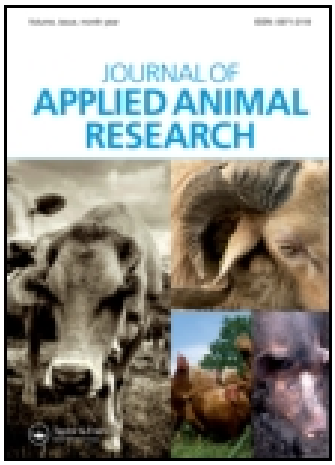

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The influence of steam treated sugarcane pith on digestibility, rumen passage rate and fermentation of Iranian Baluchi sheep

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Four rumen and abomasum-fistulated Iranian Baluchi sheep in a 4 × 4 Latin square design as changeover order were used to study the effect of steam treated sugarcane pith (STP) (210 °C,19 bar, 3 min, moisture 70%) on digestibility, rumen passage rate and fermentation by continuous marker infusion technique. The result showed that intake and apparent digestibility of dry matter (DM) are not influenced by treatment, but the high level of pith had the highest digestibility of neutral detergent fiber (NDF) (61%) and acid detergent fiber (ADF) (51%) ($P < 0.05$). Treatments significantly affected rumen nutrients digestibility ($P < 0.05$), as digestibility of DM (47 vs. 59.41 g/d), NDF (65 vs. 73%) and ADF (58 vs.70%) was highest in diet containing 120 g/kg pith (STP12) vs. 0.0 g/kg (STP0). Dry matter (50 vs. 42 g/kg DM), crude protein (CP) (131 vs. 108) and NH_3-N (172.2 vs. 147.1 mg/l) of abomasum, respectively, for STP0 and STP12, were linearly affected by treatments ($P < 0.05$). Processing with steam affected dilution rate (DR), rumen turnover time (TT), out flow rate (OFR) and mean retention time (MRT) ($P < 0.05$). The highest DR (8.35 vs. 7.09) and OFR (0.47 vs. 0.36 L/h) were obtained for STP0 in comparison to STP12. It seems that nutritive value of sugarcane pith as feed for ruminants could be improved by steam treatment.

Keywords: continuous infusion; rumen volume; steam treatment; turnover time

Introduction

Sugarcane (*Saccharum officinarum*) is an important crop in tropical and subtropical regions of the world (Horton et al. 1991; Chaji et al. 2010a). By-products such as straw, stover and bagasse are the staple livestock feed of south-east Asia, and interest in their use as livestock feed in many other parts of the world is increasing as the prices of better quality feeds go up (Jackson 1977; Xu et al. 2006). However, low digestibility, high lignin and very low nitrogen content are considered as the main reasons for unsatisfactory performance of animals fed these roughages (Osorio and Cruz 1990, Chaji et al. 2010b). Chemical methods, e.g. alkali and steam treatments, improve voluntary intake and nutritive value of low-quality roughages due to the potential and effective degradation of cell wall by rumen microbes (Jackson 1977; Panjaitan et al. 2010). In order to understand more fully the processes of digestion, knowledge of the mean retention time (MRT) and rate of removal of particular components of the diet is required (Faichney 1975; Huhtanen et al. 2006). If the digesta sample obtained is representative, only a single marker is required to estimate total flow. The marker need not be ideal nor associate with any particular phase as the method does not distinguish between different phases (France and Siddons 1986). Ulyatt (1967) showed that with continuous feeding, steady state conditions within the rumen can be closely approached. Under similar feeding conditions Weston and Hogan (1967) found that when Cr-EDTA was infused continuously into the rumen the concentration of marker in the rumen remained relatively constant within and between days.

Since in literatures there was not enough information about *in vivo* study of sugarcane pith and its efficacy on performance and rumen fermentation parameters, in particular passage rate, the objective of this investigation was to evaluate the effect of steam (210 °C, 19 bar, 3 min., moisture 70%) treated sugarcane pith (STP) as feed ingredient on rumen and total gastro-intestinal tract (GIT) apparent digestibility, fermentation, volume and passage rate parameters.

