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Influence of Improved Roughage Quality and Period of Meal Termination on Digesta Load in the Digestive Organs of Goats

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***Abstract*—**Ruminants are known to relish roughage for productivity but the effect of its quality on digesta load in rumen, omasum, abomasum and other distal organs of the digestive tract is yet unknown. Reticulorumen fill is a strong indicator for long-term control of intake in ruminants. As such, the measurement and prediction of digesta load in these compartments may be crucial to productivity in the ruminant industry. The current study aimed at determining the effect of (a) diet quality on digesta load in digestive organs of goats, and (b) period of meal termination on the reticulorumen fill and digesta load in other distal compartments of the digestive tract of goats. Goats were fed with urea-treated hay (UTH), urea-sprayed hay (USH) and non-treated hay (NTH). At the end of eight weeks of a feeding trial period, upon termination of a meal in the morning, afternoon or evening, all goats were slaughtered in random groups of three per day to measure reticulorumen fill and digesta loads in other distal compartments of the digestive tract. Both diet quality and period affected ($P < 0.05$) the measure of reticulorumen fill. However, reticulorumen fill in the evening was larger ($P < 0.05$) than afternoon, while afternoon was similar ($P > 0.05$) to morning. Also, diet quality affected ($P < 0.05$) the wet omasal digesta load, wet abomasum, dry abomasum and dry caecum digesta loads but did not affect ($P > 0.05$) both wet and dry digesta loads in other compartments of the digestive tract. Period of measurement did not affect ($P > 0.05$) the wet omasal digesta load, and both wet and dry digesta loads in other compartments of the digestive tract except wet abomasum digesta load ($P < 0.05$) and dry caecum digesta load ($P < 0.05$). Both wet and dry reticulorumen fill were correlated ($P < 0.05$) with omasum ($r = 0.623$) and ($r = 0.723$), respectively. In conclusion, reticulorumen fill of goats decreased by improving the roughage quality; and the period of meal termination and measurement of the fill is a key factor to the quantity of digesta load.

***Keywords*—**Digesta, goats, meal termination, reticulorumen fill.

I. Introduction

ALTHOUGH hunger is a distressing factor that primarily influences intake of feed and time spent eating by animals, feeds with good colour, nice aroma and pleasant taste (pre-ingestive attributes) do evoke more consumption as well and even makes intake more pleasurable to animals [1]. Likewise, nutritive value, rumen fill and toxicity (post-ingestive consequences) on the other hand, determines when animals stop eating.

Invariably, reticulorumen fill is a key factor to ruminant productivity and the extent of dry matter intake is the dominant process for assessing it. In forage-fed animals, processes that occur in the rumen play a determinant role in the amount and types of nutrients absorbed and in the control of dry matter intake [2]. Besides, the reticulorumen size of most herbivores increases isometrically with their body size and its maximum capacity in concert with metabolic demand determines the fill and retention time with a particular diet [3]. Hence, body size or maturity of ruminants [4] and some other factors such as availability of essential nutrients in feed [5] and time of feeding [6], determine the reticulorumen fill.

The objectives of this study were: to determine the effect of feed quality on rumen fill in goats; to evaluate the effects of the nutritional quality of roughages and period of meal termination on reticulorumen fill and digesta load in other distal compartment of the digestive tract of goats.

The hypotheses were that rumen fill will increase with increasing nutritional quality and that rumen fill will be similar upon meal termination, irrespective of period of meal termination: morning, afternoon or evening.

II. Materials and Methods

Procedures used on goats were approved by Animal Research Ethics Committee (AREC) of University of Kwazulu-Natal, South Africa and accorded ethical clearance certificate, with reference number: AREC (081/14/Animal).

A. Study Location

The study was carried out at Ukulinga Research Farm of the University of KwaZulu-Natal, Pietermaritzburg, in the subtropical hinterland of KwaZulu-Natal Province, South Africa. The study site lies on the geographical coordinates 30° 24' S and 29° 24' E at an altitude of 700 m. Mean annual rainfall is approximately 735 mm, falling mostly in summer, between October and April. Maximum and minimum mean annual temperatures are 25.7°C and 8.9°C, respectively. In extreme conditions, summer temperatures may be above 32°C with minimum temperatures as low as 3°C at night in winter.

