The Effects of Xylose Treatment on Rumen Degradability and Nutrient Digestibility of Soybean and Cottonseed Meals

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ABSTRACT : Two trials were conducted to evaluate the effect of xylose treatment on rumen degradability characteristics of DM, OM and CP and *in vivo* digestibility of DM, OM, CP and crude fiber (CF) of soybean meal (SBM) and cottonseed meal (CSM). In Trial 1, three ruminally cannulated Merino rams were used. Xylose treatments at both levels, 0.5 and 1%, decreased effective degradability of DM, OM and CP of SBM, whereas 0.5 and 1% xylose treatment of CSM did not show any effect on effective degradability of DM, OM and CP. By contrast, maximum potential degradabilities of DM, OM and CP of CSM seemed to be increased by 1% xylose treatment. It was concluded that xylose treatment was effective in protecting SBM proteins from degradation in the rumen, but the same treatment was not so effective for CSM protein. In trial 2, three Merino rams were used. With treatments, DM, OM, CP and CF digestibilities of SBM and CSM were not changed. Crude fiber digestibility was numerically increased by the treatments of 0.5 and 1% xylose of both SBM and CSM compared to untreated SBM and CSM but differences were not significant. In conclusion SBM proteins can be effectively protected from degradation in the rumen by xylose treatment, without negatively affecting *in vivo* digestibility of protein, whereas xylose treatment appeared to be less effective on protecting of CSM proteins. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 5 : 655-660)***

Key Words : Cottonseed Meal, Digestibility, Rumen Degradability, Soybean Meal, Xylose

INTRODUCTION

Highly productive ruminants, either rapidly growing or lactating, rely on both microbial proteins and rumen-undegradable proteins (bypass protein) digested in the small intestine to meet their amino acid requirements. Researchers have previously attempted to increase the quantity of protein reaching the small intestine of ruminants by treatments with heat (Mir et al., 1984; Nakamura et al., 1994), formaldehyde (Cooker et al., 1983; Nishimuta et al., 1974; Thomas et al., 1979), acetic acid (Robinson et al., 1994), tannic acids (Driedger and Hatfield, 1972), lignosulfonate (LSO_3) and xylose (McAllister et al., 1993; Harstad and Prestlokken, 2000). Windschitl and Stern (1988) described a processing procedure in which either 5% LSO_3 or 1% xylose was added along with 10% additional water to SBM. They reported that *in situ* ruminal protein degradabilities and N digestion rate were decreased with both LSO_3 and xylose treatments compared with water treated or untreated SBM. Nakamura et al. (1992) evaluated SBM treated with 5% sulfite lliquor containing 20% xylose. Ruminal undegradability of the treated SBM was 79%. It was determined that (Cleale et al., 1987) *in vitro* ammonia release from SBM was suppressed by non-enzymatic browning and was influenced by source and quantity of reducing sugar. And, showed the most reactive sugar was xylose because, it was activated even room temperature. On the other hand there is limited research with whole SBM and CSM investigated the benefit of xylose treatments to reduce protein degradability in the rumen. The objective of this study was to evaluate the effect of different levels of xylose treatments on *in situ* disappearance and *in vivo* digestibility of dry matter (DM), organic matter (OM) and crude protein (CP) of SBM and CSM.

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MATERIALS AND METHODS

Xylose treatment of soybean and cottonseed meals

Soybean and cottonseed meals were treated with water and heat (this treatment was applied to determine the effects of water and heat at 100°C for 2 h without xylose) or with water+heat+0.5% or 1% xylose. The DM of meals was determined by drying at 105°C for 24 h, and sufficient water or mixtures of water and xylose (0.5 and 1%) were added to increase the moisture content of SBM and CSM to 25% (McAllister et al., 1993). These meals were thoroughly mixed with each solution and heated for 2 h at 100°C in a convection air oven.

