Canadian Journal of Animal Science
Revue canadienne de science animale

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Journal:	<i>Canadian Journal of Animal Science</i>
Manuscript ID	CJAS-2015-0168.R4
Manuscript Type:	Article
Date Submitted by the Author:	12-May-2017
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Keywords:	Food intake, Forages, Nutrition, Rumen

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Intake and Digestibility of Sheep-fed Alfalfa Haylage Supplemented with Corn

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ABSTRACT

The objective of this study was to determine the effect of dry corn (DC) and fermented corn (FC) supplemented to alfalfa haylage (*Medicago sativa* L.) (AH) on feed intake, digestibility and N balance in wether sheep.

The study consisted of five feeding treatments incorporating AH alone and AH supplemented with 5 or 10 g of DC (DC5 and DC10, respectively) or FC (FC5 and FC10, respectively) kg^{-1} body weight d^{-1} to Suffolk wethers.

The DC5 and FC5 treatments were higher in acid detergent fibre (ADF) intake ($P < 0.001$), neutral detergent fibre (NDF) intake ($P < 0.001$) and nitrogen intake ($P < 0.05$) compared with the DC10 and FC10 treatments. Both energy sources (DC and FC) and supplemental levels (5 and 10 g kg^{-1} body weight d^{-1}) increased ($P < 0.05$) the digestibility of DM and organic matter (OM), and the digestibility of OM in DM (D-value), and decreased the digestibility of ADF ($P < 0.05$). The DC10 and FC10 treatments had higher D-values ($P < 0.05$) and reduced ADF digestibility values ($P < 0.05$) compared with the DC5 and FC5 treatments. The FC supplemented treatments had reduced N balances compared with DC treatments ($P < 0.001$).

It was concluded that DC was a better supplement to AH than FC in terms of NDF intake, CP digestibility and N balance. The main effect of increasing the level of starch supplementation to the diet was a reduced N and fiber intake, as well as N and fiber digestibility, but an increased D-value.

Keywords: alfalfa haylage, dry corn, fermented corn, intake, digestibility, N balance

Introduction

High protein forage, such as red clover (Leto et al., 2013) or alfalfa haylage (AH) (Vranić et al., 2011) requires supplements rich in fermentable energy, such as starch, for more efficient nutrient utilisation in ruminants (Ørskov et al., 1970; Vranić et al., 2011). The main source of dietary starch for ruminants is corn (USDA, 2008). Starch also increases the supply of microbial protein to the animal, since the rumen microbial protein production is generally determined by the total intake of fermentable carbohydrates (Gomes et al., 1994). The amount of energy that the rumen organisms and the host animal may potentially obtain from starch will vary in response to the conservation method and the starch supplementation level, among others factors (Wilkerson et al., 1997; Ørskov et al., 1974).

Previous research shows greater utilization of starch and energy from fermented corn (FC), compared to dry corn (DC), as supplement to protein rich forage (Wilkerson et al., 1997). The reason might lie in the higher effective ruminal degradability of starch in grain kernel after ensiling (92.3 %), rather than before ensiling (70.2 %) (Jurjanz and Monteils, 2005). This is also confirmed by greater dry matter (DM) digestibility in sheep fed AH supplemented with FC rather than DC (Vranić et al., 2011), or lower DM intake but similar daily gains and slightly better feed conversions of FC compared to DC in beef cattle (Owens et al., 1997). Conversely, no differences were observed in intake and digestibility in dairy cows fed FC or DC (San Emeterio et al., 2000).

The capacity of the ruminant to digest and absorb starch is still a matter of controversy. The capacity for digestion of raw starch in the small intestine is limited to between 100 and 200 g d⁻¹ in sheep (Ørskov et al., 1974). Starch should account for less than 30% of ration DM intake (Armstrong and Smithard, 1979) to achieve the maximum ration nutritive value in

terms of intake and digestibility (Armstrong and Smithard, 1979). If higher than 30% in the ration DM intake, starch can cause digestive disturbances in sheep (Mulholland et al., 1976). The starch level of up to 10% of ration DM intake has little effect on fibre digestibility, while 5% slightly depresses both intake and live weight gain (Mulholland et al., 1976; Cerrila and Martinez, 2003). The inclusion of at least 10% of starch is needed to achieve a gain in tissue energy storage while the appreciable energy retention only occurs when the diet contains at least 20 % starch (Mulholland et al., 1976; Tanveer et al., 1999).

