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Removal of sorghum stover from feed choices has no confounding effect on the quantity and quality of diets selected by group or individually fed sheep

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ABSTRACT

The study determined the effect of reducing dietary ingredients and group feeding on diet selection, nutrient intake and digestibility in choice-fed sheep. Three feeds comprising of veld hay (VH), sorghum stover (SS) and maize stover (MS) were offered ad-libitum while lucerne hay (LH) and bean straw (BS) were offered at restriction. Twelve sheep were allocated into three groups (i) group-fed in 3 sheep per pen, (ii) individually fed and, (iii) individually fed with SS exclusion. Sheep were rotated across the groups in four periods of 10 days. Diet selected, intake, refusals, spillages and faeces were monitored for seven days. The proportion of BS and LH consumed did not differ between group-fed and individually fed sheep with or without SS inclusion. Intake of MS and SS was lower in individually fed sheep while intake of VH was higher ($p < 0.05$). The proportion of BS and MS selected among individually fed sheep was similar with or without SS inclusion ($p > 0.05$). Diet selection was influenced by group feeding, but not the removal of SS. The scarcity of one dietary component may not result in the selection of undesired but available feeds if the quality is similar or poorer to the absent feed.

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Introduction

Ruminants grazing in rangelands experience reduced feed intake particularly during the dry seasons when adequate quantities of high-quality herbage to meet their nutritional requirements are scarce (Pulina et al. 2013). This is usually aggravated by land use and management factors such as overgrazing, soil erosion and the effects of climate change (Salem and Smith 2008). In most extensive systems, farmers rely on the utilization of crop residues to supplement available forages to meet animal requirements for production (Mutimura et al. 2015). The intake of pasture, shrubs and crop residues varies throughout the year depending on several factors which may include pasture availability, accessibility and quality (Moore and Jung 2001) and the presence of plant secondary metabolites, aside from animal factors (Castro and Fernandez-Nunez 2016). Often, animals avoid plants that contain a high concentration of anti-nutritional factors that can reduce their performance or affect their health (Brunsvig et al. 2017). Crop residues such as straws are characterized by high lignin and low crude protein content, and usually resulting in reduced feed intake (Meyer et al. 2010).

There are constraints in determining feed intake and subsequently, diet selection by ruminants grazing in rangelands or when different feeds are on offer to animals indoors (Osoro et al. 2013; Mkhize et al. 2014). It is not clear if an animal having the same feed choices or with one feed absent in feed ingredient choices, will consume and select diets of the same quantity or quality. Furthermore, the herd-effect when animals are fed in a group as compared to feeding individually may affect such diet selection behaviour by animals. Diet selection describes the decisions of animals with regard to feed, ingredient and plant part they choose (Basha et al. 2012; Pulina et al. 2013). It is therefore important to determine diet selection, intake and composition of forage consumed by ruminants. This will help improve the management of available feeds for ruminants among resource-limited farmers through better exploitation of alternative feed sources i.e. stovers to sustain production. It was hypothesized that group versus individual feeding, and the absence of sorghum stover from feed choices has no effect on subsequent diet selection, intake and nutrient digestibility in choice-fed sheep. Therefore, the objective of this study was to determine the effect of group versus individual feeding and the presence or absence of Sorghum stover on diet selection, intake and nutrient digestibility in choice-fed sheep.

Materials and methods

The protocol was approved by the Animal Research Ethics Committee via approval number [BLINDED FOR PEER REVIEW]. Twelve clinically healthy male Merino sheep with a mean weight of 29.7 ± 4.63 kg and an age of 24 months were housed in pens with concrete floors and iron roof and used for this trial. During a 10-day adaptation period, all sheep

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were grouped-fed with maize stover (MS), sorghum stover (SS) and veld hay (VH) *ad-libitum*, while lucerne hay (LH) and bean straw (BS) were offered at restriction levels of 0.15 and 0.35 kg/day per sheep, respectively, as a supplementary protein source (Table 1). During the adaptation as well data collection period, each feed was provided in separate feeding troughs and feeds were offered once daily at 09h00. All feeds were placed at the same time and rotated randomly every other day to avoid conditioned learning (Alonso-Díaz et al. 2009).

After adaptation, sheep were randomly allocated into three feeding groups as follows: (i) six sheeps were placed in two replicate pens of three animals and each pen was group-fed with five different feeds (ii) three sheep were placed in individual pens and each individually fed with five different feeds while (iii) three sheep were placed in individual pens and each individually fed with four different feeds with sorghum stover excluded. Animals were rotated across the three treatments in four periods of 10 days each in such a way that all animals were allocated to each treatment at least once and each pen, therefore, served as an experimental unit.

