Digestive characteristics, rumen ammonia nitrogen and volatile fatty acids levels in sheep fed commercial pellets supplemented with grimmett barley grain or freeze-dried or fresh barley sprouts

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ABSTRACT

Commercial concentrate pellets for ruminants were fed to sheep, supplemented with four different treatments of barley as control, barley grain, freeze-dried barley sprouts and fresh barley sprouts in a 4 x 4 Latin Square design. The study was conducted to compare the effect of barley grain and sprouts on production parameters. Results showed no difference ($P>0.05$) in average daily DM intake due to the feeding of sprouts supplements in comparison to the control. Supplementing with fresh barley sprouts also did not differ in average daily DM intake from barley grain. Supplementation with barley grain gave a higher ($P<0.01$) total VFA concentration than the fresh barley sprouts but not different from freeze-dried barley sprouts. Barley grain and freeze-dried barley sprouts supplementation gave a higher ($P<0.01$) lipogenic to glucogenic ratio than the fresh barley sprouts supplementation. The pH values recorded did not differ ($P>0.05$) among treatments. Rumen ammonia concentration also did not differ ($P>0.05$) among treatments in the current study. It can be concluded from this study that when diets high in nutrients are fed to livestock, there is no advantage of supplementing with hydroponic barley sprouts. There were no clear performance benefits from the hydroponic barley sprouts supplementation.

Key words: Pellets, barley, sprouts, rumen, digestive characteristics.

INTRODUCTION

Sprouting of grain brings about enzymatic activities that lead to inter-conversions of the stored nutrients in the endosperm of seeds as well as the release of simpler compounds from the breakdown of the stored compounds (Chavan & Kadam, 1989). Starch is broken down to sugars, proteins to amino acids and lipids to free fatty acids. The inter-conversions normally lead to increases in the concentrations of some vitamins to levels higher than prior to sprouting (Chavan & Kadam, 1989; Cuddeford, 1989).

The quality of proteins especially in cereals is known to improve with sprouting. The conversion of lysine deficient proteins like prolamins into albumins and globulins usually increases the lysine content and hence quality of the proteins (Chavan & Kadam, 1989).

Dung *et al.* (2010) reported a significant increase in voluntary intake (TDMI), nitrogen balance, mean rumen ammonia concentration and total VFA concentration with inclusion of sprouted barley treatments in a basal diet of oaten chaff. These increases were recorded on a low protein basal diet (8.1 % CP). Reports in the literature (Thomas & Reddy, 1962; Tudor *et al.,* 2003) have indicated that when adequate nutrition is provided, the effect of sprouts supplementation does not elicit any improvement in performance due to the fact that the animal requirements would have been met already. A report in favour of noticeable improvement in yield parameters as a result of feeding hydroponic barley sprouts (Grigor'ev *et al.,* 1986) indicated an increase in milk yield due to feeding of hydroponic barley sprouts as a supplement.

The current study was designed to feed a diet high in nutrients (commercial pellets) to the sheep with the view of observing any improvement in parameters associated with the supplementation of hydroponic barley sprouts purported to give increased performance.

MATERIALS AND METHODS

Animals and housing

Four Merino sheep (initial weight of 49.6 ± 7.4 kg) were housed in individual pens in an animal house. Each was fitted with a permanent rumen cannula.

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Diets and feeding

The four fistulated sheep above were given commercial pellets *ad libitum,* daily, and the voluntary intake determined over a period of 14 days in individual pens. After this period, the sheep were subjected to four different treatments in a Latin Square design. During the treatment phase there was a 7-day total urine and faecal collection (in metabolism cages) and also sampling of rumen fluid. Between treatment phases, there was an adjustment period of 14 days before collection of samples. The apparent digestibility of DM, OM, and N retention were determined. The rumen fluid profile of VFA (molar proportions and total concentration), and rumen ammonia in the four treatments were determined.

