The Ability of Sheep to Reach for Food Through Tombstone Barriers, as Affected by Position of Food, Body Weight and Body Dimensions

[1]Muhikambele* V.R.M., E. Owen[3], J. E. Owen[3] F.L. Mould[2] and L. A. Mtenga[1]

[1]Department of Animal Science and Production Sokoine University of Agriculture, P.O. Box 3004, Morogoro, Tanzania

[2]Department of Agriculture, University of Reading, Earley Gate P.O.Box 236,Reading RG6 6AT, UK.

[3]ADAS Bridgets, Martyr Worthy, Winchester SO21 1AP, UK.

Abstract

Two studies were undertaken to provide information on the ability of sheep to reach for food, similar to that for cattle fed through tombstone barriers. In the first study, twenty castrate and twenty non-pregnant, female unshorn Suffolk x Mule sheep (23 - 89 kg live weight) were trained to reach, through a vertical tombstone barrier, for concentrate meal placed on a horizontal platform attached to the barrier. The barrier allowed the neck to pass through, but not the shoulders. It was hypothesised that horizontal reach forwards (F, distance from mid-point of barrier to uneaten meal) and sideways (S, distance sideways from mid-point of barrier to uneaten meal adjacent to barrier) would be a function of height of platform above the floor and body size (M). Because of size, seventeen sheep (mean 34.6 kg) were unable to reach the meal when the platform height was 75 cm. Mean (s.e.) values for F at platform heights 0, 25, 50 and 75 cm were 43.91.03, 49.40.91, 47.00.96 and 27.01.27 cm respectively. Values for S were smaller, but followed a similar pattern (36.61.10, 43.50.80, 41.00.79 and 22.91.78 cm). Linear regression showed that F or S could be predicted from M (R^2 >0.5) or a combination of M and withers height (R^2>0.7) when platform heights were 25, 50 or 75 cm. Reach at 0 cm platform height was not related to body weight or linear dimensions. In the second study with unshorn Suffolk x Mule sheep, ten castrates and ten non-pregnant females (23 - 97 kg live weight) were trained to reach through the tombstone barrier for concentrate pellets 'glued', using molasses, onto a vertical plate. It was hypothesised that vertical reach (V, distance from floor to uneaten pellets) would be a function of distance between barrier and plate (20, 30, 40, 45, 50 cm), height of step (0, 14.2, 28.4, 42.6 cm) on which sheep placed their forelegs, and body size. With the exception of the largest sheep, most were unable to reach pellets either when the barrier-to-plate distance was 45 and 50 cm, or when the foreleg-step height was 42.6 cm. Mean (s.e) V values decreased with step height (e.g. at 0 cm step, 103.83.04, 96.23.23 and 82.14.37 cm, at 20, 30 and 40 cm plate distances respectively; at 20 cm plate distance, 103.83.04, 118.72.83 and 131.92.91 cm at 0, 14.2 and 28.4 cm step heights respectively). Linear regression of V on body weight and linear dimensions (e.g. withers height and rump height) showed high correlations (R^2>0.8). V could be predicted from either M (R^2>0.7) or a combination of rump height and withers height (R^2>0.9). The results confirm relationships found in a previous investigation with goats, but demonstrate that sheep have a smaller reach than goats. The data will facilitate the design of mangers for sheep with body dimensions in the range of those used.

Keywords: horizontal reach, vertical reach, sheep, tombstone barrier, body dimensions

*Corresponding author

Introduction

A previous study (Muhikambele *et al.*, 1998) with goats ranging from 13 to 67 kg body weight showed that ability to reach for food through a tombstone barrier, both horizontally and vertically, was a function of body size and position of food. Reach increased with size, irrespective of whether castrates or females were assessed. Horizontal reach increased as height of food platform was raised to 50 cm above floor level, but thereafter declined. Vertical reach decreased with distance of food from the barrier. but was improved when goats were allowed steps (up to a height of 28.4 cm) upon which to place their forelegs. The rationale for undertaking the study with goats was the absence of literature on reach, such as that for cattle fed through tombstone barriers (Versbach, 1970; Gjestang, 1983; Petchey and Hailu, 1993). Furthermore it was argued that reach information was needed for goats because of the increasing trend to practice indoor feeding and the consequent requirement for data to facilitate manger design.