During each period, sheep were adapted to pens and faecal bags for 3 days followed by 7 days of a complete collection of faecal output while diets offered, refusal, spillage and orts were collected, weighed and recorded. Feed selection (F_{s}) was determined by using the selection index for feed preference adopted by Ngwa et al. (2000). Samples collected were dried and ground to pass through a 1 mm screen and subsequently analysed according to AOAC (2000) for dry matter (DM; ID 934.01) and crude protein (ID 968.06). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined using ANKOM 220 fibre analyser (ANKOM Technology, U.S.A.). Alpha-amylase and sodium sulphite were incorporated in the NDF assay and both NDF and ADF are expressed inclusive of residual ash. Data were analysed using the PROC MIXED procedure of SAS 9.3 (SAS Inst. Inc.; Cary, NC, U.S.A.) and the model statement include:

$$Y_{ijkl} = \mu + O_i + A_j + T_k + \varepsilon_{ijkl}$$

where Y_{ijkl} is the observation, μ overall mean, O_i order ($_i$ = 1-4), A_j animal assignment, T_k effect of treatment (k = 1-3) and ε_{ijkl} residual error. Treatment was a fixed effect while animal assignment was random effect. Period was a repeated effect on the model. The probability difference (PDIFF) was used to compare group means using Tukey test while contrasts was used to compare means between (i) average of group fed vs individually fed sheep (G vs IR), (ii) individually fed sheep with or without Sorghum stover (I vs R).

Table 1. Chemical analyses of experimental feeds.

	Chemical composition (g/kg)			
Feed	DM	NDF	ADF	CP
Bean straw	911	697	485	71
Veld hay	921	779	503	41
Lucerne hay	901	448	334	182
Maize stover	915	824	532	37
Sorghum stover	916	766	482	37

Note: DM: dry matter; NDF: neutral detergent fibre; ADF: acid detergent fibre; CP: crude protein.

Results

There was a significant ($p < 0.05$) difference on the contrast in group compared to individually fed sheep (with and without SS exclusion) on the selection of BS (Table 2). However, there was a tendency ($p < 0.07$) towards significance on the proportion of BS across the treatment effects. Contrast on diet selection of VH had significant ($p < 0.05$) differences between the group and individually fed sheep (with and without SS exclusion). Also, the selection of VH varied ($p < 0.05$) amongst the individually fed sheep with or without SS inclusion on the dietary choices. The proportions of BS and LH selected were not different ($p > 0.05$) across the group-fed or individually fed sheep (Table 2). However, individually fed sheep with sorghum stover inclusion selected a diet that had a lower proportion of sorghum stover compared to the diet selected by group-fed sheep ($p < 0.05$). Hence, the were differences ($p < 0.05$) in contrast of SS selection between the group-fed and individual-fed sheep (with and without SS inclusion). Individually fed sheep with or without sorghum stover inclusion selected diets with different proportions of VH ($p < 0.05$) while group-fed sheep selected diet with the lowest proportion of VH compared to the individually fed sheep groups. There was a tendency for significant differences in the proportion of BS selected by sheep across treatments ($p = 0.07$). Whereas, there was a difference in contrast between group and individually fed sheep (with and without SS inclusion). About 50% of the diets of individually fed sheep was constituted by VH. The quality of nutrients selected based on the proportion of the individual nutrient showed that there was no difference across the animals while the digestibility DM selected was equally not different across the animal groups ($p > 0.05$). Dry matter intake digestibility had a tendency towards significance ($p = 0.062$) of treatment effect where group-fed animals had differences in contrast with individually fed sheep (with and without SS inclusion).

Group-fed sheep consumed more SS than the individually fed sheep while individually fed sheep consumed more VH than the group-fed sheep ($p < 0.05$) and when SS was excluded, VH intake was higher among the individually fed animals (Table 3). Furthermore, there was a tendency for differences in BS intake ($p = 0.06$) and DMI digestibility ($p = 0.06$) across the animal groups while MS intake was not different across the groups ($p > 0.05$). There were no differences in the consumption of LH and nutrients (CP, ADF and NDF) across all the treatments ($p > 0.05$). Also, total DMI was not different across the groups ($p > 0.05$). Nevertheless, there was a tendency for differences between group-fed sheep and individually fed sheep (with and without SS inclusion) in terms of the contrast of LH ($p = 0.07$). There were differences ($p < 0.05$) in contrast between the group-fed versus individually fed sheep (with and without SS inclusion) in BS, VH, SS and DMI digestibility. The contrast for SS between Individual sheep with or without SS was different ($p < 0.05$).