Materials and methods

Animals and experimental diets

This experiment was conducted at the research farm of Ferdowsi University of Mashhad. Four Iranian Baluchi sheep in a 4 × 4 Latin square design as

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changeover order were used in the present study. The wethers (35 ± 1.50 kg) were fitted with rumen cannulae in the dorsal sac and abomasal cannulae close to the pylorus were housed indoors and confined in metabolism cages. Before starting the main experiment, for determination of dry matter intake (DMI), the sheep were offered, once daily, approximately 120% of the expected daily feed consumption; they had access to the feed for 24 h each day. When the ration was given at a constant level, it was offered in equal portions at intervals of 3 h by means of an automatic interval feeder (Beenston 1964; Weston and Hogan 1967). Duration of each period was 29 d consisting of 14 d adaptation, followed by 7 d fecal collection periods, 6 d continuous injection of marker and abomasal sampling and 2 d rumen fluid sampling after injection was stopped.

High-pressure steam treatment

The high-pressure steam-treated (HPST) sugarcane pith was prepared at 19 bar for 3 min (70% moisture) in a Monel pressure vessel (Emamkhomeini Co., Khuzestan-Iran). Before each treatment, air was purged from the pressure vessel with steam at 100 °C. Then the vessel was quickly heated by pressurising with saturated steam from a steam generator. Cooling was achieved by venting steam from the top of the vessel (Chaji et al. 2010b).

Steam treated sugarcane pith (19 bar, 3 min, moisture 70%), wheat straw and wheat bran were prepared for feeding by chopping, and the size of the chopped hay particles was the same as for that described by Weston (1966). Experimental treatments consisted of (1) control diet (without STP, STP0), (2) 4% STP (STP4), (3) 8% STP (STP8) and (4) 12% STP (STP12) per DM of diet, which were substituted for wheat bran in control diet. The ingredient and chemical composition of the diets is shown in Table 1.

Table 1. Ingredients and chemical composition of experimental diets.

Ingredients	STP (g/kg DM of diet)			
	0	40	80	120
Alfalfa hay	300	300	300	300
Barley straw	200	200	200	200
Wheat bran	120	80	40	–
STP	–	40	80	120
Barely grain	360	350.8	350.6	350.4
Limestone	7	7	7	7
Salt	3	3	3	3
Min. and Vit.	10	10	10	10
Urea	–	0.2	0.4	0.6
Total	1000	1000	1000	1000
Chemical composition (g/kg DM)				
ME (Mcal/kg DM)	2.34	2.30	2.26	2.23
NDF	414	417	424.1	430.42
ADF	262	276.5	292.15	307.74
EE	24.44	23.30	22.33	24.44
CP	113.90	105.20	100.70	94.05
Ash	62.65	63.80	65	63.80
Calcium	5.80	5.73	5.69	5.60
Phosphorus	3.53	3.01	2.5	1.98

Note: STP, Steam treated pith; Min. and Vit., Minerals and vitamins mixture.

Preparation and administration of soluble chromium marker

Chromium-EDTA was prepared based on that described by Binnerts et al. (1968). About 14.2 g pure chromium trichloride ($CrCl3.6H_2O$) was dissolved in 200 ml distilled water whilst 20 g disodium salt of ethylene-di-amino-tetra-acetic acid (EDTA) was dissolved in 300 ml distilled water. The EDTA solution, together with two or three anti-bumping granules, was added to the Cr solution, covered with a watch glass and boiled gently for 1 h. For neutralising the small excess of EDTA, 4 ml calcium chloride 1 M was added and the pH adjusted on 6–7 by addition of NaOH solution (0.25 M), then made to 1000 ml, mixed well and stored in plastic bottles. The marker was infused continuously through rumen fistula for periods of 5–6 days according to procedures described by Hogan (1964). Continuous infusion was preceded by the administration of a priming dose of marker. With this priming dose, an attempt was made to provide the amount of marker expected to be maintained in the rumen during the experiment (Weston and Hogan 1967).