A similar argument applies to sheep - the prevalence of indoor feeding is increasing and there is no published information on reach capacity. In the UK (Wooley, 1990) and elsewhere, sheep dairying is increasing. Furthermore, in the tropics housed systems are increasing due to intensification such as cut-and-carry feeding (e.g. Tanner *et al.*, 1995) and the need to integrate crop-animal enterprises (McIntire *et al.*, 1992). Housing is also being advocated to allow pasture regeneration following overgrazing (Ogle *et al.*, 1996).

The present study was therefore undertaken with sheep and was a sequel to the previous investigation of Muhikambele *et al.* (1998) with goats, using the same facilities and methods.

Materials and Methods

Horizontal reach assessments

A total of twenty non-pregnant, female and 20 castrate Suffolk x Mule sheep, varying in live weight (M) ranging from 23 to 89 with mean (s.d.) of 44.916.57 kg and accustomed to indoor housing and feeding, were used. Materials and procedure used for measuring body weight, linear dimensions and reach, as well as for data analyses, were identical to those in a previous study with goats, described by Muhikambele *et al.* (1998). The study was undertaken in April and May 1991, sheep having been shorn in June 1990.

Vertical reach assessments

A total of ten non-pregnant, female and ten castrate, Suffolk x Mule sheep (unshorn), varying in live weight (22.8 to 97.3 kg) with a mean (s.d.) of 54.624.30 kg and accustomed to indoor housing and feeding, were used. These were not the same animals as those measured for horizontal reach. The procedures used to measure vertical reach and record body weights, linear dimensions and statistical analyses were as described by Muhikambele *et al.* (1998).

Results

Horizontal reach

Due to their size, seventeen sheep (6 females, mean M, 34.8 kg, s.d. 9.9, range 23.7 to 45.8 kg; 11 castrates, mean M, 34.4 kg, s.d. 8.56, range 23.0 to 46.5 kg) were unable to reach the meal at the 75 cm feeding height. Data from these sheep were omitted from the analyses of variance after establishing that there was no difference in reach due to sex when data were analysed omitting the 75 cm feeding height. Using body weight as a covariate in the remaining sheep, analysis of variance of reach data where all feeding heights were involved also showed sex to be non-significant ($P>0.05$).

Sheep had longer reach, both forwards ($P<0.05$) and sideways ($P<0.05$) when feeding platform height was 25 cm compared to 0 cm, but there was a significant decrease ($P<0.05$) in reach between platform heights of 25 and 50 cm (Figure 1). For both forwards and sideways reach, raising the platform height to 75 cm reduced reach markedly ($P<0.001$) compared to all other heights. At all platform heights, forwards reach (F) was larger than sideways reach (S). Values of F (mean and s.e.) at 0, 25, 50 and 75 cm platform heights, respectively, were 43.9 (1.03), 49.4 (0.91), 47.0 (0.96) and 27.0 (1.27) cm. Similarly, values of S were 36.6 (1.10), 43.5 (0.80), 41.0 (0.79) and 22.9 (1.78) cm.

The coefficients of determination from the linear regression of horizontal reach, both forwards (F) and sideways (S), on body weight and linear dimensions were low (P>0.05) at 0-cm platform height (Table 1). However, at other platform heights, coefficients of determination were high (R^2>0.5) for body weight and rump height, and, except at 25 cm, also high for withers height, heart girth and shoulder width. Other linear dimensions were poorly correlated with reach. Table 2 gives models for predicting forwards and sideways horizontal-reach at different feeding-platform heights. Since the study showed very low correlations of reach with body size at 0-cm feeding height, models for predicting reach at this height could not be developed. R^2 values increased when withers height was included, instead of using body weight alone. Choice of body dimension in the model was based on the Cp statistic, using R^2 procedure of Statistical Analysis System Institute (1989). All models for predicting horizontal reach included body weight and withers height.