Therefore, the objective of this study was to determine the impact of DC and FC supplementation to AH (*Medicago sativa* L.) at 5 and 10 g d kg⁻¹ body weight on feed intake, digestibility and N balance in wether sheep.

We hypothesised that: (i) FC would be a better supplement to AH than DC; (ii) that both corn supplementation levels to AH would positively affect the ration nutritive value in terms of intake, digestibility and N balance.

Materials and Methods

Sward and silage production

Alfalfa haylage (AH) was produced on 22 May in the early flowering stage (10-15% of the flowering crop). The crop was mown and allowed to wilt for 24 hours before being harvested at 400-500 g dry matter (DM) kg⁻¹ fresh sample with a round baler. The bales were wrapped in four layers of 500-mm wide white plastic film. The weather at harvest was warm and sunny with an average daily temperature of 23.5°C varying from 20.5°C to 30.6°C (Croatian Meteorological and Hydrological Service, 2009).

The source of kernels for fermented corn (FC) and dry corn (DC) was the maize hybrid FAO 200 group. It was sown on 5 May at the row spacing of 0.7m at the Experimental Station owned by the Zagreb Faculty of Agriculture. The soil was previously cultivated (30-32 cm plowing) and the seedbed prepared and fertilised (150 kg N ha^{-1} , $120 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$, $120 \text{ kg K}_2\text{O ha}^{-1}$). The mean daily temperatures during the growing season of September 2009 are shown in Table 1.

The corn crop was harvested after it had reached the phase of physiological maturity recognised in the emergence of a black layer at the base of the grain (Daynard and Duncan, 1969). For FC, as soon as the fresh corn kernels were harvested, they were mechanically ground to particles from 1 to 3 mm and immediately placed into jumbo bags (600 kg of fresh material bag^{-1}) to allow fermentation for at least 30 days. For DC, after having been artificially dried at temperatures ranging from 35 to 46 °C (Wych, 1988), the kernels were stored unground in 3 plastic bins (50 L each) until required for experimental purposes when they were mechanically ground to particles sized from 1 to 3 mm.

Dietary Treatments

The experiment consisted of 5 feeding treatments for Suffolk wethers: AH alone, AH supplemented with 5 or 10 g of DC (DC5 and DC10, respectively) d kg^{-1} body weight, or AH supplemented with 5 or 10 g of FC (FC5 and FC10, respectively) d kg^{-1} body weight. Corn provided for about 100 and 200 g starch intake daily. It was offered separately twice daily in equal amounts and no refusals remained.

Just prior to the start of the experiment, the FC was compressed into 5 plastic bags (approximately 30 L each) and stored in a cold chamber that was maintained at a temperature of 4 °C. The DC was ground using a hammer mill with a 3-mm screen, compressed into 5

plastic bags (approximately 30 L each) and stored in the same cold chamber as the FC. The AH was chopped to approximately 3-5 cm particle size using a commercial chopper. The chopped material was compressed into plastic bags (approximately 10 kg AH bag⁻¹) and stored in the same cold chamber as the FC and DC. The AH and the supplements were fed separately. No additional supplementary feeds were provided.

For feeding, 5 or 10 g kg⁻¹ body weight d⁻¹ of FC and DC were measured into plastic bags and fed in two equal rations.

The cages were equipped with individual drinkers that were cleaned daily and the animals were provided *ad libitum* fresh water throughout the experiment.

Animal Management and Experimental Design

Five 7-month old Suffolk wethers were selected on the basis of BW (mean BW 52 kg, s.d. 5.8 kg) and condition scores. All the animals were treated for internal parasites prior to the experiment. The sheep were subjected to artificial lighting from 08:00 a.m. to 08:00 p.m. daily.