Trial 1

Three ruminally cannulated Merino rams aged 1.5 years weighing approximately 60 kg were fed twice daily (at 09.00 h and at 16.00 h) with a ration containing 200 g concentrate (barley, 51%; sunflower meal, 25%; wheat bran, 21%; salt, 1%; dicalcium phosphate, 1% and vitamin+ mineral premix, 1%) and 1.000 g alfalfa hay. Nylon bag technique was used to measure disappearance of DM, OM and CP in the rumen of untreated and treated SBM and CSM. Nylon bags (45 μm pore size; 9×14 cm bag size)

Table 1. The chemical composition of feeds used in the experiment (g/kg)

	Dry matter	Organic matter	Crude ash	Crude protein	Ether extract	Crude fibre	Nitrogen free extract
Alfalfa hay	878.9	923.2	76.8	132.0	12.5	309.1	469.6
Concentrate mix	912.5	921.5	78.5	178.6	21.4	110.0	611.5
SBM	912.4	927.6	72.4	495.8	18.5	92.5	320.8
CSM	906.3	939.0	61.0	323.8	10.6	216.0	388.6

SBM: soybean meal. CSM: cottonseed meal.

containing 5 g of test samples were incubated in the rumen of each ram. Two bags of each type of CM and SBM were removed after 4, 16, 24 and 48 h of incubation in the rumen. Then individual bags with contents were washed in running tap water until the bags was free of the rumen matter. Bags were then dried at 60°C for 48 h and weighed. Digestion kinetics of DM, OM and CP were determined according to the equation of Ørskov and McDonald (1979):

$$p = a+b\ (1-e^{-ct})$$

where p is the amount degraded at a time, a the rapidly soluble fraction (%), b the potentially degradable fraction (%), c the constant rate of disappearance of b (% h^{-1}), t the time of incubation (h), effective rumen degradability of DM, OM and CP were estimated using the equation of Ørskov and McDonald (1979):

$$Pe = a+bc/k+c$$

Where: Pe is the effective degradation (%), k the fractional ruminal outflow rate, and a, b and c are defined above. Effective degradability was calculated with an estimated solid outflow rate from the rumen (k) of 0.05 h^{-1} (Bhargava and Ørskov, 1987). Chemical composition of experimental feeds and DM, OM and CP content of their washed residues after rumen incubation, were determined according to the methods of the AOAC (1984).

Trial 2

Three Merino rams (60±5 kg BW) were used to determine *in vivo* DM, OM, CP and CF digestibilities of water and heat or xylose treated SBM and CSM.

Rams were moved into individual pen and fitted with canvas faces collection bags and fed twice daily (at 09.00 h and at 16.00 h) with experimental feeds. *In vivo* digestibility of untreated and treated SBM and CSM were determined according to Pond et al. (1995). During the first 10 days of each period, rams were allowed to adapt to their diets, followed by a 10-d total faecal collection. Nutrient digestibilities of SBM and CSM were calculated by difference in nutrient digestibility relative to values from the alfalfa hay diet.

To determine nutrient digestibility of alfalfa hay, Rams were fed 1.200 g alfalfa hay in equal portions twice daily (at 09.00 h, 600 g and at 16.00 h, 600 g). Rams were provided with free access to water throughout the trial. To determine the untreated and treated SBM and CSM rams were fed 500 g meal sample+700 g alfalfa hay in equal parts twice daily. During the 10-d collection phase, feed intake, feed refusals, and total faecal weights were recorded daily. Faecal samples were frozen for later analysis along with feed samples. All samples were dried in a forced-air oven at 60°C (Bratzler and Swift, 1959) and ground before chemical analysis. Experimental feeds and fecal samples were analyzed to obtain digestion coefficients for DM, OM, CP and CF. Dry matter, OM, CP and CF of feeds and faeces samples were determined by AOAC (1984).

Statistical analyses of data obtained from trial 2 were done by one-way ANOVA. The significance of differences between treatment means was tested by DUNCAN test (Duncan, 1955). Statistical analyses were done using the SPSS program (version 10.0, USA). Statements of statistical significance are based on $p<0.05$.