Analytical methods and calculations

(a) Estimation of microbial N supply

Purine derivative (allantoin) conversion to microbial outflow was determined as follows:

Microbial N supply for sheep was calculated based on the equation by Chen & Gomes (1995), briefly described below.

$$Y = (0.150\ ^{W0.75}\ e^{-0.25X}) + 0.84X$$

Where:
Y = Purine derivative excretion in the urine;
X = Exogenous purines

(b) Dry matter, organic matter and ash

The DM content of feed, refusals and faeces was estimated by drying samples in triplicate from each animal in each period in a forced draught oven at 60 ^{0}C for a minimum of 72 h, or until constant weight was achieved. Thereafter, the samples were bulked and milled in a Wiley Mill to pass through 1 mm screen, and dried overnight in crucibles at 105 ^{0}C to determine the final DM content. The DM was then combusted in a muffle furnace at 600 ^{0}C for 4 h to determine both the organic matter and ash content (AOAC, 1990).

(c) Total N

The total N content in the feed ingredients, feed refusals, faeces and urine was determined using the automated semi MicroKjeldahl system (AOAC, 1990).

(d) Ammonia N

The concentration of ammonia N in the rumen fluid supernatant was estimated using an autoanalyser (Technicon) according to the method described by Beitz (1974).

The proportion of un-ionised ammonia in the total ammonia concentration was calculated using the Henderson-Hasselbalch equation (Siddons *et al*., 1985) taking into account total ammonia concentration and rumen fluid pH.

(e) Volatile fatty acids.

The total molar concentration (mmol/l) of all VFAs, and molar percentages of major

Un-ionised [NH3] = 1-(1/ (1 + antilog [pH-pK'a]
Where: pK'a = 9.02

VFA (acetic, propionic and butyric) and minor VFA (iso-butyric, iso-valeric and valeric) were estimated in the rumen fluid supernatants by methods of Erwin *et al*. (1961), using gas liquid chromatography (GLC) (Model CP 3800GC), and iso-caproic acid as an internal standard. The ratio of lipogenic to glucogenic VFA were determined as described by Maas *et al*. (2001).

Experimental design and statistical analysis

Four Merino sheep fitted with permanent rumen cannulae were used for a 4 x 4 Latin Square design. The Latin Square design (Steel & Torrie, 1980) of four treatments and four periods was used for the assessment of the three barley treatments (grain, freeze-dried and fresh hydroponic barley sprouts) and a control. The data were analysed using the analysis of variance (ANOVA) and treatment means compared using pair-wise comparisons at 5 % level of probability (Duncan's LSD).

Minitab 12.1 software was used for data analyses. Intake and digestibility data were analysed using the one-way analysis of variance while the general linear model (GLM) was used in repeated measures analysis for data repeated over time (ruminal pH, ammonia and VFA concentrations).

RESULTS

Feed DM intake, apparent DM and OM digestibility and nitrogen retention

The mean daily DMI, DM and OM digestibility and N retention are presented in Table 1. The pattern of feed DMI did not follow an expected trend based on supplements' CP content and supplementation of barley grain or sprouts. The commercial feed pellets given were high in nutrients.

The treatment supplemented with barley grain had the highest DMI, followed by the fresh barley sprouts supplementation, and

Table 1. Total DMI, DM and OM digestibility, nitrogen balance and microbial outflow in sheep fed concentrate pellets (T1), T1 + barley grain (T2), T1 + freeze-dried barley sprouts (T3), T1 + fresh barley sprouts (T4).

Component	T1	T2	T3	T4	Significance
Total DMI g/d	1297.0[a]	1401.8[b]	1276.7[a]	1340.3[ab]	**
Total DMI g/kg $W^{0.75}d^{-1}$	67.2[a]	73.0[b]	66.8[a]	71.7[b]	**
DM digestibility, %	56.5	60.1	58.4	58.5	NS
OM digestibility, %	54.3	58.1	55.5	55.9	NS
Total N intake, g/d	25	28.2	27.3	27.3	NS
Fecal N, g/d	10.3	10.7	10.4	10.5	NS
Urine N, g/d	7.6	7.5	8.3	7.2	NS
Nitrogen balance, g/d	7	10	9.1	9.6	NS
Microbial outflow, g/d	7.8	8.1	8.9	8.3	NS