A feeding trial was performed with five wethers and five treatments over five periods using a balanced 5x5 Latin square design. The sheep were allocated at random to the five dietary treatments. A 10-day acclimatisation period was followed by an 11-day measurement period (a 4-day *ad libitum* intake period was followed by 7 days of *ad libitum* intake and digestibility measurements), where the offered and refused feed was measured and the total faeces collected. The animals were housed in individual pens (1.5 x 2.2 m) during the acclimatisation period and in individual crates (1.36 m x 1.53 m x 1.49 m) during the measurement period. Animals were fed twice a day (09:00 a.m. and 04:00 p.m.) in equal

amounts. Wethers were fed AH *ad libitum* during the 4-day period, while over the following 7-day period the rations were designed to ensure a daily refusal margin of 10–15% AH.

Voluntary Feed Intake

During the measurement period, the fresh weights and DM contents of the DC, FC and the AH offered, as well as the AH refused, were recorded daily. Samples of the offered feed were taken daily and stored at a temperature of -20°C until the end of the experiment, when they were separately bulked prior to chemical analyses. The daily samples of the refused feed were bulked on an individual animal basis and stored at a temperature of -20°C prior to chemical analyses.

The daily production of faeces and urine was collected separately. The daily output of urine from each animal was preserved by acidification (100 ml of 2 mol l^{-1} sulphuric acid was added to achieve a pH value of 2-3), and its volume was measured. The daily samples of urine from individual animals were then bulked over the measurement week and stored at -20°C until analysed. The total daily faecal production of each animal was stored frozen at -20°C until the completion of the collection period. The bulked faecal output from each animal was then weighed and sampled prior to subsequent analyses. The sheep were weighed on the 10th, 14th and 21st day of each period, and the mean weight was used to calculate the daily DC and FC supplements for each animal.

The conducted experiment followed the Council Directive issued by the European Economic Community (EEC) (1986) on the approximation of laws, regulations and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes.

Chemical Analyses

The DM contents of the offered feed, refused feed and faeces were determined by oven drying to a constant weight at 60 °C in a fan-assisted oven (ELE International) (Bedfordshire, United Kingdom). The ash contents of the offered feed, refused feed and faeces were measured by igniting the samples in a microwave oven (Milestone PIYRO, Italy) at 550 °C for 3 hours. The total N concentrations of the offered feed, refused feed, faeces and urine were determined by applying the Kjeldahl method (AOAC 1990, ID 954.01) using a Gerhardt nitrogen analyser. In addition, N concentration was expressed as crude protein (CP) (total N x 6.25) g kg⁻¹ DM for the offered feed and refused feed.

The contents of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed using the procedure described by Van Soest et al. (1991), utilising the Ankom Filter bag technology (USA) with Ancom fiber bags. The pH of the silage was determined in a water extract containing 10 g of fresh silage and 100 ml of distilled water, using a pH meter 315i (WTW). Volatile fatty acids (VFA) were measured by liquid gas chromatography, and lactic acid content was determined enzymatically on an Express Auto biochemical analyser in a water extract using the juice expressed from the silage. The zein concentration was determined using the procedure described by Wallace et al. (1990). The corn particle size was determined as described by Baker and Herrman (2002) using Pennsylvania screens. The net energy for lactation (NEL) was calculated according to the following equation: NEL (Mcal/kg) = 0.0929 x Fat % + 0.0547 x Crude Protein % + 0.192 (NRC, 2001).

Statistical Analyses

The data was analysed using mixed model procedures (SAS, 1999). The mean separation was calculated using the LSD values if the F-test was significant at p=0.05. Additionally,

orthogonal contrasts were made of feed and water intake, digestibility and N balance using the CONTRAST statement of SAS. The following model was applied: $Y_{ij} = \mu + T_i + P_j + e_{ij}$, where Y is the overall model, μ is the grand mean, T is the treatment, P is the period, e is the experimental error, I is the number of treatments, and j is the number of periods.

Chemical composition of AH, FC and DC is presented in Table 2. Chemical composition of the ration fed to wether sheep is presented in Table 3. **Results**

The DC5 and FC5 treatments were higher in ADF and NDF intake ($P < 0.001$) (Table 4) (g d^{-1}) compared with the DC10 and FC10 treatments.

The starch intake was similar between similar supplementation levels of DC and FC. The zein intake was higher ($P < 0.05$) for FC supplementation than for DC supplementation between similar supplementation levels.