Measurement and analytical methods

About 120–180 ml of the abomasumal samples were obtained on two successive days (d 5 and d 6) during marker injection at 3 h interval; When injection was stopped, the rumen digesta was collected at 0, 3, 6, 9, 12, 15, 18, 24, 48 h, and pH of samples was measured (pH meter Metrohm 691, Swiss). Rumen digesta samples were obtained by suction from several sites in the rumen and bulked. Samples of rumen and abomasal liquors were prepared by filtering digesta through cheesecloth and stored in −20°C for subsequent analysis.

Dry matter intake was measured daily for all sheep on d 15–29 (Table 2). Samples of diets and orts were collected daily, dried at 65°C, ground through a Wiley mill (1-mm screen) and composited by animal within each period. Total feces were collected from all sheep for 7 d (d 15–21). Feces samples were dried at 65°C and ground through a Wiley mill (1-mm screen).

Table 2. Intake and digestibility of nutrients in Baluci sheep fed diet containing steam treated sugarcane pith.

	STP (g/kg DM of diet)					
	0	40	80	120	SEM	Effect
Intake (g/d)						
DM	831.37	823.37	80.57	839.83	11.83	NS
OM	775.50	769.52	801.88	780.20	15.61	NS
Ash	53.86a	53.85a	58.69b	59.63b	1.13	L*
NDF	355.85a	358.42	368.65	377.90	7.35	NS
ADF	227.04a	240.90a	265.70b	274.20b	3.62	L*
CP	111.36a	105.25ab	103.41b	95.08c	1.43	L*
EE	20.97a	19.80ab	19.46b	17.88c	0.27	L*
Fecal nutrient output (g/d)						
DM	332.29	323	334.29	309.63	6.48	NS
NDF	176.79a	164.71a	165.95a	147.92b	4.76	L*
ADF	129.75	128.27	133.38	118.18	3.88	NS
CP	35.82	36.59	36.04	35.31	0.56	NS
EE	4.95	5.15	4.93	4.21	0.33	NS
Nutrient digestibility (g/kg)						
DM	600.1	604.4	605.9	629.7	6.90	NS
OM	696.5	700.3	714.1	740.3	4.90	NS
NDF	507a	540.1b	563.7b	608.8c	6.90	L*
ADF	429.9a	467ab	497.8b	568.9c	11	L*
CP	677.8	649	651.3	628.3	10.10	NS
EE	764.8	737.1	746.6	763.5	14.10	NS

Note: STP, Steam treated pith, Least squares means. L:,Linear effect; NS, Not significant; and $*P < 0.05$.
Intake, output, and digestibility determined during feed sampling and fecal collection periods.

Feed, feces, orts as well as abomasumal samples were analysed for DM. Dry matter of TMR was determined by drying at 100 °C for 48 h.

Determination of total N was done by the Kjeldahl method (AOAC, 2002). Both ADF and NDF were measured according to the non-sequential procedures of Van Soest et al. (1991). Ether extraction in feed ingredients and diets was conducted with a Soxtec system HT6 apparatus (Tecator, Fisher Scientific, Montreal, QC, Canada) according to the method of AOAC (2002).