Vertical reach

Most sheep (7 females, 10 castrates) were unable to reach pellets, either when the barrier-to-plate distance was 45 and 50 cm or when the foreleg-step height was 42.6 cm. All data for these positions were therefore excluded from the analyses. For the remaining three plate-distances and three foreleg-step heights, five sheep (1 female, 4 castrates) were unable to reach pellets at some of the plate-distance/step-height combinations, these included two castrates which were disinclined to eat the pellets when the step height was increased to 28.4 or 42.6 cm. These sheep were also excluded from data analyses on the assumption that, as was the case in horizontal reach, there would be no difference in vertical reach due to sex. The analysis of variance showed that after correcting for body weight, there was no difference (P>0.05) in vertical reach due to sex. Vertical reach decreased (P<0.05) with each increase in distance between the barrier and the vertical plate, but increased (P<0.05) with each increase in foreleg-step height (Figure 2). Values of V (mean and s.e) at 20, 30 and 40 cm plate distances, respectively were 103.8 (3.04), 96.2 (3.23) and 82.1 (4.37) cm for 0 cm step, 118.7 (2.83), 111.4 (3.22) and 98.6 (4.05) cm for 14.2 cm step, and 131.9 (2.91), 122.9 (3.23) and107.7 (4.35) cm for 28.4 cm step. At each barrier distance, except 40 cm at step 28.4 cm, the increase in vertical reach approximated that of step height.

The coefficients of determination from the linear regression of vertical reach (V) on body weight and body linear dimensions, at each barrier-to-vertical plate distance and each foreleg-step height, were high throughout (Table 3). Table 4 presents models for predicting vertical reach at given barrier to vertical plate distances and foreleg-step heights. R^2 values were higher for a combination of rump height and withers height than for body weight. Choice of linear dimension was on the same basis as those in developing the horizontal reach models. All the models for predicting vertical reach included rump and withers heights.

Table 1: Coefficients of determination (R^2) from linear regression of horizonnal reach on body weight and linear body dimesions of sheep at four feeding heights

Height of feeding	Forwards reach (F)				Sideways reach (S)			
Platform (cm)	0	2	50	75	0	25	50	75
No of sheep (n)	40	40	40	23	40	40	40	23
Body weight	0.17	0.77	0.83	0.76	0.09	0.50	0.64	0.76
Heart girth	0.16	0.75	0.84	0.76	0.06	0.44	0.71	0.76
Neck-joint height	-0.03	0.15	0.29	0.06	-0.02	0.05	0.20	0.02
Withers height	0.17	0.60	0.83	0.75	0.04	0.37	0.64	0.72
Knee height	-0.02	0.16	0.26	-0.01	0.06	0.08	0.19	-0.03
Sternum height	0.00	-0.10	0.08	-0.02	-0.03	-0.02	0.03	-0.04
Rump height	0.17	0.72	0.86	0.79	0.07	0.52	0.68	0.81
Head length	0.27	0.47	0.53	0.68	0.15	0.27	0.69	0.67
Neck leghth	0.10	0.42	0.50	0.17	0.01	0.22	0.34	0.16
Body length	0.13	0.59	0.69	0.59	-0.00	0.27	0.41	0.54
Diagonal length	0.10	0.54	0.68	0.58	0.03	0.36	0.51	0.62
Neck width	0.05	0.40	0.49	0.30	-0.02	0.17	0.25	0.28
Shoulder width	0.16	0.62	0.72	0.63	0.04	0.35	0.51	0.65

Table 2: Models for predicitng forwards (F) abd sudeways (S) horizontal-reach (cm)