Both energy sources (DC and FC) and supplemental levels (5 and 10 g kg^{-1} body weight d^{-1}) increased ($P < 0.05$) the digestibility of DM and organic matter (OM), and the digestibility of OM in DM (D-value), and decreased the digestibility of ADF ($P < 0.05$) compared with the AH alone. The DC10 and FC10 treatments had higher D-values ($P < 0.05$) and reduced ADF digestibility values ($P < 0.05$) compared with the DC5 and FC5 treatments.

The highest starch digestibility was observed with the DC5 treatment ($P < 0.05$), followed by the FC5 and FC10 treatments, which were similar, while the lowest starch digestibility ($P < 0.05$) was recorded for the DC10 treatment.

Both energy sources (DC and FC) and supplemental levels (5 and 10 g kg^{-1} body weight d^{-1}) had reduced ration N intake ($P < 0.05$), higher N output in the faeces ($P < 0.05$) and reduced CP

digestibility ($P < 0.05$) values compared with the AH alone treatment (Table 5). Among supplemented treatments, DC5 had increased N intake ($P < 0.01$), reduced faecal N excreted (g kg^{-1} of N intake) and increased CP digestibility values ($P < 0.05$). The FC supplemented treatments had reduced N balances compared with the AH alone and DC treatments which were similar.

DC supplementation resulted in a reduced N output in the faeces ($P < 0.001$) and in the urine ($P < 0.01$), and therefore in higher N balance ($P < 0.001$) and CP digestibility ($P < 0.05$) values compared with the FC supplementation treatments (Table 5).

The faeces that originated from animals fed AH alone had higher DM ($P < 0.05$) and pH ($P < 0.001$) (Table 6) values compared with the faeces that originated from animals fed with the supplementation treatments. Similar lactic acid concentrations were recorded in the faeces that originated from animals fed with the DC5 and FC5 treatments, and similar lactic acid concentrations were also found in the faeces that originated from animals fed with the DC10 and FC10 treatments.

Discussion

Feed Intake

The voluntary DM intake levels across the five feeding treatments were within the reported intake range of $800\text{--}1100 \text{ g d}^{-1}$ for 50 kg intact male lambs (AFRC, 1993). The supplementation of DC and FC reduced the DM intake (DMI) of AH, which may be due to the effects of grain feeding on rumen fermentation. Besides, the DMI in lambs is influenced by the ration energy concentration, in that lambs fed a low energy ration have a higher feed intake than with a high energy ration (Sayed, 2009). This study confirms it given that the

lower corn (starch) supplementation level resulted in a higher DMI, ADF and CP intake compared to the higher supplementation rate. Neither the level nor the source of supplementation affected the overall ration DMI, which might be explained by the level of starch (10 and 20% out of the ration DMI) recommended for protein forage to prevent the negative impact of starch on the ration nutritive value (Mulholland et al., 1976; Tanveer et al., 1999).

Earlier research (Robinson and Kennelly, 1988; McCarthy et al., 1989) reported a decrease in the DMI when more than 30% of starch was supplemented to high protein forage in dairy cows. The authors (Robinson and Kennelly, 1988; McCarthy et al., 1989) reported fluctuations in the rumen pH due to the excess fermentation of starch to volatile fatty acids in the rumen, which overwhelmed the buffering and absorptive capacity of the rumen thus resulting in the lower DMI.

Due to similar starch concentrations in DC and FC, and the fact that the sheep consumed all the corn offered, the starch intake was similar with similar supplementation levels.

In this research, the AH was of high intake potential because it was consumed in larger amounts as the concentrate decreased (Waldo, 1986). Besides, due to high forage in the diet (80-100%) the forage quality had a greater impact on the ration intake than the corn supplementation level did (Waldo, 1986). This is confirmed by a higher NDF and ADF intake with a lower corn supplementation level.

Previous research (Waldo, 1986, Van Soest et al., 1991) reported that the cell wall concentration of forage diets is the best single chemical predictor of intake. Allen (2000) reported that no effect of NDF ranging from 25% to 40% was found on DM intake in dairy cows, although the feed intake generally decreases as NDF increases. That was not the case

in this research where the fibre concentration in the diet did not influence the DMI. This might be explained by the fact that AH was of good quality and chopped prior to feeding (3-5 cm), which encourages intake (Minson, 1982). Consequently, the intake was probably regulated by energy rather than physical fill (Allen, 2000).