B. Experimental Design and Feeding Management

Eighteen experimental goats were randomly divided into two groups comprising of nine light weight goats (12-23 kg)

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and nine heavy weight goats (25-40 kg). Each group was randomly allotted to three treatment feeds, which were UTH, USH and NTH. Fresh water and salt licks containing trace minerals (calcium = 120 g/kg, manganese = 1200 mg/kg, copper = 200 mg/kg, cobalt = 1 mg/kg, sodium = 10 g/kg, zinc = 1200 mg/kg) were made available at all time. Feed was dispensed to goats ad-libitum at 0800 h and at 1500 h. An adaptation of 10 days was allowed to familiarize animals with the new feeding system and feed, to observe any side effect from possibly the UTH or USH. Thereafter, 63 days feeding trial was done and animal behaviour was observed to note meal termination times in the morning, afternoon and evening so as to establish the likely time reticulorumen fill (RF) would be measured. Three goats, randomly selected from one of the three treatments, were slaughtered during the morning, afternoon or evening.

C. Slaughtering Procedure

Slaughtering was carried out during week 9 and week 10. At the end of the experimental trial, goats were randomly selected from one of each of the treatments for slaughtering in batches of three goats/day in the morning, afternoon or evening for reticulorumen fill measurement. The fill of other digestive organs was also assessed. The animals were transported in the farm's vehicle from livestock section to the abattoir at the Ukulinga Research farm each day between 1000 h and 1100 h in the morning, between 1400 h and 1530 h in the afternoon or between 1930 h and 2100 h in the evening following pre-slaughtering weight measurement of the selected animal on an electronic weigh-scale. Immediately afterwards, the animals were slaughtered by stunning with electrical stunning machine and then severed with a knife to let out blood. The entire gut was removed from the carcass, and ends of reticulorumen, omasum, abomasum, small intestine, large intestine, and caecum and colon were identified and tied to avoid mixing of digesta contents. Each compartment was then emptied completely by scraping the contents into a foil container. The RF and other digesta contents were weighed to the nearest gram on a portable electronic scale (Mettler Toledo Spider 2, 1-15 kg). The fill of every compartment was pre-dried in a forced-air oven at 700 °C until their mass was constant.

D. Chemical Analyses

After pre-drying, samples of rumen fill (RF) and other digesta contents were instantly weighed, sub-sampled (200 g to 300 g) and ground to pass through 1 mm sieve and stored in airtight containers. All samples of feed were ground to pass through 1 mm sieve. Duplicate samples of each of 3 treatment feeds UTH, USH and NTH fed to the goats were analyzed for dry matter (DM), organic matter (OM), crude protein (CP) [7], neutral detergent fibre (NDF), acid detergent fibre (ADF) [8]. PerkinElmer series 11 CHNS/O analyzer was used to determine nitrogen content according to [7], and a conversion factor 6.25 was used to calculate CP to standard Kjeldahl value (Nx6.25). Also, ANKOM fibre analyzer was used to determine NDF and ADF. The NDF content was determined without a heat stable alpha amylase.

E. Statistical Analysis

All results were presented as mean ± SE and analysed with SAS (2013) [9]. The model used was:

$$\boldsymbol{Y_{ijkl} = \mu + S_i + P_j + (SP)_{ij} + BW_k + \varepsilon_{ijkl}}$$

where, Y_{ijkl} is the observation, μ is the overall mean common to all observation, S_i is the effect of diet, P_j is the effect of time, $(SP)_{ij}$ is the interaction between diet & time and ε_{ijkl} is the residual error. Time was declared as a repeated measurement. Pearson correlation analysis (SPSS) was used to determine the relationships between RF and other digesta contents, and among the digesta contents.

III. Results

TABLE I
CHEMICAL COMPOSITION (G/KG) OF UTH, USH AND NTH

Diets	UTH	USH	NTH
DM	904	920	923
OM	70	83	89
CP	75.6	47.5	20.0
NDF	723	723	735
ADF	632	592	581

TABLE II
DIET EFFECT ON WET AND DRY RETICULORUMEN FILL, OMASAL DIGESTA LOAD AND ABOMASUM DIGESTA LOAD (G) OF GOATS

Diets	UTH	USH	NTH	*RMSE*	P Value
Wet matter					
Reticulorumen	5004	5479	6410	496.9	0.0282
Omasum	314	468	322	76.5	0.0133
Abomasum	214	99	230	57.4	0.0110
Dry matter					
Reticulorumen	680	1016	972	216.2	0.0538
Omasum	78	110	78	23.4	0.0916
Abomasum	14	7	31	9.2	0.0492
Wet matter					
Small intestine	36	64	88	54.2	0.5079
Large intestine	311	377	322	82.2	0.3969
Caecum	375	415	605	94.7	0.0667
Colon	228	253	278	58.1	0.5961
Dry matter					
Small intestine	7	5	10	4.3	0.5156
Large intestine	54	134	95	153.6	0.6735
Caecum	58	62	124	23.0	0.0264
Colon	72	76	107	24.6	0.3233