		Number of sheep (n)	$S_{x.y}$	R^2
Models based on live body weight, M (kg)				
Feeding height (cm)				
25	F=0.23M + 37.90	40	2.05	0.77***
50	F=0.28M + 32.24	20	2.04	0.83***
75	F=0.31M + 10.56	23	2.97	0.76***
5	S=0.15M + 35.77	40	2.50	0.50***
50	S= 0.21M + 30.18	40	2.59	0.64***
75	S= 0.45M + 0.97	23	3.95	0.79***
Best models based on M and withers height, WH (cm)				
0	F=0.19M + 0.14 WH + 30.97	40	1.81	0.87***
25	F=0.15M + 0.52 WH - + 6.31	20	1.81	0.87***
50	F=0.18M + 0.75 WH- + 10.31	23	2.36	0.86***
75				
25	S = 0.14M + 0.05WH + 33.14	40	2.47	0.67***
50	S = 0.12M + 0.4 WH + 10.35	40	2.47	0.67***
75	S = 29M + 89WH - 49.0	23	3.31	0.86***

Table 3: Coefficients of Determination (R^2) from linear regression of vertical reach on live on body weight and body dimensions at three foreleg step heights and three barrier distances from vertical plate.

Height of foreleg step (cm)	0	14.2	28.4
Barrier to vertical plate 20 cm (n=18)			
Body weight	0.82	0.80	0.80
Heart girth	0.83	0.81	0.82
Withers height	0.90	0.90	0.90
Rump height	0.96	0.96	0.97
Body lenglth	0.91	0.91	0.90
Diagonal length	0.84	0.82	0.82
Shoulder width	0.73	0.70	0.71
Barrier to vertical plate 30 cm (n=18)			
Body weight	0.80	0.79	0.79
Heart girth	0.81	0.80	0.80
Withers height	0.88	0.90	0.92
Rump height	0.94	0.96	0.97
Body length	0.90	0.90	0.89
Diagonal length	0.82	0.81	0.80
Shoulder width	0.69	0.68	0.68
Barrier to vertical plate, 40 cm (n=15)			
Body weight	0.71	0.66	0.70
Heart girth	0.72	0.63	0.69
Withers height	0.81	0.82	0.82
Rump height	0.91	0.89	0.92
Body length	0.86	0.84	0.83
Diagonal length	0.75	0.68	0.70
Shoulder width	0.59	0.53	0.59

Table 4: Models for predicting vertical (V) reach (cm)

		No.of sheep (n)	$S_{x.y}$	R^2
Models based on live body weight, M (kg)				
Barrier to vertical plate 20 cm				
Height of foreleg step (cm)	V=0.50M + 74.29	20	5.68	0.82***
	V=0.52M + 88.92	18	5.67	0.80***
0	V=0.53M + 101.52	18	5.82	0.80***
14.2				
28.4				
Barrier to vertical plate 30 cm		20	6.52	0.80***
0	V=0.54M + 64.27	18	6.51	0.79***
14.2	V=0.58M + 78.37	18	6.75	0.79***
28.4	V=0.59 + 89. 24			
Barrier to vertical plate 40 cm				
0	V=0.61M + 46.64	19	8.84	0.74***
14.2	V=0.76M + 54.26	18	10.22	0.73***
28.4	V=0.67M + 70.37	15	9.30	0.70***
Best models based on linear body dimenstions (cm)§				
Barrier to vertical plate 20 - 40 cm				
0	V=2.90RH- .11WH-1.08dϕ + 9.76	19	4.72	0.93***
14.2	V=2.31RH-0.21WH-1.11d+7.77	18	4.92	0.93***
28.4	V=2.60rh-0.51wh-1.21d+22.53	15	4.36	0.94***

§ Linear body dimensions viz: RH, rump height; WH, withers height.
ϕd is barrier to vertical - plate distance, 20, 30 or 400 cm

