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Effect of Pectin in Ameliorating Grain Induced Digestive Upset in Sheep: Focus on Cation Exchange Capacity

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Abstract: The effect of pectin for reducing the intensity of digestive upsets induced by a high grain ration was assessed with emphasis on its high cation exchange (buffering) capacity (CEC). Four Karakul lambs were fed a ration containing 37.5% dry forage and 62.5% ground barley for 30 days (induction period). During a further treatment period (8 days), pectin was added to the ration at 44 grams/kg to increase the CEC of the diet and to equate it to that of an all forage ration fed to a control group (n=4) for 38 days. In the experiment group, the post-feeding rumen pH was 5.84±0.14 at day 30 and increased ($P<0.05$) to measures above 6 during the treatment period. Also, feces dry matter declined from 39.79±3.06 percent at day 10 of the induction period to 20.34±1.67 percent at day 30 ($P<0.05$), losing its normal shape. At day 8 of the treatment period, the feces regained its normal shape and its dry matter increased to 25.05±1.86 percent ($P<0.05$). Feed intake depressed in the experiment group during the induction period ($P<0.05$) and increased non-significantly ($P>0.05$) during the treatment period. Pectin may help modify the rumen pH with high grain ration by increasing dietary CEC despite its rapid fermentation. Examining different rations with different CEC levels and developing a system to adjust dietary CEC may be beneficial in controlling rumen pH and/or treatment of digestive diseases associated with low pH.

Key words: Pectin, digestive upsets, high grain ration, cation exchange capacity

INTRODUCTION

Adjustment of particle size, chemical characteristics and the amount or proportion of dietary fiber is probably the most prominent practice for controlling rumen pH and digestive upsets associated with high concentrate rations in ruminants. In addition, adjustment of non-fiber carbohydrates (NFC) is also important because their excess is a major underlying reason for ruminant digestive diseases. However, even with good nutritional and management practices, some digestive diseases frequently make problems in commercial farms. For instance, subacute ruminal acidosis (SARA) is a disease of well managed dairy farms (Enemark, 2008) with high prevalences. Prevalences as high as 19% of early lactation and 26% of mid lactation cows (Garret, *et al.,* 1997), 20.1% of early and peak lactation cows (Oetzel, *et al.,* 1999) and 11% of early lactation and 18% of mid lactation cows (Enemark, 2008) have been reported. In fact, SARA is a disease of well managed dairy farms (Enemark, 2008). In addition to the physical and chemical properties of fiber, another important feed characteristic that contributes to rumen buffering is the buffering capacity of the feed, which depends on cation exchange capacity (CEC) of the fiber and, to some extent, on the fermentation of protein to ammonia (van Soest *et al.,* 1991). Plant cells generally have many negative charges on their surface. CEC is the ability of fiber to bind metal ions ($K+$, $Ca++$, $Na+$, and $Mg++$) on its surface and exchanging them for $H+$ when rumen pH drops. If the $H+$ ions are chemically bound to the plant rather than free, the rumen will become less acidic. If the rumen pH rises, the fiber is recharged with metal ions (van Soest *et al.,* 1991). The higher the cation exchange capacity, the better the plant will be as a rumen buffer. Mature legume forages are the most effective dietary ingredients for supplying exchangeable buffering capacity (van Soest *et al.,* 1991), but the amount and proportion of forages are usually limited in high energy rations. Thus, application of forage CEC in controlling and/or treating digestive upsets may not be possible even with ration reformulation.

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Feeds or products with high CEC, which could be used in small amounts without reformulating of the ration, may be a solution for the problem. Pectin is an example. Some concentrate fibers as are as good as or better than mature legumes for supplying exchangeable buffering capacity (van Soest *et al.,* 1991) through their non-starch polysaccharides such as pectin. However, pectin is a rapidly digested carbohydrate, included in the NFC fraction in traditional feed analysis (NRC, 2001). Pectin has an exceptionally large CEC but rapidly disappears from the gastrointestinal tract because of its ease of fermentation (McBurney *et al.,* 1983). Thus, its usage for application of the effect of CEC may be controversial.

Overall, it is hard to say that adjustment of CEC has been applied to routine formulation of rations of commercial farms. The authors couldn't find reports from controlled studies on the effect of CEC in lessening digestive disorders associated with high energy rations. The present study assessed the effect of pectin for reducing the intensity of digestive upsets induced by high grain ration in lambs, without any major adjustment in the basal ration.

MATERIALS AND METHODS

A) Animals, rations and samplings:

Eight Karakul lambs were divided into a control (n=4, body weight=24.25±4.03) and an experiment group (n=4, body weight=24.5±2.42) and were kept in individual pens for a period of 38 days, divided into an induction period (30 days) and a treatment period (8 days). The induction period (30 days) was divided into 3 equal steps for ration adjustments and samplings. The control group was fed a ration consisting of 80% alfalfa hay and 20% wheat straw *ad libitum* for the whole period of the study. In the experiment group, ground barley was substituted for 40% of the ration for the first step (10 days) and 62.5% of the ration for the rest of the study (20 days). Thus, during the first step the ration of the experiment group consisted of 48% alfalfa hay, 12% wheat straw and 40% ground barley. During the 2nd and 3rd steps, the ration contained 30% alfalfa hay, 7.5 % wheat straw and 62.5% ground barley. The signs of digestive malfunction appeared during the 2nd step of the study (see below); hence, no further adjustment was made in the ration. A trace mineralized salt was top-dressed in the rations of both groups at 0.3% of feed (as fed basis). No buffer was included in the rations. The rations were prepared as TMR and were allocated everyday at 09:00 and their residuals were removed and weighed the next day at 06:00 for detection of daily feed intake.