In Vivo Digestibility

Improvements in the digestibility of DM and OM and the D-value in corn supplementation are in agreement with previous results showing improved digestibility of rations based on high protein forages supplemented with fermentable energy (Ørskov et al., 1970; Vranić et al., 2008). Increased OM digestibility was associated, in some cases, with improved NDF digestibility, whereas there was no effect on starch digestibility (Gado et al., 2009; Klingerman et al., 2009; Gencoglu et al., 2010) or on true digestibility of OM in the rumen (Hristov et al., 2008).

Soluble sugars and starch generally ferment rapidly in the rumen, depressing the pH of the rumen, which can adversely affect microbial growth and cellulolytic activity (Mould et al., 1983; Grant, 1994). Corn starch decreases fibrolytic activity, which further reduces fibre digestibility (Minson, 1982). It was probably the case in the present study where a higher starch level (20% in DM intake) reduced fibre intake and fibre digestibility compared to the lower supplementation level (10% in DM intake).

The reduced N digestibility accompanying increasing starch levels in the ration is consistent with previous results, where energy supplements to forage-based rations also reduced the N digestibility (Ferrell et al., 1999; Migwi et al., 2011). In the present study, FC supplementation, unlike DC supplementation, resulted in an increased N output in the faeces (% of intake) and in urine, and in lower CP digestibility. Previous research reported

depressed apparent total tract N digestibility with supplementation containing a higher level of starch (30%) (Taniguchi et al., 1995).

Ørskov et al. (1970) reported a greater loss of N with the faeces of sheep due to a limited but substantial capacity for starch fermentation in the large intestine, which indicated increased levels of microbial synthesis in the large intestine and the subsequent loss of nitrogen to the faeces. The result of starch fermentation in the large intestine is a lower pH and higher lactic acid in the faeces of sheep (Ørskov et al., 1970), which might support the present results where the lower starch level in the diet resulted in a reduced starch and lactic acid concentration in the faeces, compared to the higher starch supplementation level. In addition, in the study by Reynolds et al. (2001), the faecal pH decreased from 6.64 to 6.26 with the starch infusion, indicating that some of the infused starch escaped digestion in the small intestine and fermented in the hindgut.

The nearly complete digestion of dietary starch observed in the present study (from 0.949 in the DC10 treatment to up to 0.987 in the DC5 treatment) is consistent with the study by Armstrong and Beever (1969), which showed a high level of dietary starch digestion in cattle fed with ground corn. Previous research has shown that both cattle and sheep are able to digest almost all dietary starch (Waldo, 1973).

On average, the apparent digestibility of starch is almost twice as high as that of NDF when fed to lactating dairy cows (Firkins et al., 2001), which should increase the digestible energy (DE) concentrations of diets. For starch digestibility, there were no clear differences recorded in this study between the starch levels supplemented in the diet or the conservation methods applied.

The increased zein intake observed in the FC supplemented treatments did not reduce the total tract starch digestibility, likely due to the smaller particle size in FC compared to DC (Owens et al., 1997) and the impact of the ensiling process, which improves starch degradation by significantly altering the rapidly degradable starch fraction (80.7% in FC versus 65.6% in DC) and the starch degradation rate (12.4% versus 8.0%/h) (Jurjanz and Monteils, 2005).

Nitrogen -Balance

In view of the substantial environmental impact of livestock production (Stehfest et al., 2013), the N output of livestock production systems is to be reduced by improving N utilisation by animals (Hoekstra et al., 2011).

Higher CP concentration in AH alone treatment resulted in a higher N intake compared to DC and FC supplemented treatments. A higher level of starch supplementation to AH increased the N output in faeces but reduced the N output in urine. There were no differences in N utilisation when compared to the lower starch supplementation level to AH.

The faecal N, which includes N of metabolic origin and varies with DM intake (AFRC, 1993), was within the range of 21-40 g N kg⁻¹ of DMI (NRC, 2001). The increased faecal N excretion observed in animals fed with the DC or FC supplemented to AH can be attributed to an extensive microbial fermentation activity (Siddons, 1968; Orskov et al., 1972).