Using the chemical components of diet and feces, intake and digestibility of nutrients were calculated (Table 2). Portions of the collected sample were centrifuged for 30 min at 3000 rpm (Mistral 3000i, S. H. Scientific) (Grovum and Williams 1973), and Cr in the supernatant fraction was assayed by atomic absorption spectrometry at 357.9 nm using an acetylene flame (SP9, Pye Unicam Ltd, Cambridge, Cambs.) (Mathers et al. 1997). When a water-soluble marker is continuously infused into the rumen, the concentration of the marker in the rumen and abomasum should be relatively constant within and between days (Weston and Hogan 1967). This constant concentration of marker indicated that the rate of entry and exit of liquid into the rumen was constant (steady state) (Faichney 1975). Therefore, for testing the steady state condition in the rumen, 24 h after the start of continuous infusion (on d 17 and d 18), some samples were taken by 8 h interval, and the concentration of Cr in samples was measured. In the present experiments, when a water-soluble marker was continuously infused into the rumen, the concentration of the marker in the rumen relatively remained constant within and between days (Figure 1a). Thus it has been assumed that conditions in the rumen during these experiments approached a 'steady state'. The recommended equations of Weston and Hogan (1967) in steady state situation were used for calculation of rumen volume and passage rate parameters. Turnover time is the reciprocal of the absolute value of the natural logarithm of the slope of the regression line fitted to the declining phase of the marker disappearance (from rumen when injection was stopped) curve and is used to estimate the time of residence of the marker in a compartment (Grovum and Williams 1973; Ehle et al. 1982).

Statistical analysis

Using the PROC GLM procedure of SAS (1999), this experiment was carried out in a changeover design; four Baluchi wethers were allotted to four diets by a 4×4 Latin square design with the following model: $Y_{ijk} = \mu + T_i + S_j + P_k + e_{ijk}$, where Y_{ijk} was the dependent variable, μ is the overall mean, T_i is the random effect of the treatments ($i = 1, 2, 3$ and 4); S_j is the sheep effect; P_k is the effect of each period and

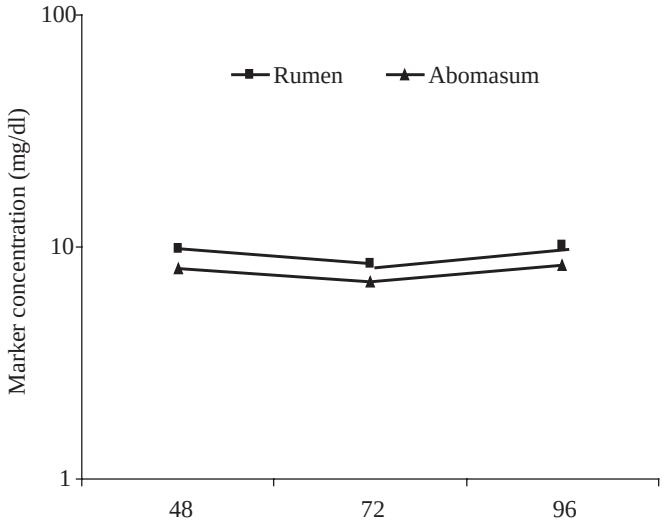

Fig. 1a

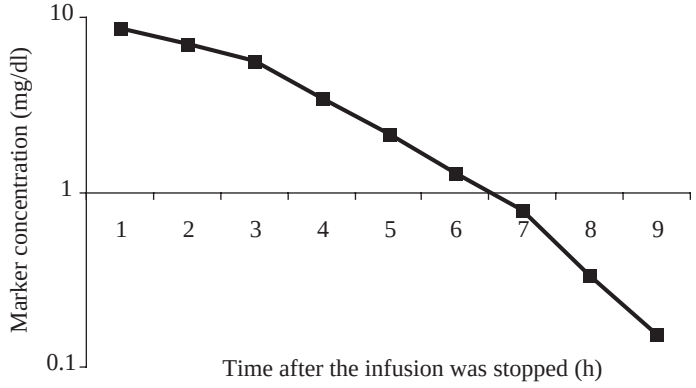

Fig. 1b

Figure 1. Mean concentration (log scale) of marker in the rumen liquor (■) and abomasal liquor (▲) of four sheep during continuous infusion of marker (Figure 1a) (0–96 h) and after the infusion was terminated (Figure 1b).

e_{ijk} is residual error. Ammonia nitrogen (NH_3-N) and pH data were analysed in a split-block arrangement of treatments with treatment in the main plot and time of sampling in the subplot.