** ($P<0.01$), NS = not significantly different.
Means with different superscripts, a, b, c within the same row differ significantly ($P<0.01$).

then the unsupplemented treatment and finally the freeze-dried hydroponic barley sprout supplementation. The barley grain supplementation gave a higher ($P<0.01$) DMI than both the unsupplemented treatment and the supplementation using freeze-dried barley sprouts. Barley grain supplementation, however, did not give a higher ($P>0.05$) DMI than the fresh barley sprouts supplementation, though the values tended to be higher. Generally, the intake values were higher than reported by the current authors (Dung *et al.,* 2010), when the basal diet was oaten chaff.

A similar pattern of intake occurred when DMI was considered on the basis of metabolic weights of the sheep used in the trial.

The DM and OM digestibility did not differ among the four treatments, so also the N balance. The DM digestibility varied from 56.5 % for the pellets only diet to 60.1 % for the barley grain supplemented treatment. The OM digestibility varied from 54.3 % to 58.1 % for unsupplemented pellets and barley grain supplementation, respectively. The N balance varied from 7.0 g/d for the unsupplemented pellets to 10.0 g/d for the barley grain supplementation.

In all the parameters listed in Table 1, the treatment supplemented with barley grain had the highest values recorded for both the significant and non-significant means, except for microbial outflow.

Total VFA concentrations, VFA proportions and pH in rumen fluid

There was no observed time x treatment interaction among treatments for total VFA concentration as well as VFA proportions due to type of supplements given. Total VFA concentrations were different ($P<0.01$) due to supplementation of different types of barley to the pellet diet as shown in Table 2 and Figure 1. The highest total VFA concentration was recorded for the barley grain supplementation which was higher ($P<0.01$) than the unsupplemented pellets (control) and the fresh hydroponic barley sprouts supplementation. The barley grain supplementation, however, did not differ ($P>0.05$) from the freeze-dried hydroponic sprouts supplementation in total VFA production. It is likely that the barley grain supplementation encouraged the amylolytic bacterial population noted for fermentation of high grain concentrates.

The mean acetic acid proportion did not differ ($P<0.01$) due to supplementation type imposed on the basal diet of commercial pellets used in the trial. This is presented in Table 2. The molar proportions of acetic acid varied from 57.5 % for the barley grain supplemented treatment to 63.1 % for the fresh hydroponic sprouts supplementation.

The molar proportions of propionic acid differed ($P<0.001$) as a response to the different supplementations given (Table 2). The highest propionate proportion was recorded for freeze-dried barley sprouts supplementation which was higher ($P<0.001$) than the fresh hydroponic barley-supplemented treatment. The freeze-dried barley supplemented treatment was however not higher ($P>0.05$) than the control or the barley grain-supplemented diets. The fresh barley sprouts-supplemented diet had the lowest figure for propionic acid proportion in the rumen fluid.

Table 2. Concentrations of rumen fluid ammonia and VFA, molar proportions of VFA and rumen pH of sheep fed concentrate pellets (T1), T1 + barley grain (T2), T1 + freeze-dried barley sprouts (T3), T1 + fresh barley sprouts (T4).

Components	T1	T2	T3	T4	SEM	Significance
Ammonia concentration (mg N/L)	77.0^{a}	87.1^{a}	86.6^{a}	119.1^{b}	28.2	**
Non-ionised NH3-N (mg N/L)	0.13	0.29	0.09	0.13	0.39	NS
Total VFA concentration (m mol/L)	105.9^{a}	125.6^{b}	119^{ab}	105^{a}	17.5	**
Acetic, %	61.4^{ab}	57.5^{a}	59.3^{ab}	63.1^{b}	4.0	**
Propionic, %	23.2^{ab}	26.4^{bc}	28.9^{c}	20.4^{a}	3.4	***
Butyric, %	11.8^{b}	12.2^{b}	8.6^{a}	12.3^{b}	2.9	**
Minor VFA, %$^{+}$	3.6^{ab}	3.8^{ab}	3.1^{a}	4.2^{b}	0.96	*
Glucogenic VFA, %$^{++}$	26.8^{a}	30.3^{b}	32.0^{b}	24.6^{a}	3.6	**
Lipogenic VFA,%$^{+++}$	73.2^{b}	69.7^{a}	68.0^{a}	75.4^{b}	3.6	**
Glucogenic:Lipogenic VFA	0.4^{b}	0.5^{c}	0.5^{c}	0.3^{a}	0.08	**
pH	5.8	5.6	5.7	5.7	0.2	NS

