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Rate of Passage of Digesta in the Rumen in Holstein-Friesian and Hereford Heifers Grazing on Kikuyu *(Pennisetum clandestinum)* Pasture

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Abstract: Hereford and Holstein-Friesian heifers were grazed on kikuyu pasture in late summer. There were six animals in each breed group. Half of the heifers in each breed were also offered 1 kg maize meal supplement per day. Ruminal fractional outflow rate was estimated using iterative procedures by fitting a two and a multi-compartmental mathematical model on fecal marker excretion data after a pulse dose of chromium oxide by mouth. The first fecal sample was collected by rectal grabbing after 8 h and thereafter at 4 h intervals up to 48 h, at 6 h intervals up to 80 h and finally, one last sample was taken at 96 h. Fractional outflow rate in the rumen using the two-compartment model was estimated at 0.069±0.0196 and 0.063±0.0167 for the Herefords without supplement and on supplement, respectively and 0.090±0.0502 and 0.061±0.0151 for the Holstein Friesians without and on supplement also, respectively. Estimates from the multi-compartment model were 0.056±0.0090 and 0.062±0.0089 for the Herefords without supplement and on supplement, respectively and 0.0607±0.0134 and 0.0559±0.0057 for the Holstein Friesians without and on supplement also, respectively. There were no significant ($P>0.05$) breed or supplement effects on fractional outflow rate in the rumen.

Key words: Holstein-Friesian, Hereford, kikuyu, fractional outflow rate

INTRODUCTION

Exotic dairy breeds are dominant in commercial milk production in most tropical regions. Nutrition is, however, probably the major restriction on their productivity. Nutritionists generally recommend that solutions to the nutritional limitations in milk production in developing countries lie in the production of adequate and high quality forage crops. Tropical pastures, however, tend to be of relatively low nutritive value compared to temperate species due to partly genetic and partly environmental effects[1].

Evidence of poor growth performance on kikuyu pasture in Holstein-Friesian heifers compared to breeds of similar character has been apparent in trials by Allwood[2] and Horne[3]. Performance seems to be only enhanced at the added cost of energy supplements. In breeds of similar character, the same supplementary regimes result in less dramatic changes in growth[3]. On pasture, breed differences in the growth are likely to be restricted to factors affecting either intake and or digestion in the gastrointestinal tract. It is unlikely however that differences in the rumen environment with regards physiological factors affecting digestive capacity can result in marked differences in performance. Such breed differences have been found to be small and usually insignificant[4,5]. It is likely however that variation in intake can largely explain the observed differences in comparison with the Hereford. This was confirmed by Horne[3], who found significantly lower intake in the Holstein-Friesian, which was about 55% lower than Herefords. On a forage diet, where intake is likely to be limited mainly physically through gut capacity, differences in digesta movement within the reticulorumen may significantly affect nutrient flow due to a direct effect on dry matter intake. In comparisons between Brahman crosses and purebred Hereford steers, Kennedy[6] found more extensive digestion in the rumen in crossbreeds resulting from longer retention time. Since this was a restricted diet, differences in weight gain could have derived from either extensive digestion in the rumen or from differences in the efficiency of synthesis of body proteins. Lower passage in this case could be a natural adaptation to a diet both poor in quality and limited in supply. On an *ad lib* diet however, differences in retention time suggested above, could result in

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significantly less total dry matter intake and thus lower growth rates. Smuts *et al.*[7] observed differences in retention time in the rumen in sheep, which were highly correlated with both intake and wool production. The lower intake apparent in Holsteins could be due to restricted flow of digesta through the rumen, arising probably inadvertently from intensive selection on concentrate diets.

The objective of this study was to investigate relative fractional outflow rates between Holstein-Friesian and Hereford heifers on kikuyu pasture.

MATERIALS AND METHODS

Experimental design: The experiment was conducted in late summer (March/April) in the KwaZulu–Natal mistbelt of South Africa. Six Hereford heifers and the same number of Holstein-Friesian heifers aged about one and half years old were randomly selected. The breed groups were then split into two equal groups, one on a maize meal supplement (HS) and (HFS) for the Herefords and Holstein-Friesians, respectively and the other on kikuyu alone (H) and (HF) also, respectively. The animals were grazed on a continuous grazing programme on 6.25 ha of kikuyu pasture. The maize meal was dispensed using a solar powered computerized automatic individual feeding system fitted on a mobile feed wagon. The machine was programmed to dispense 1 kg of supplement in each 24 h cycle, divided into two 12 h sub cycles. Due to intermittent power failure as a result of the poor weather conditions prevailing prior and during the experimental period, average actual supplement intake was 539±48 and 267±27 g of feed per day for the (HS) and (HFS) groups, respectively. The Holstein - Friesians tended to be shy of the mobile feed wagon, despite a prolonged period of access to the wagon prior to the experimental period.

Marker administration and feces collection: A 10 g capsule of chromium oxide was administered to each animal through the mouth at 1100 h. The first fecal sample was collected by rectal grabbing after 8 h and thereafter at 4 h intervals up 48 h, at 6 h intervals up to 80 h and finally, last one sample was taken at 96 h. An attempt was made at each sampling to avoid feces that could have been stored in the rectum for long periods by moving the hand as far anteriorly as possible. The samples were heated to dryness at 100°C and milled through 0.5 mm screen before the determination of chromium oxide.

Mathematical and statistical analyses: Non-linear iterative procedures using the SAS[8] statistical package were used to fit two compartment models by Dhanoa *et al.*[9] (Equation I) and Blaxter *et al*[10]. (Equation II). The model of Blaxter *et al.*[10] was analyzed using the interpretation of Grovum and Williams[11] in which k1 and k2 represent events in the rumen and in distal compartments, respectively which is same as interpretation was adopted by Dhanoa *et al.*[9].