Results

Intake and digestibility, estimating rumen nutrient digestibility by marker, composition of abomasums

The effect of STP on intake and total tract digestibility of nutrients in sheep are presented in Table 2. Intake of DM, OM and NDF did not affect by experimental treatment ($P > 0.05$), but there was a linear effect on ash and ADF intake (227 vs. 274 g/d for STP0 and STP12, respectively), as it was the greatest in sheep that consumed the diet containing of 12% STP ($P < 0.05$). In addition, increased percentage of the STP in diet linearly decreased CP (111.36 vs. 95.08 g/d in STP0 and STP12) and ether extract (EE) intake ($P < 0.05$). There was not any difference in fecal nutrient output between treatments ($P > 0.05$), except of NDF, which was lowest ($P < 0.05$) in STP12 (147.92 g/d). Digestibility of NDF and ADF linearly increased with increasing dietary STP ($P < 0.05$), but DM, CP and EE digestibility were not affected ($P > 0.05$), although, digestion of CP suggested a quadratic trend ($P = 0.07$) to decline.

Estimation of rumen nutrients digestibility is shown in Table 3. The treatment had noticeable effect on digestion of all nutrients, except OM ($P < 0.05$); increased percentage of STP in the diet linearly increased digestibility of DM, NDF, ADF, CP and EE. The effect of diet on NDF and ADF content of abomasum was not significant ($P > 0.05$). Content of DM (50 vs. 42 g/kg DM), CP (131 and 108 g/kg DM) and ammonia nitrogen (17.22 and 15.71 mg/dl), respectively, for STP0 and STP12,

Table 3. Estimating digestibility of nutrients in rumen of sheep fed STP.

	STP (g/kg DM of diet)					
	0	40	80	120	SEM	Effect
Digestibility (g/kg)						
DM	469.9b	535.4ab	563.3ba	594.1a	25.40	L*
OM	696.2	702.4	719.8	741.4	4.99	NS
NDF	649.3b	657.8b	715.1a	726.8a	25.80	L*
ADF	579.7b	632.9ab	689.9a	698.8a	27.30	L*
CP	481.7b	560.3a	588.3a	624.4a	24.70	L*
EE	568.7c	648.4b	683.6ab	749.6a	19.70	L*

Note: STP, Steam treated pith, Least squares means. L, Linear effect; NS, Not significant; and $*P < 0.05$.

linearly increase with increase in dietary STP ($P < 0.05$).

Rumen metabolites and digestion kinetics

Fermentation variables, volume and rumen fluid passage characteristics are shown in Table 4. Amount of NH_3-N, pH and volume of rumen was same between treatments ($P > 0.05$). Dilution rate (DR), turn over time (TT), out flow rate (OFR) and MRT (12.39 and 14 h in STP0 and STP12, respectively) were linearly affected by experimental diets ($P < 0.05$), as increasing the levels of STP in diet resulted in a decline of DR, TT and OFR, but increase of MRT.

Abomasal nutrients concentration is shown in Table 5. Abomasumal DM (50 vs. 42 g/kg DM), CP (131 vs. 108) and NH_3-N (172.2 vs. 147.1 mg/l), respectively, for STP0 and STP12, were linearly affected by treatments ($P < 0.05$).

The concentrations of marker in rumen and abomasal liquors during a representative experiment are shown in Figure 1a. Cr concentration of samples taken at 8 h interval, 24 h after the start of continuous infusion (on d 16 and d 17), was same to that maintained for the remaining infusion period.

Discussion

Intake and digestibility, estimating rumen nutrient digestibility by marker, composition of abomasums

There was a linear effect on ash and ADF intake. In respect of this fact that DMI of sheep in all treatments was same, therefore, existence difference in nutrient intake (ADF, CP and EE) (Table 2) reflected to chemical composition of wheat bran and STP, since this difference of diets attributed to the percentage of STP that situated for wheat bran (Table 6). Comparison of total GIT digestibility of nutrients (Table 2) with their ruminal digestion (Table 3) suggested that nutrients, which had lower digestibility in rumen, could be digested in hindgut, e.g. CP and EE.