IV. Effects of Roughage Quality on Wet and Dry Digesta in the Reticulorumen, Omasum, Abomasum and Other Distal Organs

A. Wet Digesta in Proximal Organs

Inclusion of urea to feed either by treatment or spraying was accompanied by a progressive decline ($P<0.05$) in the fill; consequently, the quality of diets negatively influenced reticulorumen fill of goats. Thus, reticulorumen fill decreases with improved roughage quality. Omasal digesta load of USH

was larger than UTH (P<0.01), while abomasum digesta of USH was less than UTH (P<0.01) and NTH (P<0.05). Both digesta load in omasum and abomasum were influenced by the diet quality (P<0.05).

B. Dry Digesta in Proximal Organs

Diets had similar (P>0.05) dry reticulorumen fill and digesta load of omasum but affected (P<0.05) the digesta in the abomasum. Abomasum digesta of goats fed USH was less (P<0.05) than NTH and the NTH value was larger (P<0.05) than UTH. Diet had no effect on the digesta load of the distal organs of the GIT either in dry or wet form.

C. Dry and Wet Digesta in Distal Organs

Diet quality affected (P<0.05) digesta load in caecum in the order: NTH>USN>UTH. All other distal organs had similar digesta irrespective of diet consumed.

V. Effects of Period of Meal Termination on Dry Reticulorumen Fill, Omasal Digesta Load and Abomasum Digesta in Goats

A. Wet Digesta in Proximal Organs

The period of meal termination affected (P<0.05) both wet reticulorumen fill and abomasum digesta load. Reticulorumen was higher (P<0.05) in the evening than afternoon while RF for both morning and afternoon were similar. Abomasum digesta load was lower (P<0.05) in the evening compared to morning but were similar for both afternoon and evening.

B. Dry Digesta in Proximal Organs

Period did not influence rumen fill and digesta loads of the omasum and abomasum. Amazingly, all dry values of RF, ODL and abomasum digesta load were similar (P >0.05) for all feeds.

C. Dry and Wet Digesta in Distal Organs

Trends of wet digesta load in other distal compartments of the gastro intestinal tract comprising small intestine, large intestine and colon were (P>0.05) independent of the period of meal termination but declined (P<0.05) with time from morning to afternoon and till evening except in the caecum. However, differences among feeds approached significance (P=0.0507) only in wet colon. Differences among dry caecal digesta were significant (P<0.01) in the order: Morning > afternoon = evening.

VI. Correlation between Wet and Dry Digesta Along the Git

Rumen fill was positively correlated with omasum (P<0.01), large intestine (P<0.01), caecum (P<0.01) and colon (P<0.01). Likewise, ODL was also positively correlated with the small intestine (P<0.01), large intestine (P<0.01) and colon (P<0.05). Abomasum digesta load was only correlated positively with caecum (P<0.05). While caecum load was positively correlated with colon (p<0.01), the large intestine was also correlated positively with caecum (P<0.01) and colon (P<0.05).

In dry form, reticulorumen fill was positively correlated with omasum (P<0.01) and colon (P<0.05); the abomasum digesta load with caecum (P<0.05) and caecum content with colon (P< 0.05) but digesta in other compartments were not correlated.

TABLE III
Period Effect on Wet and Dry Reticulorumen Fill (G), Omasal Digesta Load (G) and Abomasum Digesta Load (G) of Goats

Diets	Morning	Afternoon	Evening	*RMSE*	Period Effects
Wet matter					
Reticulorumen	5481	5274	6139	496.9	0.0424
Omasum	369	361	375	76.5	0.9569
Abomasum	266	140	138	57.4	0.0367
Dry matter					
Reticulorumen	797	819	1052	216.2	0.2129
Omasum	75	94	97	23.4	0.5332
Abomasum	22	17	12	9.2	0.3890
Wet matter					
Small intestine	102	45	42	54.2	0.3854
Large intestine	376	335	300	82.2	0.5596
Caecum	573	426	395	94.7	0.1146
Colon	258	299	202	58.1	0.0507
Dry matter					
Small intestine	13	5	5	4.3	0.0894
Large intestine	96	63	124	153.6	0.7918
Caecum	125	61	58	23.0	0.0092
Colon	90	100	65	24.6	0.1037

TABLE IV
CORRELATION MATRIX OF WET AND DRY RETICULORUMEN FILL AND DIGESTA LOADS IN DISTAL COMPARTMENTS OF THE GIT OF GOATS