RESULTS AND DISCUSSION

Trial 1

Untreated SBM was progressively degraded in the rumen. By contrast, CSM was less degraded in the rumen. With treatments by water and heat or by xylose, the degradability of SBM was reduced and the CP losses were particularly diminished. The retardation of SBM degradation was precociously observed (since 4h incubation) especially when SBM was treated by xylose (0.5% and 1%), and became more and more intense when incubation times increased (Table 1). Treatment of CSM by water and heat slightly decreased DM and OM degradation but not xylose treatment. For SBM, the DM rapidly soluble fraction (a) was decreased by all treatments (water and heat-0.5% xylose-1% xylose) and this reduction was more pronounced when SBM was treated by 1% xylose. In the same way, xylose treatment also induced decreasing of OM and CP - "a" values whereas water and heat treatment did not notably affect these parameters. By contrast, treatments of CSM did not affect a and b values, and even 1% xylose treatment induced moderate increases of the 2 parameters (Table 2). Treatments of SBM decreased the rates of disappearances of the DM, OM and CP potentially degradable fractions (c) and DM, OM and CP "c" values

Table 2. Rumen degradability characteristics and effective degradability values of dry matter, organic matter and crude protein of untreated and treated soybean meal

Feeds	Incubation (h)				a	b	a+b	c	Pe %
	4	16	24	48	(%)	(%)	(%)	(% h^{-1})	(0.05 h^{-1})
Dry matter									
SBM	39.00	66.36	76.96	91.35	25.24	71.65	96.89	0.0533	62.20
SBM+WH	36.60	62.88	73.59	89.13	23.86	72.34	96.20	0.0485	59.50
SBM+0.5% X	31.03	49.02	58.13	76.14	23.61	72.14	95.75	0.0271	49.00
SBM+1.0% X	29.74	46.64	55.41	73.32	22.89	72.37	95.26	0.0249	46.90
Organic matter									
SBM	36.42	64.86	76.12	91.86	22.33	76.03	98.63	0.0512	60.80
SBM+WH	34.27	58.19	68.99	87.05	23.51	75.44	98.95	0.0385	56.30
SBM+0.5% X	28.02	46.50	55.96	74.88	20.44	76.00	96.44	0.0262	46.60
SBM+1.0% X	27.18	44.52	53.55	72.07	20.16	74.97	95.13	0.0246	44.90
Crude protein									
SBM	27.31	58.11	71.34	90.16	12.26	86.70	98.96	0.0476	54.60
SBM+WH	23.62	49.88	62.05	83.14	12.02	86.50	98.52	0.0360	48.20
SBM+0.5% X	13.99	33.98	44.37	65.65	5.90	86.08	91.98	0.0247	34.30
SBM+1.0% X	11.87	27.79	36.27	54.28	5.55	74.23	79.78	0.0223	28.40

SBM: soybean meal, a: the rapidly soluble fraction b: the potentially degradable fraction c: the constant rate of disappearance of *b* Pe: the effective degradation WH: water+heat treatment, X: xylose treatment.

were dramatically reduced when xylose treatments were applied to SBM (Table 2). For CSM, only 1% xylose treatment induced decreases of rates of disappearance of potentially degradable fractions for DM, OM and CP, whereas water and heat or 0.5% xylose treatment had no effect (Table 2). Significant increases of OM and CP amounts potentially degradable at a particular time (p value) were evidenced on all treated SBM for all incubation times (according to the different treatments) (Table 2). But again, these variations were lower when water and heat treatment was applied to SBM, and in this case, DM values were not different untreated SBM. These results showed that: 1) degradation of DM, OM and CP began since 4 h incubation, 2) SBM treatments induced marked increases of the quantities of potentially degradable DM, OM and CP residues, 3) 1% xylose treatment has limited more efficiently the effective degradation of SBM, and particularly the CP effective degradation than 0.5% xylose or water and heat treatments. Water and heat or 0.5% xylose treatments of CSM did not modify the DM, OM and CP potentially degraded amounts whatever the incubation time (Table 3). Again only 1% xylose treated CSM presented more elevated DM, OM and CP values than untreated CSM. Moreover, only 1% xylose treatment affected the CP effective degradation (Pe) by 4% according to the estimated solid outflow rate (k values). OM and DM effective degradation were not significantly modified whatever the treatment applied to CSM. By contrast, SBM treatments with water and heat, 0.5% xylose and 1% xylose decreased the DM, OM and CP effective degradation (Pe). The calculated reduction coefficients were 11.7%, 37.2% and 48.0% respectively.