Models:

$$\ln \frac{dX_N}{dt} = \ln A - k1t - (N-2)e^{-(k2-k1)t} \qquad \text{(Model I)}$$

Where, X is the marker concentration in feces at time t, N is the number of compartments, k1 and k2 are rate constants and A is scale parameter dependent on k1, k2 and N.

$$y = Ae^{-k1(t-TT)} - Ae^{-k2(t-TT)} \qquad \text{(Model II)}$$

Where, y and are adjusted marker concentration in fecal dry mater at time t, k1 and k2 are rate constants and TT is a calculated time in hours for first appearance of marker in feces.

A general linear model was then fitted on k1 values to investigate treatment effects on k1 using the SAS[8] statistical package.

RESULTS AND DISCUSSION

The models for fecal marker excretion fitted the data sets well and that criteria suggested by Dhanoa *et al.*[9]. The criteria include no systematic under or overestimation of parts of the curve, biologically acceptable estimates and convergence to a repeatable solution for different initial parameter estimates. The model parameters are shown in Table 1. The multi-compartment model (model I) tended generally to consistently predict lower values of k1. This was consistent with observations by Dhanoa *et al.*[9]. There was however significant correlation between the predicted k1. The linear regression equation with the parameter k1 from two compartment model (model II) as the dependent variable was:

Y = -0.053 (SE 0.0436) + 2.112 (SE 0.735)x
(residual error 0.02136), with $R^2 = 0.453$.

Mean fractional outflow rate in the rumen using the two-compartment model was estimated at 0.069±0.0196 and 0.063±0.0167 for the Herefords without supplement and on supplement, respectively and 0.090±0.0502 and 0.061±0.0151 for the Holstein Friesians without and on supplement also, respectively. Estimates from the multi-compartment model were 0.056±0.0090 and 0.062±0.0089 for the Herefords without supplement and on

Table 1: Model parameters

		Parameters: Model I				Parameters: Model II			
Treatment groups	Animal number	A	K1	k2	N	A	K1	K2	TT
HS	1	24471.48	0.07	0.19	9.40	424514.84	0.08	0.08	7.3
HS	2	17245.47	0.06	0.19	11.69	20542.99	0.06	0.08	7.4
HS	3	28546.85	0.05	0.18	5.53	3898.70	0.05	0.34	9.2
H	4	7492.99	0.05	0.36	29.76	28537.25	0.08	0.011	7.3
H	5	17241.74	0.07	0.19	10.82	38765.09	0.08	0.09	8.1
H	6	10984.30	0.60	0.30	21.67	6343.47	0.05	0.19	6.1
HFS	7	11920.27	0.05	0.33	32.38	12541.69	0.06	0.12	7.5
HFS	8	12072.01	0.06	0.25	17.71	115935.12	0.08	0.08	8.3
HFS	9	13624.53	0.06	0.33	44.78	5301.32	0.05	0.37	11.2
HF	10	18465.65	0.08	0.45	50.05	384322.75	0.14	0.15	7.6
HF	11	10877.08	0.06	0.24	17.81	345376.99	0.08	0.08	8.2
HF	12	10969.65	0.05	0.22	15.78	5106.16	0.04	0.20	10.5

supplement, respectively and 0.0607±0.0134 and 0.0559±0.0057 for the Holstein Friesians without and on supplement also, respectively. There were no significant (P>0.05) breed or supplement effects on fractional outflow rate in the rumen.

The lack of a breed effect in this trial invalidates the argument that differences in the flow of digesta in the rumen could be largely responsible for lower intake of kikuyu pasture in the Holstein-Friesians. It is necessary however, to highlight critical limitations regarding methods of estimating compartmental flow rates such as used in this experiment. Between animal variation from a review of many experiments using various methods in estimating retention times in single compartments of the gut revealed coefficients of variation averaging as high as up to 24%[12]. Though lower, within animal coefficients of variation averaged about 15%. The magnitude of variability of mean retention times necessarily has implications on the experimental design. In many studies in which the effects of experimental treatments on mean retention time, in which the expected results were not found, the problem could be failure to sufficiently allow for this variability[12]. In this experiment, between animal coefficients of variation in k1, ranging from 16.4-41.2% for model I and model II, respectively were obtained. Although two methods were used to improve on the experimental design, this magnitude of variation is probably still indicative of the need to have used a larger number of animals. Another criticism on the design of this experiment could be the physical form in which chromium oxide was administered. Chromium mordents[13] are commonly used to measure 'absolute' outflow rate. In this experiment the use of chromium oxide in capsular form could have encouraged migration of marker from digesta particles to the liquid phase. It can still be argued however, that the objective of estimating relative instead of 'absolute' fractional outflow rates as would be obtained with chromium mordants, was consistent with the observed magnitude of the disparities in intake between the breeds[2,3]. Similarly, it can be argued that the sample size used was also sufficient to capture the expected differences in outflow rate. Thus, all the potential limitations highlighted above could not have completely overridden the expected differences in fractional outflow rate, if such differences existed to the magnitude that can adequately explain the differences in performance.

The unexpected lack of response in fractional outflow rate to supplementation on k1 especially in Herefords, which had a relatively higher concentrate intake, could have resulted from the intermittent maize meal dispensed by the mobile feed wagon due to power failure resulting from the incessant rainfall. Thus, at the critical times, supplement intake was probably not high and consistent enough to markedly influence rumen kinetics.

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