Rumen liquor (>25 ml) was collected via stomach tube on days 7 and 9 of each step, at 08:00 (one hour before feeding) and 12:00 (3 hours after feeding) to detect rumen pH, which was done within one minute of sampling (Schott pH meter, model CG824, Germany). Feces samples were collected on the 9th day of each step for measuring feces dry matter. Manure was observed everyday for consistency and shape.

B) Signs of digestive upset:

A rumen pH ≤5.9 (3 hours after feeding, averages of days 7 and 9), loss of manure consistency, reduced feces dry matter and fluctuation in feed intake were considered as signs of negative alteration of the rumen environment, resulting in digestive upsets. All of these signs appeared gradually in the experiment group during the 2nd and 3rd steps of the study (Table 2).

C) Increasing the CEC:

After the establishment of the signs of digestive malfunction, the experiment group was subjected to an additional treatment period of 8 days and was fed the same diet (37.5% forages and 62.5% ground barley) plus 44 grams per kg pectin (pineapple 360 Sieve 8, Nestle, Art. No. 101605) to increase the CEC of the ration. Pectin has a cation exchange capacity (CEC) of 2272 mmol kg-1 which is much more than those of forages (McBurney *et al.,* 1983) and could be a potent material to increase the CEC provided in the ration by forages (Table 1). The amount of pectin was calculated as follows:

The difference between the CEC of the control and experiment rations = 160-60 =100
Pectin weight (g) for equating the CEC of the experiment and control rations = (100 x 1000/2272) = 44

Thus, the addition of 44 grams of pectin could theoretically equate the CEC of the experiment ration to that of the control ration with a negligible increase in the bulk of the ration. The pectin used in this study, however, was a fine powder and could be prone to rapid microbial fermentation and rapid disappearance from the rumen.

Table 1: Cation exchange capacity provided in the ration by forages in control and experiment groups

Forage	Dry matter %	CEC (hydrogen mmol/kg cell wall)	Cell wall as fed %	CEC as fed (CEC x %cell wall)	Weight of feed in the ration (kg/kg as fed)	CEC provided per kg of the ration
Alfalfa hay	90	356	49	174.4	Control: 0.8 Experiment: 0.3	Control: 139.5 Experiment:52.3
Wheat straw	90	132	77.5	102.3	Control: 0.2 Experiment: 0.075	Control: 20.5 Experiment: 7.7
		Sum				Control: 160 Experiment: 60

Rumen pH was detected on days 3 and 8 of the treatment period. Manure was observed everyday for consistency and shape and feces samples were collected on day 8 for measuring feces dry matter. Feed intake was detected every day as before.

Statistics:

Statistical analysis was performed using Proc-mixed procedure by SAS statistical software (version 9.1, SAS Institute Inc., Cary, NC, USA). To determine the effect of treatment on the study parameters (except feed intake) sheep was considered as subject and step of the experiment as repeated effect in the model. Interaction term for step x group was also included in the model. For analysis of feed intake, the variable day was considered as second repeated effect in the model and all interaction terms were introduced in the mixed model.

RESULTS AND DISCUSSION

Rumen pH:

Significant declines (P<0.05) were observed in both pre-feeding and post-feeding rumen pH in the experiment group during the induction period (Table 2). At day 30, the post-feeding rumen pH in the experiment group was 5.84±0.14, which increased (P<0.05) to 6.11±0.2 and 6.2±0.08 at days 3 and 8 of the treatment period.

Fecal Consistency and Dry Matter:

Feces dry matter was almost constant in the control group during the study (P>0.05). In the experiment group, however, feces dry matter (%) declined from 39.79±3.06 at day 10 to 28.17±2.94 at day 20 and 20.34±1.67 at day 30 (P<0.05, Table 2). Feces became soft in all lambs during the 2nd step of the induction period. At day 20 the feces was soft but had its normal shape. At day 30 it was very soft and amorphous. At day 8 of the treatment period, the feces regained its normal shape and its dry matter (%) increased (P<0.05) to 25.05±1.86.

Feed Intake:

Feed intake increased in the control group during the first 20 days of the experiment and remained almost constant between days 20 and 30. In the experiment group, a significant depression in feed intake was observed between day 20 and 30 of the study (P<0.05, Table 2). Actually, feed intake was affected from day 16 of the study (not shown in Table 2). Feed intake increased nonsignificantly (P>0.05) in the experiment group during the treatment period.

