Effect of increasing levels of rice polishings on ruminal dry matter degradability and productive performance of fattening sheep

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The objective of this study was to evaluate the parameters of ruminal degradation and behavior in fattening ovine fed highly concentrated diets with increasing levels of rice polishing. Two experiments were developed: 1.- effects of increasing levels of rice polishing (RP) on ruminal degradability of dry matter (RDDM) and 2.- behavior of fattening ovine. Three diets or treatments were used with equal content of CP (14 %) and metabolizable energy (8.36 MJ/kg of DM). The RP contents in diets were 0 % (T1 or control), 11 % (T2) and 22 % (T3). The RDDM was determined in Pelibuey sheep, using ruminal cannulas. Bags with food samples were incubated in the rumen during 4, 8, 12, 24 and 48 h. Sheep (75 % Pelibuey x 25 % Doper) of 20 ±2.99 kg at the beginning were used for the test of fattening behavior, randomly distributed in individual cages with the same treatments of the RDDM test. Degradation parameters show that the diet with 22 % of RP had higher values in the rapidly soluble fraction (a), as well as the DM which disappeared from the rumen in the 4, 8 and 12 h of incubation. In respect to the control diet, the diet with 22 % of RP had lower ruminal degradability of the soluble fraction (b) and the DM disappeared from the rumen after 48 h of incubation. The potential degradability (a + b) and the constant degradation (c) were not affected by the RP level. Effective degradability at the rumen turnover rate (k) from 5 to 10 % was higher in the diet with 22 % of RP. The highest daily food intake for the behavior test was for sheep in T3 and the lowest in T2 ($P < 0.05$). The biggest daily gain in sheep was in the control group and the lowest in the T2 group ($P < 0.05$). The best feed conversion was observed in the control group and the lowest in T3 group ($P < 0.05$). It can be concluded that the RP, at high concentrated portions, can increase the RDDM and the rate of ruminal fluid, and can affect the behavior in sheep fattening. However, the RP reduces the most expensive conventional ingredients such as soybean, sorghum grain and cattle bait.

Key words: rice by-product, ovine fattening, ruminal kinetics.

During the milling process of rice grain (*Oryza sativa* L.) for human consumption various useful by-products for animal feeding are produced: polishings, bran and rice tips. Rice polishings has better nutritive value than the bran. However, the mixture of both is very advisable for cattle feeding, although there are variations in the nutritive content of each one of these by-products (Belyea *et al*. 1989, NRC 1996 and De Peters *et al*. 2000). CP of rice polishings is 14 % and ether extract 15 % (Sikka 2007). In view of its high protein-energy composition can be used in sheep fattening in replacement of traditional ingredients, as sorghum grain and soybean meal, with advantages in the cost of the finished feed. In sheep fattening, in rations with 18 % rice polishings plus 5 % beef tallow, Salinas-Chavira *et al*. (2008) did not find negative effects on live weight gain or in carcass characteristics. However, the high cost of conventional rations compels to search for alternative ingredients of low cost not affecting sheep growth or feeding efficiency. Rice polishings is obtained at a relatively low cost regarding other conventional ingredients, but there is poor data on ruminal indicators and the productive performance of fattening sheep, fed increasing levels of rice polishings in substitution of conventional ingredients. The objective of this study was to evaluate the ruminal degradation indicators and the performance of fattening sheep, fed diets high in concentrates, with increasing levels of rice polishings.

Materials and Methods

The study was conducted in a subtropical area at the Northeast of Mexico (23º44'06" N; 97º09'50"W). The area is located 340 m above sea level. Average annual rainfall is 900 mm and mean temperature of 25º C (INEGI 1995).

Two experiments were carried out to evaluate the use of increasing levels of rice polishings in fattening diets, for confined yearling sheep. Experiment I estimated the effect of increasing levels of rice polishings on ruminal DM degradability of the diets. In experiment II, the fattening performance of sheep fed these diets was assessed.