In addition, there was a converse action about the cell wall (CW) materials (NDF and ADF), which could not be digested in hindgut, consequently most of them were digested in rumen. On the other hand, comparison nutrients between treatments showed that with increased percentage of STP and following fibre of diet, the difference of digestibility of total GIT with rumen was lower, and reverse. Probably, this indicated that for non-fibrous nutrient remain of digestion could be done after rumen.

Table 4. Ruminal metabolites and digestion kinetics of Baluchi sheep fed diets containing STP.

Items	STP (g/kg DM of diet)					
	0	40	80	120	SEM	Effect
PH	6.42	6.44	6.57	6.62		NS
NH_3 (mg/dl)	11.71	13.20	13.14	14.12		NS
Rumen kinetic						
Ruminal fluid dilution rate (%/h)	8.53a	7.66b	7.42b	7.09b	0.22	L*
Ruminal fluid volume (L)	5.45	5.21	5.035	4.05	0.94	NS
Turnover time (h)	11.97b	13.14a	13.53a	14.17a	0.34	L*
Ruminal outflow rate (L/h)	0.47a	0.397ab	0.374b	0.36b	0.03	L*
Mean retention time (h)	12.39b	13.19ab	13.50a	14.03a	0.40	L*
Marker pool (mg)[a]	445.58	425.11	397.79	375.81	32.80	NS

Note: STP, Steam treated pith, Least squares means. L, Linear effect; NS, non significant; $*P < 0.05$.
[a]Quantity of marker present in rumen (Weston and Hogan, 1967).

Table 5. Effect of diet containing STP on abomasum measures.

	STP (g/kg DM of diet)					
	0	40	80	120	SEM	Effect
Nutrients (g/kg DM)						
DM	49.8a	46.9ab	44.3bc	41.9c	1.46	L*
NDF	283.3	288.7	290	300	11.40	NS
NDF/NDFI	0.80	0.80	0.79	0.79	0.01	NS
ADF	216.6	220	230	243.3	9.90	NS
ADF/ADFI	0.95	0.91	0.87	0.90	0.05	NS
CP	131.1a	121.4ab	112.9bc	107.6c	3.42	L*
NH_3-N (mg/dl)	17.22a	16.73ab	16.31ab	15.71b	0.59	L*

Note: STP, Steam treated pith, Least squares means. L, Linear effect; NS, Not significant; and $*P < 0.05$.

It was shown (Tables 3 and 5) that nutrients which were lesser digested in rumen had more concentration in abomasum. For instance, in Table 5, concentration of abomasal CP in diets containing of less pith was higher. It means that the amount of CP digestion done in hindgut may be more, and vice versa for NDF.

Margan et al. (1982) and Martinez et al. (2005) demonstrated that more than three quarters of the cellulose digestion and less than half the hemicellulose digestion occurred in the rumen (Kumar et al. 2008). Animal enzymes cannot break down the bounds between sugars and also linkage of them with other non-carbohydrate content of CW materials (Cowling and Kirk 1976; Van Soest 1994; Kumar et al. 2008). Only enzymes of rumen microorganisms, if have enough time, are able to degradae the bounds (Hungate 1966; Van Soest 1994; McDonald et al. 2002; Perez et al. 2002; Martinez et al. 2005). Therefore, whatever fibre components more remained and be digested in rumen the efficiency of consuming energy is better (Grethlein et al. 1984; Kling et al. 1987). The result of present study agreed with these senses, as NDF and ADF ruminal digestibility increased linearly with increasing dietary STP (Table 3).

Table 6. The comparative chemical composition of STP and wheat bran.