Table 2: Rumen pH, feces dry matter and characteristics, and feed intake at various steps of the study (mean±SD)

		Induction period (30 days)			Treatment period (8 days)	
Parameter	Group	Day 10	Day 20	Day 30	Day 3	Day 8
Rumen pH	Control					
	Before feeding	6.98±0.25	7.11±0.27	6.95±0.17*	6.93±0.17*	6.92±0.11*
	After feeding	6.55±0.17^{a}	6.41±0.10^{a*}	6.33±0.12^{b*}	6.45±0.06^{a*}	6.38±0.06^{a*}
	Experiment					
	Before feeding	7.25±0.13^{a}	6.99±0.25^{a}	6.30±0.36^{b*}	6.43±0.34^{b*}	6.42±0.23^{b*}
	After feeding	6.40±0.15^{a}	6.12±.20^{b*}	5.84±0.14^{c*}	6.11±0.20^{b*}	6.20±0.08^{b*}
Feces dry matter (%)	Control	38.05±4.04	37.53±1.19 *	36.95±2.69 *		37.02±2.21*
	Experiment	39.79±3.06^{a}	28.17±2.94^{b*}	20.34±1.67^{c*}		25.05±1.86^{b*}
Fecal consistency and shape	Control	Normal	Normal	Normal	Normal	Normal
	Experiment	Normal	Soft, normal shape	Soft, amorphous	Soft, normal shape	Soft, normal shape

Table 2: Continue

		Day 1-10	Day 11-20	Day 21-30	Day 1-8 of treatment
Feed intake (g)	Control	542±87	672±233	667±250*	671±240*
	Experiment	590±30 [a]	580±265 [a, c]	442±214 [b *]	482±179[b, c *]

a,b,c: Different letters in each row correspond to significant differences within each group
* Significant difference of the corresponding data between the control and the experiment group at different steps

Discussion:

The signs of digestive upset in the present study resembled to those of SARA. Reduced feed intake (Enemark, 2008; Plaizier *et al.,* 2008), rumen pH below 5.9 in samples taken via stomach tube (Duffield *et al.,* 2004) and reduced feces consistency (Hall, 2002; Nordlund, 1995; Kleen, 2003) have been noted in animals with SARA. In the present study a non-significant increase in feed intake was observed following pectin treatment. This was accompanied with post-feeding rumen pH values above the threshold of 5.9 which could be interpreted as improvement in the conditions of rumen environment. This change could result in increased retention time of feed in the rumen and increased feed efficiency (Ahvenjarvi *et al.,* 2004). Significant increase in feces dry matter ($P<0.05$), increase in fecal consistency and restoring the normal shape of the feces were detected during the treatment period. These effects could be attributed to the CEC of pectin regardless its high ruminal digestibility. Pectin has an exceptionally large CEC (2272 mmol kg-1) but rapidly disappears from the gastrointestinal tract because of its ease of fermentation (McBurney *et al.,* 1983). However, pectin digestibility reduces at low pH and ceases at pH=4 (Walter, 1991). It is concluded that the hydrogen ions released rapidly from starch fermentation, may be temporarily trapped for a while with pectin before the latter is fermented. So, the fluctuations in ruminal pH could be lessened. The assessed parameters, however, didn't return to the conditions detected before the induction of the disease and the measures of the control group (Table 2). In addition to high digestibility of pectin, this could be explained by the form of pectin used in the study (fine powder), which was more prone to rapid fermentation. Plant fiber in its natural form is not totally digested in the rumen, and as it passes down the digestive tract, contributes buffering action farther down the gut (van Soest *et al.,* 1991) resulting in better nutrient utilization. It is concluded that the effect of pectin in the powdered form would be transient and limited mainly to the rumen with low postruminal buffering effect. However, abomasal infusion of pectin in dairy goats has resulted in decreased feed intake, digestibility and milk production probably by reducing postruminal nutrient utilization (Sari *et al.*, 2009).

Feeds such as beet pulp (rich in pectin) have been noted in controlling rumen pH with high starch diets by exerting a diluting effect on high-starch rations (Stone, 2004). In addition, they are not fermented to lactic acid (Storbel and Russell, 1986; van Soest *et al.,* 1991). It appears that high CEC of pectin would also have a major effect since 44 grams of pure, finely powdered, pectin used in the present study had little if any diluting effect on the diet. Besides, lactic acid formation is not a problem in SARA in animals adapted to high starch diets (Krause and Oetzel, 2005).

Conclusion:

Pectin, in relatively small amounts, may be helpful for modifying the rumen pH with high grain ration by increasing the CEC of the ration despite its rapid fermentation. The price of pectin, however, may be an important limiting factor. In practice, the actual grain mixes containing various feeds and may be less acidogenic than the one used in the present study with barley as the mere constituent. Thus, smaller amounts/proportions of pectin or, as a result, natural pectinacious materials such as beet and citrus pulps may have similar effects with regards to total CEC of the ration. Examining different rations with different levels of CEC and developing a system for adjustment of dietary CEC may be beneficial in controlling rumen pH and/or treatment of digestive diseases associated with low pH.

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