Our studies indicated that SBM was more degradable than CSM in the rumen although the CP digestibility was roughly identical and that xylose treatments were more efficient than water and heat treatment for limiting meal degradability. Furthermore, a direct relationship between effective degradation of SBM and the xylose levels used during treatment was evidenced, since 1% xylose induced more marked decreases of DM, OM and CP effective degradation than 0.5% xylose. In our study, the observed rapidly soluble CP contents of SBM and CSM were lower than the previously reported values (Mir et al., 1984; Güclü, 1999, Harstad and Prestlokken, 2000). This can be attributed to varietals differences in the meal. Despite these discrepancies, maximum potential degradability of CP of untreated SBM was similar to previous results (Little et al., 1963; Lycock and Miller, 1981; Mir et al., 1984). For CSM, there were no differences in maximum degradability of CP among the untreated CSM, and water and heat or 0.5% xylose treated CSM. On the other hand 1% xylose treatment was increased maximum potential degradability of CP of CSM. Similarly, Güçlü (1999) have reported that 5% LSO_3 treatments was not altered the maximal potential DM, OM and CP degradability while 10% LSO_3 treatment increased the rumen degradability of the same parameters. Additionally, the large reductions in effective degradability of crude protein recorded in the present study cannot be attributed solely to the effect of heating. Smilarly, Subuh et al (1994) reported that heating canola meal and SBM at 110 °C for 2 h led a large reduction in the soluble protein fractions, but did not alter the effective degradability of crude protein of both meals. More recently, Chen and Quin (2005) reported that processing method markedly affected ruminal and post ruminal amino acid digestibility of rapeseed meal when the temperature exceeded 110°C. Xylose treatment reduced the protein soluble fraction to a greater extent in SBM. As e-amino groups of lysine could

Table 3. Rumen degradability characteristics and effective degradability values of dry matter, organic matter and crude protein of untreated and treated cottonseed meal

Feeds	Incubation (h)				a	b	a+b	c	Pe %
	4	16	24	48	(%)	(%)	(%)	(% h^{-1})	(0.05 h^{-1})
Dry matter									
CSM	16.85	29.67	36.37	50.84	11.75	59.05	70.80	0.0226	30.10
CSM+WH	16.57	28.44	34.87	48.81	11.91	58.47	70.38	0.0208	29.10
CSM+0.5% X	17.33	30.79	37.78	52.06	11.87	57.70	69.57	0.0248	31.00
CSM+1% X	17.77	28.82	35.10	49.83	13.61	68.33	81.94	0.0157	30.00
Organic matter									
CSM	15.14	27.95	34.79	49.36	10.06	60.23	70.29	0.0220	28.50
CSM+WH	14.72	26.55	32.95	46.86	10.07	58.33	68.40	0.0208	27.20
CSM+0.5% X	15.56	28.26	35.12	49.99	10.56	62.27	72.21	0.0209	28.90
CSM+1% X	16.18	27.31	33.65	48.52	11.98	69.08	81.06	0.0157	28.50
Crude protein									
CSM	17.16	31.71	39.82	58.14	11.58	81.07	92.65	0.0178	32.90
CSM+WH	17.26	32.08	40.22	58.28	11.50	77.41	88.91	0.0193	33.10
CSM+0.5% X	17.96	34.09	42.72	61.20	11.58	76.57	88.15	0.0218	34.80
CSM+1% X	18.28	30.05	36.93	53.78	13.94	86.06	100.00	0.0130	31.60

CBM: cottonseed meal, a: the rapidly soluble fraction b: the potentially degradable fraction c: the constant rate of disappearance of *b* Pe: the effective degradation WH: water+heat treatment, X: xylose treatment.

Table 4. *In vivo* dry matter, organic matter, crude protein and crude fiber digestibilities of xylose treated soybean meal (%)

	SBM x±Sx	SBM+WH x±Sx	SBM+0.5% X x±Sx	SBM+1% X x±Sx	F
Dry matter	92.77±0.52	92.38±1.40	93.25±1.82	93.32±1.03	0.12
Organic matter	92.69±1.26	88.88±1.25	89.78±2.61	92.47±1.88	1.08
Crude protein	96.10±0.33	95.31±0.18	95.89±0.46	95.84±0.44	0.82
Crude fiber	85.60±0.73	86.18±0.68	89.63±1.10	88.93±1.87	2.76

SBM: soybean meal, WH: water+heat treatment, X: xylose treatment.