$^{+}$Sum of isobutyric, isovaleric and valeric
$^{++}$Sum of propionic, isobutyric, isovaleric and valeric
$^{+++}$Sum of acetic and butyric
*(P,0.05), **(P<0.01), ***(P<0.001), NS = Not significantly different (P>0.05)
Means with different superscripts, a, b, c within the same row differ significantly

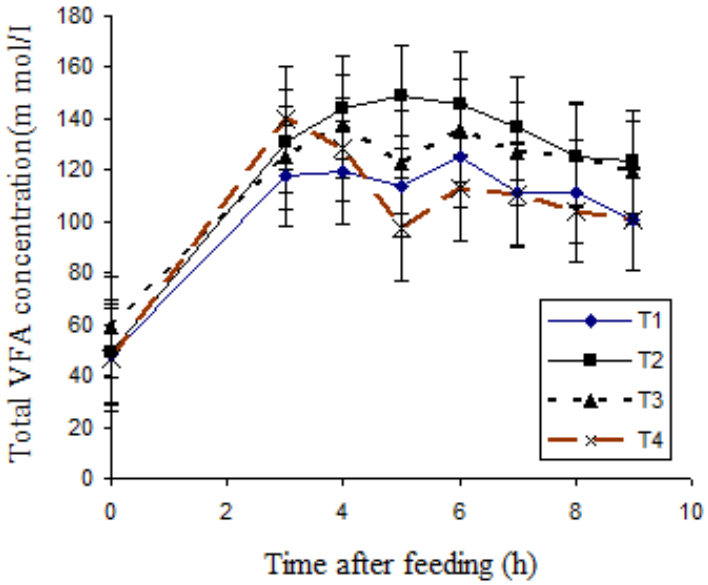

Figure 1. Total VFA concentration in rumen fluid of sheep fed concentrate pellets (T1), concentrate pellets + barley grain (T2), concentrate pellets + freeze-dried barley sprouts (T3), and concentrate pellets + fresh barley sprouts (T4).

Butyric acid proportion differed (P<0.01) among the treatments (Table 2). The freeze-dried hydroponic barley produced the least proportion of butyric acid and this was different (P<0.01) from the other three treatments in the trial (pellets only, pellets + barley grain, and pellets + fresh hydroponic barley sprouts); these three, however, did not differ from one another.

The proportion of minor VFA (isobutyric, isovaleric and valeric) in the rumen fluid of sheep fed the four treatments in Table 2 differed (P<0.05). The highest proportion of minor VFA was recorded for the fresh hydroponic barley sprouts supplementation and this differed (P<0.05) from the freeze-dried hydroponic barley treatment but did not differ for the control, or barley grain supplementation to pellets diets.

The mean concentration of glucogenic VFA differed (P<0.01) among the four treatments (Table 2). The lowest concentration of 24.6 % was recorded for pellets supplemented with fresh hydroponic barley sprouts

and this was lower (P<0.01) than the values for the diet supplemented with freeze-dried barley sprouts. The mean values for glucogenic VFA for pellets only and barley grain supplementation of pellets were, however, not different from the fresh barley sprouts supplementation although the latter two treatments tended to be higher. Treatments that give a good supply of glucogenic VFA are desirable because of the higher efficiency of energy supply associated with it.