Table 5: Maximum reach (cm, predicted from body weight) of sheep(present study) and goats (Muhikambele *et.al.*, 1998) at different weights

Body weight (kg)	Forward reach (F)				Sideways reach (S)				Vertical reach		
	Height of feeding platform (cm)								Barrier - vertical plate distance (cm)♣		
	0	25	50	75	0	25	50	75	20	30	40
Sheep											
20	*	42.4	37.8	-	*	38.8	34.4	-	84.3	75.1	58.8
40	*	47.1	43.4	23.0	*	41.8	38.6	17.0	94.3	85.9	71.0
60	*	51.7	49.0	29.2	*	44.8	42.8	26.0	104.3	96.7	83.2
80	*	56.3	54.6	35.4	*	47.8	47.0	35.0	114.3	107.5	95.4
Goats											
20	44.9	47.3	43.7	-	40.2	43.2	40.7	-	97.8	91.0	81.4
40	53.3	55.7	54.5	37.4	47.2	50.4	50.1	33.0	112.2	106.0	97.8
60	38.7	64.1	65.3	51.2	54.2	57.6	59.5	46.0	126.6	121.0	114.2
80	70.1	72.5	76.1	65.0	61.2	64.8	68.9	59.0	141.0	136.0	130.6

* Values omitted beccause of low coefficients of determination

♣The values are for 0 - cm foreleg step height.

Discussion

The results for horizontal reach supported the hypothesis, reach increasing as feeding-platform height increased from 0 to 25 cm, and decreasing thereafter as platform height increased to 50 and 75 cm. The increase in reach on raising the feeding platform above floor level compares with an earlier study with goats (Muhikambele *et al.*, 1998) and with reach studies in cattle fed through tombstone barriers. (Versbach, 1970; Gjestang, 1983; Petchey and Hailu, 1993). In the study of Muhikambele *et al.* (1998) with goats, both forwards and sideways reach were higher at 25 cm than 0 cm platform height but were comparable at 25 cm and 50 cm platform heights. The results of the present study showing sheep to have larger horizontal reach forwards than sideways agrees with those of Muhikambele *et al.* (1998) for goats. Maximum forwards and sideways reach for goats were 47-67 and 40-58 cm respectively. The results for sheep also agree with those of Versbach (1970) with cattle. Versbach suggested maximum forwards and sideways reach to be 90-100 and 55 cm respectively. The ratio of maximum forward to sideways reach obtained in the present study with sheep (1.2:1) is intermediate between that reported for cattle (1.64:1-1.82:1; Versbach 1970), and that reported for goats (1.13:1; Muhikambele *et al.* 1998). This suggests that sheep are better able than cattle to twist their necks to feed, but are less able than goats.

The results for vertical reach also supported the hypotheses; reach decreasing with increasing distance between the barrier and the vertical feed-plate, and increasing with increasing foreleg-step height. At the outset of the study, the barrier-to-vertical feed-plate distances were chosen arbitrarily. However, Figure 2 suggests that the barrier to feed-plate distance should have been less than 20 cm for sheep to achieve maximum vertical reach. Figure 2 also shows that vertical reach was much increased if sheep placed their forelegs on steps. However, the increase in reach from increasing the step-height from 0 to 14.2 cm was more than that from 14.2 to 28.4 cm, indicating a limit to this method of increasing reach. Similar findings were obtained in the study with goats (Muhikambele *et al.*, 1998).

The results support the hypothesis that reach is a function of sheep size; R^2 values in Table 1 were0.5 or more (excluding 0 cm height), and in Table 3, 0.7 or more for linear regression of reach on body weight. The R^2 values from regression of reach on linear body measurements varied; although values for withers height, with the exception of reach at 25-cm height, were consistently high. The low correlation between reach and dimensions such as head length, neck length and neck-joint height was surprising as a correlation with these dimensions would be expected on account of their being components of reach as defined in the present study.