Table 5. *In vivo* dry matter, organic matter, crude protein and crude fiber digestibilities of xylose treated cottonseed meal (%)

	CSM x±Sx	CSM+WH x±Sx	CSM+0.5% X x±Sx	CSM+1% X x±Sx	F
Dry matter	60.57±1.49	59.78±1.70	59.47±0.68	63.43±2.90	0.93
Organic matter	59.44±1.17	58.81±0.45	58.79±0.59	61.89±1.81	2.21
Crude protein	82.06±0.25	81.67±1.04	82.40±0.75	82.85±0.51	0.51
Crude fiber	57.69±4.65	55.11±0.71	61.18±1.66	60.79±3.63	0.86

CSM: cottonseed meal, WH: water+heat treatment, X: xylose treatment.

realize nucleophile attacks on aldehyde and produce Maillard reactions (Windschitl and Stern, 1988), it was probable that xylose treatments have promoted the amine formation with lysine rich proteins and consequently have limited SBM protein degradation in the rumen. By contrast, as CSM would probably contain less lysine rich proteins, the Maillard reactions would be limited, and the treatment of this meal would require a more elevated quantity of xylose for CP degradation.

Trial 2

The DM, OM, CP and CF digestibility values were 92.77, 92.69, 96.10 and 85.60% for untreated SBM and 60.57, 59.44, 82.06, 57.69% for untreated CSM, respectively (Tables 4 and 5). With treatment by water and heat or by xylose, nutrient digestibility of SBM and CSM were not affected. Although OM digestibility of SBM and, DM and OM digestibilities of CSM were reduced by water and heat and 0.5% xylose treatments, but this diminishes were not reach statistically difference. These results were similar to previous (Mansfield et al., 1994; Stern, 1994; Lebzien et al., 1995; Stanford et al., 1995) results reported that OM digestibilities of CM and SBM were not affected by LSO_3 treatment. Similarly, Stanford et al. (1995) reported that treatment of SBM and CM at the level of 7 % LSO_3 was not altered the DM digestibility. Again, the addition of soy-pass (LSO_3 treated SBM) to the ration did not reduced DM and nitrogen free extract digestibilities (Lebzien et al., 1995). Güçlü (1999), have reported that LSO_3 treatment was reduced ($p<0.01$) DM and nitrogen free extract of CSM especially when CSM was treated by 10% LSO_3.

Crude protein digestibilites of SBM and CSM were unchanged by all treatments (water and heat-0.5% xylose-

1% xylose). Similarly, CP digestibility was not affected by the addition of soy-pass to the ration (Lebzien et al., 1995) and 7% LSO_3 treatment of SBM and CM (Stanford et al., 1995). In contrast to these results, Windschitl and Stern (1988) have reported that 5% LSO_3 treatment of SBM was reduced CP digestibility of SBM.

Xylose treatments did not change CF digestibilities of SBM and CSM. When compared to untreated meals xylose treated SBM and CSM had numerically higher in CF digestibilities. Results were in agreement with the work of Lebzien et al. (1995) in which unchanged CF digestibility was found in the rations with soy-pass. By contrast, Stanford et al. (1995) and Hussein et al. (1991) found an improvement in fiber digestion in their works. Veen (1986) observed that slowly degradable proteins and the resultant gradual release of ammonia-N, peptides and branched chain fatty acids, promoted the availability of these essential growth factors to cellulolytic bacteria for extended period of time after feeding. In contrast to this, Stern (1984), Windschitl and Stern (1988) have reported diminish in fiber digestibility when SBM in corn-based diets was treated with LSO_3, and attributed this to a deficiency of NH_3-N for microbial protein synthesis.

In conclusion, this study demonstrated that SBM proteins can be effectively protected from degradation in the rumen by xylose treatment through Maillard reaction, without negatively affected *in vivo* digestibility of protein, whereas xylose treatment appeared to be less efficient on CSM proteins.

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