Lipogenic VFA concentration differed (P<0.01) among the four treatments (Table 2). The fresh barley sprouts supplementation of pellets gave rise to a higher (P<0.01) concentration of lipogenic VFA above the other treatments; the three treatments did not differ from one another.

The ratio of glucogenic to lipogenic VFA differed (P<0.01) among the treatments (Table 2). The fresh barley sprouts supplement brought about the least ratio of glucogenic to lipogenic VFA and was lower (P<0.01) than the freeze-dried barley and barley grain supplementation. It was, however, not different from the control diet treatment.

The pH values shown in Table 2 did not differ (P>0.05) due to the different treatments, though the treatment with the highest pellets intake tended to be slightly more acidic. Generally, the pH values were considered extremely low. They were at the lower end of the range conducive for rumen microbes (pH 5.5 to 7.5).

Ammonia concentration in rumen fluid

There was no time x treatment interaction for ruminal ammonia concentration. The mean rumen fluid ammonia concentration due to supplementation of barley grain, freeze-dried barley sprouts, and fresh hydroponic barley sprouts are presented in Table 2 while the profile of ammonia concentration in the rumen fluid is presented in Figure 2.

The mean rumen fluid ammonia concentration in Table 2 differed (P<0.01) due to type of supplementation given on the pellets used in the current study. The fresh barley sprouts supplementation gave the highest (119 mmol/l) mean ammonia concentration in the rumen fluid of sheep used in the current study; this value was higher (P<0.01) than the control diet but not different from the supplementation using barley grain or freeze-dried hydroponic barley sprouts.

The trend of rumen fluid ammonia concentration as shown in Figure 2 portrays a similar trend for three of the treatments (pellets only, freeze-dried barley and barley grain supplementation) which differed from the fresh barley sprouts supplementation. The fresh barley sprouts supplementation gave rise to a sharp increase in rumen ammonia concentration from 3 – 5 h after feeding then

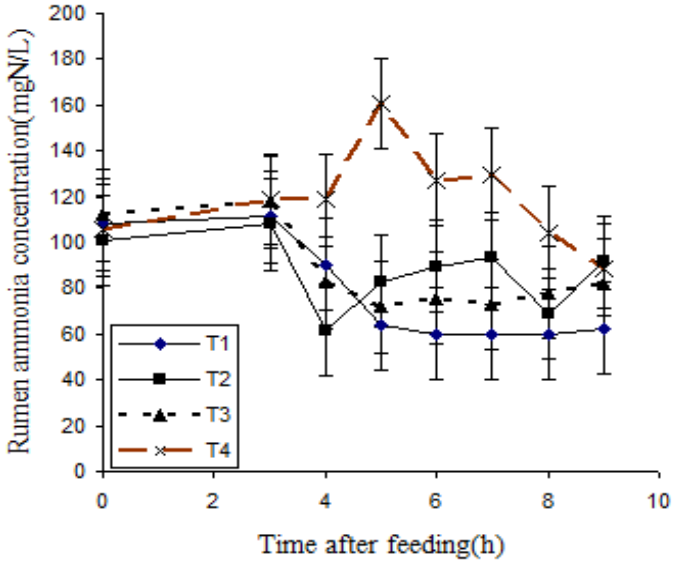

Figure 2. Total ammonia concentration in rumen fluid of sheep fed concentrate pellets (T1), concentrate pellets + barley grain (T2), concentrate pellets + freeze-dried barley sprouts (T3), and concentrate pellets + fresh barley sprouts (T4).

dropping sharply from 5 – 6 h after feeding before ending in a gradual decline till 9 h post feeding. The other treatments with a similar trend had a rapid decline in rumen fluid ammonia concentration between 3 – 5 h post feeding then stabilised to near constant levels from about 5 – 9 h post feeding.

Rumen bacterial outflow

The rumen bacterial outflow did not differ as a result of supplementation given to the sheep in this study. The treatments with sprouts supplementation were numerically higher than the treatments without sprouts, albeit not significantly so. The microbial outflow values in the current study were generally higher than the study by the authors using oaten chaff as basal diet (Dung *et al.,* 2010).