Although R^2 values of the models in Tables 2 and 4 increased if linear dimensions were included, R^2 values were only marginally improved over using body weight alone. Body weight would also be the preferred parameter in practice because of its ease of measurement compared to linear dimensions.

It is notable that R^2 values relating reach to body weight and linear measurements in the present study with sheep were substantially smaller than those for goats in the earlier study by Muhikambele *et al.* (1998). For example, in goats R^2 values relating body weight and horizontal forward reach were 0.87, 0.86, 0.88 and 0.85 the models at food platform heights of 0, 25, 50 and 75 cm respectively. Comparable R^2 values for sheep in the present study were 0.17, 0.77, 0.83 and 0.76. There is no obvious explanation for the lower R^2 values in sheep. The presence of wool in the sheep used may have contributed to the much lower values for reach compared to hair goats in the study of Muhikambele *et al.* (1998) (Table 5).

Table 5 demonstrates that the greater predicted reach of goats compared to sheep increased with body weight. For example, forward reach at a feeding-platform height of 25 cm above floor level was 0.12, 0.18, 0.24 and 0.29 greater for goats than sheep at live weights of 20, 40, 60 and 80 kg respectively. Similarly, predicted vertical reach, at a barrier-to-vertical plate distance of 30 cm and animals not using foreleg steps, was higher for goats compared to sheep by 0.21, 0.23, 0.25 and 0.27, at live weights of 20, 40, 60 and 80 kg respectively. Since goats and sheep are normally housed together in the tropics, the differences in capacity to reach for food through barriers need to accommodate differences in species and body size when designing mangers for them.

The present study demonstrates that the ability of sheep to reach for food through tombstone barriers, both horizontally and vertically, is a function of the position of the food and the size of sheep. The data will be of use in the design of mangers for sheep with body dimensions in the range of those used. The study also confirms the effect of position of food and body size obtained with goats in the earlier study of Muhikambele *et al.* (1998)

Acknowledgement

V.R.M. Muhikambele wishes to thank the Norwegian Agency for Development Co-operation (NORAD) for a postgraduate scholarship. Professor R. Curnow of the Department of Applied Statistics, The University of Reading, is gratefully acknowledged for statistical advice.

References

Gjestang, K. 1983. Feeding table geometry for dairy cows. *Transactions of American Society of Agricultural Engineers* **26**:890-892.

McIntire, J., Bourzat, D. and Pingali, P. 1992. *Crop-livestock interaction in Sub-Saharane World Bank, Washington D.C., 246 pp.*

Muhikambele, V.R.M., Owen, E., Owen, J.E. and Mtenga, L.A. 1998. Capacity of goats to reach for food through tombstone barriers, as affected by position of food, body weight and body dimensions. *Animal Science* **66**:415-422

Ogle, R.B., Wiktorsson, H. and Masaoa, A.P. 1996. Environmentally sustainable intensive livestock systems in semi-arid Central Tanzania. *Proceedings of The Tanzania Society of Animal Production* **20**:90-96.

Petchey, A. M. and Hailu, T. 1993. The effect of varying cattle trough height on their reach and food wastage. *Animal Production* **56**:457.

Statistical Analysis System Institute. 1989. SAS/*STAT User's guide, Version 6, Fourth edition, volume 2.* SAS Institute, Inc., Cary, NC.

Tanner, J.C. Owen, E. Winugroho, M. and Gill, M. 1993. Cut and carry feeding of indigenous grasses in Indonesian smallholder sheep production. In: *Proceedings VII World Conference on Animal Production. Edmonton, Canada*, **3**: 102-103 (Abstr.)

Wooley, H. 1990. Sheep dairying. *The sheep farmer*, **9** (9): 26-27

Versbach, M. 1970. Technik und Verfahren der Einzeltierfutterung im Rindviehlaufstall [Techniques and procedures for feeding individual animals in loose-housed cattle]. *KTBL Berichte uber landtechnik no. 239.*