The increased efficiency of N utilisation observed for DC supplementation compared to FC supplementation is in contrast to the results of previous studies (Harpster et al., 1975), where FC was reported to be superior to DC for nitrogen retention. Consequently, more starch originating from FC was probably digested in the colon, thus increasing the production of

microbial N (Plascencia and Zinn, 1996; Knowlton et al., 1998) which was not absorbed but was instead excreted with the faeces (Armstrong and Smitha, 1979).

Conclusions

It was concluded that DC was a better supplement to AH than FC in terms of NDF intake, CP digestibility and N balance. The main effect of increasing the level of starch supplementation to the diet was a reduced N and fiber intake, as well as N and fiber digestibility, but an increased D-value. The results of this research might be of general interest, especially in areas where high protein forage is produced.

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Table 1 Monthly mean temperature and total rainfall during the growing season of 2009 and the 30 year averages (Maksimir, Zagreb)

Month	2009		30-years average	
	Mean temperature (°C)	Rainfall (mm)	Mean temperature (°C)	Rainfall (mm)
April	14,5	52	10,5	59
May	18,4	49	15,3	75
June	19,8	68	18,6	98
July	22,2	96	20,4	79
August	22,6	79	19,5	96
September	18,9	22	15,8	78

† Average for period 1963.-1992.

Table 2.

Chemical composition of alfalfa haylage, fermented corn and dry corn fed to wether sheep.

Chemical composition	AH	DC	FC	SEM	P
DM (g/kg fresh)	535 ^c	915 ^a	796 ^b	7.9	<0.001
OM (g/kg DM)	916 ^b	980 ^a	985 ^a	2.2	<0.001
CP (g/kg DM)	171 ^a	97 ^c	102 ^b	4.4	N.S.
NDF (g/kg DM)	459 ^a	101 ^b	98 ^b	17.0	N.S.
ADF (g/kg DM)	378 ^a	35 ^b	34 ^b	14.9	<0.001
Starch (g/kg DM)	N.D.	703	705	5.1	N.S.
Starch digestibility	N.D.	0.883 ^a	0.933 ^b	0.005	<0.001
Zein (g/kg DM)	N.D.	64.5 ^b	73.2 ^a	1.5	<0.01
Zein (% of starch)	N.D.	9.2 ^b	10.4 ^a	0.27	<0.01
Particle size (µm)	N.D.	1290 ^a	915 ^b	16.5	<0.001

Calculative values

NEL (MJ kg ⁻¹ DM)	5.2 ^c	8.2 ^b	8.6 ^a	0.15	<0.05
PDIN	11.5	7.7	7.5	N.D.	N.D.
PDIE	10.8	10.1	8.3	N.D.	N.D.
Fermentation characteristics					
pH	5.0 ^b	N.D.	6.1 ^a	0.06	<0.001
Lactic acid (g/kg DM)	16.9 ^a	N.D.	0.9 ^b	1.9	<0.001
Acetic acid (g/kg DM)	14.5 ^a	N.D.	0.8 ^b	4.0	<0.05
Butyric acid (g/kg DM)	0	N.D.	0	-	-
NH ₃ -N (g N/kg total N)	79.9 ^a	N.D.	16.3 ^b	1.1	<0.001

AH: alfalfa haylage; DC: dry corn; FC: fermented corn; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; N: nitrogen; NEL: neto energy of lactation; PDIN: protein digestible in the small intestine; PDIE: digestible protein in the small intestine supplied by microbial protein from rumen-fermented OM; PDIN: digestible protein in the small intestine supplied by microbial protein from rumen-degraded protein; SEM: standard error of the mean; N.D.: not determined; N.S.: not significant (P>0.05); Values within the same row with different superscript (a, b, c) differ significantly (P< 0.05).

Table 3

Chemical composition of the ration fed to wether sheep.