Discussion

Compared to individually fed sheep with or without SS inclusion, group-fed sheep selected higher proportions of sorghum stover despite its low CP content. This may have

Table 2. Effect of group feeding and removal of sorghum stover on diet selection (g/g), diet quality (g/kg) and digestibility (g/kg) by Merino sheep.

Parameter	[1]Treatment G	I	R	[2]p-values Treatment	G vs. I & R	I vs. R
Diet selection (g/g)						
Bean straw	0.348 ± 0.009	0.303 ± 0.008	0.247 ± 0.0089	0.07	0.04	0.107
Veld hay	0.314 ± 0.05[c]	0.473 ± 0.033[b]	0.594[a] ± 0.063	0.03	0.02	0.06
Lucerne hay	0.148 ± 0.009	0.139 ± 0.007	0.121 ± 0.0019	0.149	0.07	0.464
Maize stover	0.060 ± 0.014	0.035 ± 0.012	0.039 ± 0.012	0.491	0.625	0.291
Sorghum stover	0.138 ± 0.001[a]	0.05 ± 0.001[b]	0.000[c]	0.002	0.002	0.003
Diet quality selected (g/kg)						
Crude Protein	71.6 ± 2.00	69.6 ± 1.75	73.1 ± 1.75	0.534	0.389	0.540
NDF	703 ± 6.788	704 ± 5.94	694 ± 5.94	0.588	0.359	0.926
ADF	471 ± 3.81	471 ± 3.33	452 ± 3.33	0.092	0.06	0.925
DM digestibility	634 ± 1.82	641 ± 2.61	607 ± 2.32	0.582	0.322	0.818

[1]G, group-fed sheep; I, individually fed sheep; R, individually fed sheep with sorghum stover excluded. Diets include maize straw, veld hay, & sorghum stover *ad lib,* plus 0.15 kg lucerne hay & 0.35 kg bean straw daily.
[2]Contrast across treatments; G vs IR, contrast group fed sheep (G) vs. average of individually fed sheep (I &R); I vs. R, individually fed sheep with or without Sorghum stover.
[abc]Means with different superscripts within a row differ significantly ($p < 0.05$).

been due to facilitated-feeding behaviour where visual cues of one animal consuming a certain feed stimulate others to consume the same feed (Rook and Penning 1991). The establishment of a dominance hierarchy in group-fed animals may have caused subordinate animals to feed on poorer quality feed (SS) resulting in higher consumption of the stover. Great variation in diet selection as diet quality increases has been noted in sheep (Wang et al. 2011). In this trial, a decline in the availability of better-quality alternatives (BS and LH) which were fed at restricted feeding levels, may have forced group-fed sheep to consume the stovers. Furthermore, the physical and chemical components of a feed play an important role in intake and digestibility (Provenza et al. 2003). High levels of cell wall relative to cell contents (i.e. protein, lipids and starch) are responsible for the observed lower selection of SS and MS among the diets. Feeds with low digestibility are often associated with low intake because intake has an indirect relationship with NDF concentration. Crude protein has been shown to increase intake through the improvement of associative digestibility, attributed to the intensification of microbial activity in the rumen (Duncan and SA 2002; Bach et al. 2012). Total DMI was not different between the group-fed sheep and individually fed sheep, with or without SS inclusion. The results are different from the observations of Phillips (2004), who reported increased DMI in group-fed calves compared to isolated calves. A slight increase in total DMI due to individual feeding is observable and this implies that in the absence of competition, DMI may be higher and relates to stocking patterns when animals are grazed. Sheep are gregarious and generally eat at the same time or follow precedence, therefore association and competition become important factors affecting feed intake. However, wider variability in diet selection among individually fed animals compared to group-fed animals has been noted (Forbes and Kyriazakis 1995; Chua et al. 2002).

The similarity in DM digestibility of diets consumed suggests that despite the differences in the proportion of individual diets selected by sheep, overall selection by individually fed or group-fed animals will be similar in quality. In the study on dairy calves, Brunsvig et al. (2017) observed that DM, OM and NDF digestibility increased in response to greater stocking density (Brunsvig et al. 2017). In contrast, Olson et al. (2002) reported that increased stocking density reduced total-tract OM digestibility among steers grazing shortgrass prairie. In the current study, no differences were observed in DM digestibility and digestible DMI between group-fed sheep and individually fed sheep. According to previous reports, post-ingestive

Table 3. Effect of group feeding and removal of sorghum stover on ingredient intake (kg/day), total dry matter intake (kg/day), digestible dry matter intake and nutrient intake (g/kg day) by Merino sheep.