DISCUSSION

Feed DM intake, apparent DM and OM digestibility and nitrogen retention

There was no definite pattern of feed intake as a response to supplementation given to the sheep used in the current study. Only the grain supplemented sheep had a higher ($P<0.01$) average daily DMI than the control (pellets only), (Table 1). The treatments with supplementation using a higher CP content (sprouts supplementation) did not generate a better response than the control.

Intake of low-quality forage increases with protein supplementation (McCollum & Galyean, 1985; Beaty *et al.,* 1994; Krehbiel *et al.,* 1998). However, others (Ferrell *et al.,* 1999; Swanson *et al.,* 2000; Bohnert *et al.,* 2002) have reported no difference in forage intake when ruminants fed low-quality forages were supplemented with protein. Swanson *et al*. (2000) reported that forage intake by mature ewes fed a forage containing 6.7 % CP did not increase in response to supplemental protein. They were of the view that the 49 g/d digestible intake protein from the forage offered the control ewes might have been adequate for maintaining ruminal fermentation and therefore no DM intake resulted from additional CP. A similar result was obtained with lambs when CP supplementation was given to a forage diet containing 7.5 % CP (Salisbury *et al.,* 2004).

The CP content in the commercial pellets fed to the sheep in the current study was higher (12 % CP) than those in the preceding reports, and therefore would have supported adequate ruminal fermentation by the microbes.

The barley grain supplementation tended to give a numerically higher DM intake than the fresh barley sprouts supplementation which was however, not significant. The fresh sprouts supplementation likely gave more gut fill due to the fluid enclosed in the cells of the sprouts making it take more volume of rumen space. Each animal fed fresh barley sprouts in the current study had 500 g fresh sprouts daily. The time taken to ferment the sprouts and clear that space in the rumen needs to be considered compared to the time taken to clear the barley grain. The pellets used in the current study had a high grain component that favoured rapid fermentation in the rumen. The barley grain supplement likely encouraged rapid fermentation and greater intakes comparatively.

When the supplements used in this study were compared on the basis of metabolic weight of animal, the barley grain supplement gave the highest intake.

The DM and OM digestibility did not differ ($P>0.05$) among the treatment means of the supplements offered in this study, although barley grain supplementation tended to be higher numerically. The composition of the total feed ingested which were about 90 % pellets for all the treatments would not have varied enough to cause a noticeable difference in digestibility of OM and DM.

Total VFA concentrations, VFA proportions and pH in rumen fluid

The values of VFA reported in this study are similar to those of Susin *et al*., (1995) on a high-grain diet fed to ewes. The results in the current study showed differences in mean VFA concentrations among treatment means due to supplementation, but the interaction of time x treatment was not noticed for any of the rumen fluid parameters measured.

Barley grain supplementation gave the highest total VFA concentration among the treatments. It was higher ($P<0.01$) than the fresh barley sprouts supplementation and the control but not different from the freeze-dried barley sprouts supplementation. More degradable starch tends to decrease rumen pH, increase rumen VFA production and decrease rumen ammonia concentration (Cabrita *et al.*, 2006).The commercial pellets used in this study were high in grain concentrate, therefore addition of barley grain supplement would

have given rise to greater VFA production. Barley grain is noted for high rates of DM and starch degradabilities in the rumen (Herrera-Saldana *et al.,* 1990; Zinn, 1993) and diets based on barley grain increase microbial protein synthesis (Zinn, 1993) and produce a high level of fermentation and lower pH in the rumen immediately after feeding (McAllister *et al.,* 1990; Yang *et al.,* 1997). The high mean daily DMI recorded for the barley grain supplementation (Table 1) would have favoured greater VFA production above the other treatments under the conducive pH mentioned earlier. From Figure 2, the sharp decrease in rumen ammonia levels is likely a result of its usage in protein synthesis stimulated by the presence of a high VFA level. This corroborates the report by Cabrita *et al*. (2006).