Item	Feeding treatment					SEM	P
	AH	DC5	DC10	FC5	FC10		
CP (g/kg DM)	178 ^a	165 ^b	154 ^c	163 ^d	157 ^{cd}	4.6	<0.05
ADF (g/kg DM)	379 ^a	333 ^b	282 ^c	327 ^d	280 ^{cd}	10.1	<0.05
NDF (g/kg DM)	508 ^c	451 ^b	393 ^a	438 ^b	381 ^a	12.5	<0.05
Starch (g/kg DM)	N.D.	101 ^a	203 ^b	102 ^a	198 ^b	4.5	<0.001

Zein (g/kg DM)	N.D.	22.1 ^a	50.4 ^b	28.9 ^c	56.8 ^d	0.4	<0.05

AH: alfalfa haylage; DC5: alfalfa haylage supplemented with 5 grams of dried corn grain kg⁻¹ of body weight; DC10: alfalfa haylage supplemented with 10 grams of dried corn grain kg⁻¹ of body weight; FC5: alfalfa haylage supplemented with 5 grams of fermented corn kg⁻¹ of body weight; FC10: alfalfa haylage supplemented with 10 grams of fermented corn kg⁻¹ of body weight; CP: crude protein; ADF, acid detergent fibre; NDF, neutral detergent fibre; SEM.: standard error of the mean; NS: not significant (P>0.05); Values within the same row with different superscript (a, b, c) differ significantly (P< 0.05); N.D., not determined.

For Review Only

Table 4

Voluntary feed intake and total tract *in vivo* digestibility of alfalfa haylage fed alone to wether sheep or supplemented with dry corn or fermented corn.

Item	Feeding treatment					SEM	P	§Contrast significance		
	AH	DC5	DC10	FC5	FC10			p1	p2	p3
Voluntary intake (g d ⁻¹)										
DM from AH	961 ^a	875 ^b	692 ^d	792 ^c	709 ^d	24.6	<0.001	<0.001	<0.001	NS
DM from DC	N.D.	146 ^b	280 ^a	N.D.	N.D.	5.4	<0.001	N.D.	N.D.	N.D.
DM from FC	N.D.	N.D.	N.D.	145 ^b	279 ^a	5.8	<0.001	N.D.	N.D.	N.D.
DM from total diet	961	1021	972	937	988	27.7	NS	NS	NS	NS
OM from total diet	873	943	908	867	925	25.7	NS	NS	NS	NS
ADF from total diet	365 ^a	340 ^a	274 ^c	307 ^b	277 ^c	13.5	<0.05	<0.001	<0.001	NS
NDF from total diet	444 ^a	425 ^a	357 ^b	380 ^b	352 ^b	16.6	<0.01	<0.001	<0.001	<0.05
Starch	N.D.	103 ^a	197 ^b	103 ^a	196 ^b	6.5	<0.001	N.D.	N.D.	N.D.
Zein intake	N.D.	9.4 ^d	18 ^b	11 ^c	20 ^a	0.6	<0.05	N.D.	N.D.	N.D.
Digestibility										
DM	0.615 ^a	0.619 ^{ab}	0.649 ^b	0.648 ^b	0.652 ^b	0.011	<0.05	<0.05	NS	NS
OM	0.637 ^a	0.642 ^a	0.673 ^b	0.675 ^b	0.677 ^b	0.010	<0.01	<0.05	NS	NS
ADF	0.439 ^a	0.416 ^{ab}	0.385 ^b	0.417 ^{ab}	0.388 ^b	0.014	<0.05	<0.05	<0.05	NS
D-value	0.593 ^a	0.595 ^a	0.631 ^b	0.622 ^b	0.636 ^b	0.011	<0.05	<0.05	<0.05	NS
Starch	N.D.	0.987 ^a	0.949 ^b	0.973 ^c	0.977 ^c	0.032	<0.05	N.D.	N.D.	N.D.

AH: alfalfa haylage; DC5: alfalfa haylage supplemented with 5 grams of dried corn grain kg⁻¹ of body weight; DC10: alfalfa haylage supplemented with 10 grams of dried corn grain kg⁻¹ of body weight; FC5: alfalfa haylage supplemented with 5 grams of fermented corn kg⁻¹ of body weight; FC10: alfalfa haylage supplemented with 10 grams of high moisture corn kg⁻¹ of body weight; DM: dry matter; OM: organic matter; ADF: acid detergent fibre; D-value: the digestibility of the organic matter in the dry matter; SEM.: standard error of the mean; N.D.: not determined; NS: not significant (P<0.05); Values within the same row with different superscript (a, b, c) differ significantly ($p < 0.05$). §Orthogonal contrast significance: p1: AH vs. DC5, DC10, FC5, FC10; p2: DC5, FC5 vs. DC10, FC10; p3: DC5, DC10 vs. FC5, FC10.