Parameter	[1]Treatment G	I	R	[2]p-values Treatment	G vs. I & R	I vs. R
Ingredient intake (kg/day)						
Bean straw	0.348 ± 0.021	0.303 ± 0.018	0.247 ± 0.017	0.07	0.03	0.197
Veld hay	0.315 ± 0.04[c]	0.467 ± 00333[b]	0.599 ± 0.03[a]	0.027	0.017	0.062
Lucerne hay	0.150 ± 0.001	0.141 ± 0.001	0.122 ± 0.01	0.149	0.074	0.436
Maize stover	0.060 ± 0.05	0.037 ± 0.012	0.039 ± 0.012	0.491	0.625	0.291
Sorghum stover	0.138[a]	0.050[b]	0.00[c]	0.002	0.003	0.002
Total dry matter intake	0.929 ± 0.069	1.018 ± 0.063	1.185 ± 0.0599	0.183	0.109	0.424
Nutrient intakes (g/ day)						
CP intake	649 ± 3.31	706 ± 3.01	769 ± 2.83	0.316	0.130	0.316
NDF intake	633 ± 57.718	727 ± 52.23	856 ± 50.29	0.177	0.111	0.340
ADF intake	425 ± 37.28	485 ± 33.89	569 ± 32.50	0.176	0.111	0.338
Digestible dry matter intake	758 ± 1.881	743 ± 2.830	656 ± 2.59	0.062	0.031	0.683

[1]G, group-fed sheep; I, individually fed sheep; R, individually fed sheep with sorghum stover excluded. Diets include maize straw, veld hay, & sorghum stover *ad lib,* plus 0.15 kg lucerne hay & 0.35 kg bean straw daily.
[2]Contrast across treatments; G vs IR, contrast group fed sheep (G) vs. average of individually fed sheep (I &R); I vs. R, individually fed sheep with or without Sorghum stover.

feedback such as increased digestibility and higher rumen passage rate influences feeding behaviour in ruminants (Costes-Thire et al. 2019). Additionally, increases in diet digestibility allow greater DMI when ruminal fill limits DMI (Redmon et al. 1995). When ruminal fill is not limiting, chemostatic mechanisms such as the energy density of diet can also control DMI (Allen et al. 2009; Pulina et al. 2013).

Individually fed Sheep with or without sorghum stover inclusion consumed a similar intake of the other dietary ingredients. This may have been achieved by slight alterations in the proportions of feeds selected in each treatment and this was likely done to buffer changes in digest a composition as noted by Baumont et al. (2000). Ginane et al. (2002) noted that feeding on more diverse plant communities would stimulate improved intake compared to less diverse plant communities. The lower acceptability of sorghum stover showed that its removal had no significant influence on diet selection and intake because it was not supplying any limiting nutrient compared to other diets on offer which is justified by a non-significant difference between treatment I versus R ($p > 0.05$) in the contrast. When a diet is able to provide a limiting nutrient, ruminants tend to exhibit a compensatory intake of a feed among those on offer (Bach et al. 2012). Preference towards energy, protein and minerals to remediate the specific deficiencies has been established (Villalba and Provenza 2009).

The threshold of the number of feeds removed in a selection that will change the quality of diets selected and alter total dry matter intake is still not well defined. Wang et al. (2011) noted that selectivity index will reduce as the number of plant species/diets on offer increases because animals may not properly differentiate between the nutritional values of the diets on offer at a single meal. Nevertheless, it seems possible that the quality of diet selected by sheep may be controlled using two mechanisms by either slightly altering or adjusting proportions of feeds consumed among feeds on offer while maintaining similar total intake, or by altering total intake of diets in a selection of feeds. Previous exposure to feeds such as in utero or early stages of life could enhance animal's ability to extract nutrients efficiently from accustomed feeds regardless of the quality, compared to feeds they are exposed to more recently when both feeds are offered in free choice (Villalba et al. 2015). Aside from the aforementioned epigenetic factors, the poor quality of the *ad libitum* feeds on offer, and the positive contextual learning (Villalba et al. 2015) may have caused the individually fed sheep to preferentially select veld hay. Such would have been due to that sheep in this trial had been accustomed to veld hay before the trial and reduced competition compared to group-fed animals and also the CP content of VH. However, the threshold of ingredient choice, above which ingredient removal will alter diet quality warrants further evaluation.

Disclosure statement

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