Compartments	Colon	Caecum	Large intestine	Small intestine	Abomasum	Omasum
Wet digesta loads						
Colon	1.00					
Caecum	0.60**	1.00				
Large intestine	0.71**	0.54*	1.00			
Small intestine	0.17	0.34	-0.04	1.00		
Abomasum	0.09	0.48*	0.10	0.08	1.00	
Omasum	0.51*	0.62**	0.69**	0.13	0.22	1.00
Reticulorumen	0.64**	0.73**	0.60**	0.04	0.29	0.62**
Dry digesta loads						
Colon	1.000					
Caecum	0.52*	1.00				
Large intestine	-0.10	0.29	1.00			
Small intestine	0.09	0.30	0.08	1.00		
Abomasum	0.33	0.55*	0.12	0.20	1.00	
Omasum	0.41	0.27	0.23	-0.08	0.20	1.00
Reticulorumen	0.50*	0.44	0.22	0.01	0.11	0.72**

VII. DISCUSSION

A. Digesta Load in the Reticulorumen and Other Organs of the GIT

Unlike [10] who reported little variation in reticulorumen fill at a longer time after meal termination, reticulorumen fill measurement in goats fed UTH, USH and NTH upon termination of meals differed. This variation was probably due to different nutritional quality of roughages [11], [12]. This variation in the reticulorumen fill was affected by diet quality, dry matter intake and water intake which may be moisture content of feed, metabolic water or drinking water, and it is still in contrast with previous findings [5], [13], [9].

Wet reticulorumen fill of goats fed UTH was less than that of goats fed NTH and could be the result of fast rate of degradation due to urea treatment of hay [14]. It is possible that improved quality of roughage increases microbial mass and activity eliciting greater degradation of roughage, as witnessed in high rate and effective DM disappearance, possibly reducing the retention of feed in the reticulorumen [15]. Invariably, reticulorumen fill was decreased with improved roughage quality. On the contrary, dry reticulorumen fill of goats fed UTH was only less than that of goats fed USH and not NTH. This signals to the possible fact that rumen fluid in the reticulorumen digesta load of goats fed NTH was rather higher than those of UTH and USH, more so, that the dry matter intake of the two feeds were higher than NTH. However, both wet and dry digesta in the reticulorumen, omasum and abomasum followed a decreasing trend reinstating the result in all treatment feeds UTH, USH and NTH in the same order.

Period of measurement of reticulorumen fill of goats and digesta in other compartments was also significant. Wet reticulorumen fill of goats measured in the evening was larger than in the afternoon, which was similar to that of the morning. But on the contrary, wet abomasum load in the morning was larger than evening, which was similar to afternoon. Wet reticulorumen fill was strongly related to omasum positively. It also implied that as the fill of the reticulorumen increases, omasal digesta load also increases (r= 0.623). Besides, wet reticulorumen fill of goats has a strong positive relationship with digesta loads of all distal compartments, except the abomasum and small intestine. It simply means that for every increase in the weight of the fill of reticulorumen, there is a corresponding and resultant increase in the weights of digesta load in omasum, large intestine, caecum and colon. Invariably, there are predictable relationships between wet reticulorumen fill and digesta loads in these distal compartments.

The wet omasal digesta load was positively correlated with the colon, caecum and large intestine, so its value could be invariably used to predict the expected values in these distal compartments having unravelled that the more it increases, the more the contents of these compartments would increase. Amazingly, abomasum load both in wet and dry form was positively correlated with the caecum digesta load and could apparently be used for its prediction, as increase in its value leads to a corresponding increase in caecum digesta load [16]. There seems to be an inverse relationship between the wet digesta load of the large intestine of goats in relation to the colon and the dry digesta load of the large intestine of goats in relation to the colon as well, since the former was significant and positively correlated (r= 0.706) with the colon, while the later was not significant and negatively correlated (r= -0.097) with the colon. Hence, increase in wet digesta load of the large intestine leads to an increase in digesta load of the colon and decrease in dry digesta load of the large intestine leads to increase in dry digesta load of the colon as well.

VIII. CONCLUSION

Improved nutritional quality of roughages initiated with urea treatment or spray, significantly improved the quality of roughage. It reduced the reticulorumen fill of goats. Digesta loads in omasum, abomasum and other distal compartments of the GIT were affected. The period (morning, afternoon or evening upon meal termination) also affected the

reticulorumen fill of goats. It is therefore postulated that reticulorumen fill reduced with improved diet quality, becomes larger in the evening and can be predicted via digesta load in other distal compartments.

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