260
$13{,}48\ \text{Carcass mass} - 615$	0,931	509	± 1095
Non-carcass energy of combustion =			
$7{,}206\ \text{Urea}_{10} - 367$	0,833	311	± 673
$-5{,}257\ \text{Urea}_{10} + 5{,}649\ \text{Mass}$	–	112	± 248
$5{,}065\ \text{TOH}_{360} - 375$	0,888	244	± 525
$-5{,}382\ \text{TOH}_{360} + 6{,}873\ \text{Mass}$	–	115	± 254
$6{,}631\ \text{TOH}_{5} - 229$	0,889	243	± 523
$-7{,}396\ \text{TOH}_{5} + 6{,}870\ \text{Mass}$	–	133	± 294
$3{,}407\ \text{Mass} - 222$	0,952	160	± 344

References

A.O.A.C., 1970. Official Methods of Analysis of the Association of Official Analytical Chemists, 11th ed. Ed. by W. Horwitz. Washington. Ass. of Off. Anal. Chem.

CLARK, J.L., HEDRICK, H.B. & THOMPSON, G.B. 1976. Determination of body composition of steers by ^{40}K. *J. Anim. Sci.* 42, 352.

MEISSNER, H.H., VAN STADEN, J.H. & PRETORIUS, ELMA., 1980a. *In vivo* estimation of body composition in cattle with tritium and urea dilution. 1. Accuracy of prediction equations for the whole body. *S. Afr. J. Anim. Sci.*