Table 5

Nitrogen utilization of alfalfa haylage fed alone to wether sheep or supplemented with dry or fermented corn

Item	Feeding treatment					SEM	P	[§] Contrast significance		
	AH	DC5	DC10	FC5	FC10			p1	p2	p3
N intake (g/d)	27.3 ^a	27.0 ^a	24.0 ^b	24.9 ^b	24.9 ^b	0.7	<0.01	<0.05	<0.05	NS
Fecal N (g/d)	5.4 ^a	6.9 ^b	7.9 ^c	8.7 ^d	9.8 ^e	0.1	<0.001	<0.001	<0.001	<0.001
Fecal N (g/kg of N intake)	198 ^a	255 ^b	329 ^c	349 ^c	394 ^d	17.3	<0.05	N.D.	N.D.	N.D.
Urinary N (g/d)	10.7	9.6	5.8	9.8	7.6	0.4	<0.001	<0.001	<0.001	<0.01
Urinary N (g/kg of N intake)	392 ^a	355 ^b	241 ^c	393 ^{ab}	305 ^d	23.0	<0.05	N.D.	N.D.	N.D.
N balance (g/d)	11.2 ^a	10.5 ^a	10.3 ^a	6.4 ^b	6.5 ^b	0.7	<0.001	<0.01	NS	<0.001
CP digestibility	0.802 ^a	0.740 ^b	0.670 ^c	0.650 ^c	0.606 ^d	0.0102	<0.05	<0.05	<0.01	<0.05

AH: alfalfa haylage; DC5: alfalfa haylage supplemented with 5 grams of dried corn grain kg⁻¹ of body weight; DC10: alfalfa haylage supplemented with 10 grams of dried corn grain kg⁻¹ of body weight; FC5: alfalfa haylage supplemented with 5 grams of fermented corn kg⁻¹ of body weight; FC10: alfalfa haylage supplemented with 10 grams of fermented corn kg⁻¹ of body weight; CP: crude protein; SEM.: standard error of the mean; NS: not significant (P>0.05); Values within the same row with different superscript (a, b, c) differ significantly (P< 0.05); N.D., not determined; [§]Orthogonal contrast significance: p1: AH vs. DC5, DC10, FC5, FC10; p2: DC5, FC5 vs. DC10, FC10; p3: DC5, DC10 vs. FC5, FC10.

Table 6

Chemical composition of faeces originated from alfalfa haylage fed alone to wether sheep or supplemented with dry or fermented corn.

Item	Feeding treatment					SEM	P
	AH	DC5	DC10	FC5	FC10		
DM (g kg ⁻¹ fresh)	310 ^a	293 ^b	258 ^c	277 ^d	237 ^e	5.2	<0.05
Moisture (g kg ⁻¹ fresh)	689 ^a	707 ^b	742 ^c	722 ^d	763 ^e	5.2	<0.05
pH	7.97 ^a	7.78 ^b	7.37 ^c	7.79 ^b	7.33 ^c	0.034	<0.001
Starch (g kg ⁻¹ DM)	N.D.	36.7 ^a	278.3 ^b	79.8 ^c	131.3 ^d	1.03	<0.01
Lactic acid (g kg ⁻¹ DM)	N.D.	1.08 ^a	3.67 ^b	1.15 ^a	3.85 ^b	0.15	<0.001

AH: alfalfa haylage; DC5: alfalfa haylage supplemented with 5 grams of dried corn grain kg⁻¹ of body weight; DC10: alfalfa haylage supplemented with 10 grams of dried corn grain kg⁻¹ of body weight; FC5: alfalfa haylage supplemented with 5 grams of fermented corn kg⁻¹ of body weight; FC10: alfalfa haylage supplemented with 10 grams of fermented corn kg⁻¹ of body weight; DM: dry matter; SEM.: standard error of the mean; Values within the same row with different superscript (a, b, c, d) differ significantly (p < 0.05); N.D., not determined.