	Feed			
Items (g/kg DM)	STP	Wheat bran	SEM	*P*
NDF	550a	412b	8.80	*
ADF	505a	143b	33.32	*
CP	23b	181a	6.60	*
Ash	110a	61b	17.6	*
Lignin (sa)	60a	30b	6.70	*
CL	445a	113b	10.40	*
HCL	45b	260a	9.40	*
CL/HCL	0.1b	2.3a	0.09	*

Note: STP, Steam treated pith; CL, cellulose; HCL, Hemicellulose; NS, Not significant; and $*P < 0.05$.

In spite of linearly increased in ruminal digestion of NDF and ADF with increased of STP, more concentration ($P > 0.05$) of these ingredient in abomasum perhaps attributed to the amount of their intake (see NDF/NDFI ratio and ADF/ADFI, Table 5). It has been shown that the higher intake was associated with reduced digestion of organic matter (OM) and fibre in the whole gastro-intestinal tract with increased of rumen passage rate and consequently decrease of MRT (Margan et al. 1982; Panjaitan et al. 2010; Hogan and Phillips 2011).

Rumen metabolites and digestion kinetics

Rumen ammonia concentration (Table 4) almost was placed among the highest values from the recommended range for maximum digestion or microbial protein production (8.8 to 13.3 mg NH_3-N/dl, Hume et al. 1970). Thus, it may be concluded that the ammonia concentration was enough for adequate microbial activity, but slightly lower than the minimum value (15 mg/dl) suggested by Preston and Leng (1987, cited by Castro and Machado 1990) as being necessary for optimum rates of digestion of fibrous feeds. On the other hand, ruminal ammonia was higher than those reported by Castro and Machado (1990) when steam treated bagasse fed to dry cows. This inhibitory effect on the NH_3-N production at the high steam pressures may be attributed to some anti-nutritional compounds produced during steam treatment (Liu and Orskov 2000). Castro et al. (1994) observed that low (134 °C) and high (210 °C) temperature steam treatment produced some compounds which could inhibit rumen microbial activity and that in the harsher treatment conditions, the greater amount of these anti-nutritional factors were produced. Since in present study, NH_3-N concentration was higher in diets containing higher STP, therefore, our observation was not similar to Castro and Machado (1990). Lowest concentration of NH_3-N in diet with 0.0% STP (12% wheat bran) may be

attributed to resistance of its protein to rumen degradability, 75% RUP (NRC 2001) as well as lowest MRT (Table 4); the protein digestion rate of wheat bran was reported to be about 20%/h (NRC 2001).

The rumen pH in all diets was above the critical level (pH = 6) considered as providing an adequate environment for cellulolytic bacteria (Russell and Wilson 1996; Palmonari et al. 2010) which conflicted that reported by Castro and Machado (1990). They reported that rumen pH in the animals receiving the steam treated bagasse was below the critical level, but agreed with Medeiros and Machado (1993) when there was 26–52% sugarcane bagasse (STB) in diet of steer. They demonstrated that, if basically the inclusion of STB were the responsible for the decreasing pH values, the diets with more STB should present lower pH, but, pH increases as the proportion of STB increases in the diets; they also indicated that when greater proportions of STB were provided it must have stimulated salivation.

In the present experiments, when water-soluble marker was continuously infused into the rumen, the concentration of the marker in the rumen remained relatively constant within and between days that confirmed with the study by Weston and Hogan (1967). They found that when Cr-EDTA was continuously infused into the rumen, the concentration of marker in the rumen remained relatively constant within and between days. Therefore they assumed that conditions in the rumen approached a 'steady state'. In addition, Ulyatt (1967) and Faichney (1968) showed that with a constant ration in equal amounts at 3-hourly intervals (continuous feeding), steady state conditions within the rumen can be closely approached.