The fresh sprouts supplements which had a higher CP content than the barley grain also had readily available sugars, but this did not favour as much VFA production as the barley grain supplement. The likely reason being the time taken to dislodge the cell contents in the sprouts and also the time taken for degradation and outflow of the whole sprouts to create space in the rumen for more intake of the commercial pellets.

The proportion of acetic acid (percentage of total VFA) differed ($P<0.01$) among the treatment means as a result of the supplementation given. Acetic acid constituted the largest molar proportion VFA in the rumen fluid. Acetic acid is lipogenic and formation of lipogenic VFA in large concentrations is mainly from high fibre diets with slow rates of fermentation. Sutton *et al.* (2003) reported a shift in fermentation pattern from high acetate to high propionate on low roughage rations. In the current study, the fresh sprouts supplement had the highest acetate proportion albeit only different ($P<0.01$) from barley grain supplementation.

Propionic acid differed ($P<0.01$) among treatment means due to type of supplementation. Rumen propionate levels increase rapidly on a high grain diet (Susin *et al.,* 1995; Russell, 1998) as was the case in this study. The freeze-dried barley supplement gave the highest propionate proportion although it differed ($P<0.01$) only from the fresh barley sprout supplementation. An inter-play of intake, diet and microbial population as affected by pH would likely have caused the variation. It is believed the high intake rates of the pellets (high in grain) gave rise to proportionately higher levels of readily fermentable carbohydrates which favoured higher levels of incorporation into microbial protein, in the presence of the adequate ammonia N (Stern & Hoover, 1979). Rapid fermentation rates are usually associated with high propionate production.

Butyric acid proportions differed ($P<0.01$) among treatment means due to effect of supplementation. The freeze-dried barley supplement gave the lowest which differed ($P>0.05$) from all the other treatments. Butyric acid is lipogenic but the diet in this study favoured glucogenic precursors because of the high grain nature. High ruminal concentration of butyrate is known to have an adverse effect on glucose production and lactate synthesis (Miettinen & Huhtanen, 1996), so the treatment that favours that is likely to bring about low efficiency of production. It appears the interaction of microbial type, pH and diet intake did have a strong bearing on butyrate concentration as to bring much difference due to supplementation.

The minor VFA (isobutyric, isovaleric and valeric) differed ($P<0.05$) in response to supplementation given. The freeze-dried sprout supplement had the lowest mean value for minor VFA concentration which was different from fresh barley sprouts supplementation but not different from the other treatments. The minor VFA are glucogenic and high levels are encouraged except for isovaleric and valeric VFA. These can be formed from protein fermentation (Davidson *et al.,* 2003) and could be an inefficient way of energy supply.

Glucogenic VFA normally increase in concentration when a high concentration of grains are fed with an accompanying high bacterial population and activity (Cheng & Hironaka, 1973; Jouany *et al.,* 1998; Hristov *et al.,* 2001). In the current study, the freeze-dried barley sprouts supplementation had the highest glucogenic VFA concentration in the rumen fluid. It was higher ($P<0.05$) than the fresh barley sprouts supplementation only. The barley grain supplementation tended to be higher than the fresh barley sprouts and the control treatments but the differences were not significant. Production of high levels of glucogenic VFA is desirable because of their higher energy efficiency (Preston & Leng, 1987). *In vivo*, the flow of total and bacterial protein to the intestines has been correlated

with the molar percentage of propionic acid in the rumen fluid (Ishaque *et al.,* 1971; Jackson *et al.,* 1971).

There were differences in the concentration of lipogenic VFA in the current study, due to the different supplements used. The fresh barley sprouts supplements gave the highest lipogenic VFA concentration which differed ($P<0.05$) from all the other treatments. Lipogenic VFA production can have adverse effects on the more energy-efficient glucogenic VFA; reports by Miettinen & Huhtanen (1996) showed that high ruminal butyrate production can have adverse effects on glucose production and lactose synthesis. The glucogenic VFA is usually encouraged especially in high-yielding dairy cows by manipulation of fermentation characteristics (Vanhatalo *et al.,* 2003).