Turnover time, mean retention time and out flow rate

The passage rate of liquids and therefore the rate of turnover were highest in diet without STP (STP0) and lowest in diet containing 12% STP (Table 4). This means that the there was less opportunity for microorganisms to degrade STP0 than STP12, which may explain the lower apparent digestion of CW composition in GIT of sheep. OFR and MRT results agreed with Weston and Hogan (1967) when the sheep fed with alfalfa and wheaten hay in a level same as the present experiment (90% of voluntary intake). It may be suggested that using STP not only did not result in a great rumen DM fill, which declined DMI, but also increased nutrients digestibility through increased MRT (Tables 2 and 3). The use of forages as diets for ruminants is associated with prolonged retention times within the digestive tract (Warner 1981). The degree of distension and fill of the reticulo-rumen (RR) can therefore be an important factor limiting the voluntary intake of forage diets (Aitchison et al. 1986).

Explanation of digestibility in aspect of rumen passage and retention characteristic

Increasing STP in diet resulted in decline of OFR, but increase of MRT and TT (Table 4). The microbial degradation of plant cell walls is a rather slow process. To achieve a high digestibility of cellulose, feed particles have to remain longer than fluid in the RR (Kaske and Engelhardt 1990). Most feeds contain a surface layer that is resistant to attachment and therefore to digestion. (McAllister et al. 1994); therefore if roughages remain longer in RR, this may be due to their digestion being more efficient. As the effect of a decrease in MRT in the rumen is to decrease the opportunity for microbial attack, less OM and fibre were digested in the rumen, and fermentation in the hindgut did not compensate for this (Beever et al. 1980–1981; Margan et al. 1982). Therefore maybe the higher rumen and overall digestibility of STP12 than STP0 was similarly associated with longer MRT in the rumen. Our reasoning about decrease in the digestibility of CW in STP0 was consistent with the results of Ehle et al. (1982) using diets containing coarse bran, fine bran, alfalfa or cellulose and the effects of these sources of fibre on digestibility and rate of passage. The coarse bran diet had the greatest CW digestibility, cellulose the lowest and fine bran and alfalfa were intermediate. The trend towards higher CW digestibility for the coarse bran diet than for the fine bran diet could be related to rate of passage. The CW particles of the coarse bran diet had a significantly longer retention time.

Density is another factor that may affect the digestion and passage of particles in the rumen (Ehle 1984; Kaske and Engelhardt 1990), in wheat bran the functional specific gravity (FSG) (1.40 g/ml, measured by authors, unpublished data) was equal to the lowest MRT, which it may influence its digestibility, because these particles left the RR 2.6 times faster than those with lower densities (0.92 and 1.03 g/ml) (desBordes and Welch 1984; Ehle 1984; Kaske and Engelhardt 1990).

Gas produced as a result of microbial degradation of feeds can be entrapped in the substrate thereby affecting its density and buoyancy (Hooper and Welch 1985; Wattiaux et al. 1992). The extent of gas entrapment is positively correlated with degradation rate of the substrate (Wattiaux et al. 1991). Such an effect was observed by Castro et al. (1994) when samples were incubated *in vitro* with rumen microbes. Such change in particle density due to gas

entrapment, particularly at initial stages (12–24 h) of fermentation, may well increase the chance for particles to leave the rumen (desBordes and Welch 1984). In case of diets containing most wheat bran (STP0), probably due to its high degradability, large quantities of potentially degradable substrate leave the rumen after short periods of fermentation. Therefore, the result of present study from these sights confirmed the literatures.

Conclusion

The result of present experiment suggested that since diets containing STP, especially STP12, in comparison to the wheat bran diet (STP0) had lower OFR, DR and TT and higher MRT in rumen of Baluchi sheep, consequently there was greater digestibility of NDF and ADF in rumen and total GIT. Dry matter intake and rumen volume were not affected by treatment. Therefore, although chemical composition of wheat bran is better than the STP, but in domain of this experiment according to the rumen digestion kinetic result, maybe data concluded that chemical composition solely was not enough for evaluation of nutrition value of feedstuffs, e.g. STP and wheat bran.

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