The lipogenic to glucogenic ratio differed ($P<0.01$) among the means of the treatments in the current study. The barley grain and freeze-dried barley sprouts supplements had the best lipogenic to glucogenic VFA ratio and both were higher ($P<0.01$) than the fresh barley sprouts supplement. They were, however, not higher ($P<0.01$) than the control. The treatments with the best glucogenic to lipogenic ratios are desirable due to the better energy efficiency of glucogenic VFA (Preston & Leng, 1987; Vanhatalo *et al.,* 2003).

The pH values in the current study did not vary ($P>0.05$) among the means of all the treatments due to supplement type given. The mean pH values did not drop below pH 5.5 in any of the treatments giving the impression that it was not too acidic for the rumen microbes to flourish.

Ammonia concentration in rumen fluid

The mean rumen ammonia N concentration differed ($P<0.01$) among treatments due to supplementation types administered. The control had the lowest concentration of rumen ammonia N which differed ($P<0.01$) only from the fresh barley sprouts supplementation. All the supplemented treatments did not differ ($P>0.05$) from one another although the fresh barley sprouts supplement tended to be higher than the others.

The barley grain supplementation which had the highest value for rumen fluid total VFA concentration showed a drastic response (decline) in rumen ammonia levels probably due to the increase in the VFA levels (Figures 1 and 2). This shows an interaction between VFA levels and rumen ammonia N concentration. More degradable starch tends to decrease rumen pH, increase rumen VFA and decrease rumen ammonia concentration (Plascencia & Zinn, 1996; Yang *et al*., 1997). When the basal diets are high in forage, however, the increase in VFA can decrease roughage degradation due to lowering of the rumen pH and its effects on roughage degrading microbes (Cabrita *et al.,* 2006). The diet in the current study being a high grain diet would, therefore, not be adversely affected by the rapid fermentation of grain in the presence of adequate ammonia levels.

The decreased ammonia concentration levels observed with high concentrate diets likely stem from a higher level of utilization of ammonia as a result of more readily available carbohydrate and increased ammonia assimilation (Hristov *et al.,* 2001).

The un-ionised ammonia did not differ in concentration among the different treatments. The pH and total ammonia concentrations determine the non-ionised ammonia N concentration (Abdoun *et al.,* 2006).

Rumen bacterial outflow

The rumen microbial outflow did not differ among treatments. Efficient microbial protein synthesis depends on supply of adequate N and readily fermentable carbohydrates as well as other nutrients for uptake and utilisation by microbes. The high level of nutrients in the pellets used in this study provided the required levels for all the treatments.

CONCLUSION

Results of the current study suggest that sprouting did not bring about an increase in DMI when compared to barley grain supplementation. Barley grain supplementation of high grain concentrate pellets in this study gave the highest DMI which was better than all other treatments except the fresh barley sprouts supplement. Apart from DMI, other digestibility parameters did not differ among the four treatments, suggesting that supplementing high nutrient diets with sprouts was of no advantage. The increase in performance alluded to the presence of a "grass juice factor" was therefore not noticed in the current study.

Supplementing concentrate pellets with freeze-dried sprouts did not give a higher concentration of rumen ammonia N above treatments without sprouts, although fresh

barley sprouts gave the highest rumen ammonia concentration. The total VFA concentrations in the four treatments did not show an advantage of supplementing with hydroponic barley sprouts.

Other rumen fluid parameters (proportions of VFA) did not show a clear advantage of feeding sprouts supplements to sheep on high concentrate pellet diet.

It can be concluded that when diets high in nutrients are fed, there is no advantage of supplementing with hydroponic barley sprouts and there was no clear indication of a "grass juice factor" giving improved performance. The current study does not suggest any likely performance benefits from using sprouted grain for livestock feed supplementation even when the basal feed has a high level of nutrients; a similar performance trend was reported using a low quality basal feed by the current authors (Dung *et al.,* 2010). Sprouting in a situation like this would amount to spending time and money for no special advantage.

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