Experiment I. Ruminal kinetics was determined with three non-castrated Pelibuey yearling sheep of 6 months of age (25 kg of initial live weight), with permanent rumen cannulae (40 mm of diameter), and distributed in a 3 x 3 Latin square design. Prior to the beginning of the trial, animals were treated against parasites (Ivermectine) and injected with a preparation of vitamins A, D and E. Yearling sheep were housed in metabolic cages with roof and ventilation. They were fed *ad libitum* with three treatments (T) or diets, based on sorghum grain and soybean meal (table 1), and supplied in two equal

Table 1. Experimental diets used in the study (DM basis)

Ingredients, %	Rice polishings, %		
	0	11	22
Urea	0.20	0.25	0.5
Sorghum grain	61.9	49.7	27.0
Soybean meal	20.0	15.0	9.0
Sugar cane molasses	2.0	5.05	13.0
Minerals (premix)[1]	2.0	2.0	2.0
Sorghum shoot	10.0	10.0	12.0
Wheat bran	1.0	7.00	14.5
Beef tallow	3.0	0.0	0.0
Rice polishings	0.0	11.0	22.0
Nutrients			
CP, %	14.2	14.2	14.1
ME, MJ/kg	8.36	8.36	8.36

[1]Ovisalt ® (San Pedro Feed, Salt, & Mineral Co. S.A. of C.V. Mexico). Contains: Ca 100 g, P 80 g, Mg 30 g, Zn 4 g, Mn 3 ppm, Fe 3 ppm, Cu 0.0025 g, I 0.04 g, Se 0.04 g, Co 0.02 g, Vit. A 150 000 IU, Vit. D 25 000 IU, Vit. E 150 IU, ionophore 2.5 g (q.s.1 kg)

feedings at 9 a.m. and 4 p.m. Treatments were: T1) 0 % rice polishings, T2) 11% and T3) 22 %. Diets were similar in CP (14 %) and ME (8.36 MJ/kg) contents on DM basis and were formulated to cover the requirements of growing and fattening sheep (NRC 1985). Animals had free access to water.

Three ruminal incubation periods of samples or samplings were used with previous adaptation of 10 d each, before rumen suspension of bags. For ruminal incubation, nylon bags of 5 x 10 cm were used with 53-µm pore size (ANKOM Technology, Macedon NY, USA). Each bag contained 6 g of feed sample, grounded at 2.0 mm sieve, in a Wiley No. 4 mill. The bags with the sample of the feed were tied to a nylon rope 20 cm long, having a metallic weight to assure that samples stay immersed in the ventral sack of the rumen. Bags were incubated in the rumen for 4, 8, 12, 24 and 48 h. For determining *in situ* DM digestibility for each incubation time, three bags were utilized that were removed from the rumen for each determination. They were washed with running water at a low pressure until clean water came out the bag, and dried in an oven of forced air at constant weight (60º C 48 h. *In situ* DM degradability for the samples at each incubation time was calculated by the weight loss in the bags, before and after rumen incubation (Ørskov and McDonald 1979). The readily soluble fraction (washing loss) was estimated with the same model. The non-linear parameters for the estimation of ruminal DM degradability were realized according to the technique of Ørskov and McDonald (1979), from the following equation:

$P = a + b\ (1 - e^{-c(t-lag)})$

Where:

P = ruminal DM disappearance at time t

a = readily soluble fraction or washing loss

b = degradative fraction

c = fractional rate of degradation per hour

a + b = potential degradability (% representing the amount of feed that can be solubilized or degraded in the rumen, when the time is not a limiting factor)

t = time (h)

The constant ruminal exchange (k) at 1, 5 and 10 % per hour were used to estimate the effective degradation (ED) of DM (Ørskov and McDonald 1979) from the following equation:

ED = a + b (b*c)/(c + k).

Experiment II. Performance of fattening sheep was determined with 21 yearling sheep (75 % Pelibuey x 25 % Dorper), with an initial live weight of 20 ± 2.99 kg. Animals were housed in sheep pens with roof in individual corrals of 2 m^2, with a feeding trough and individual drinking place. Lambs were assigned to a completely randomized design in three equal groups. The same diets or treatments were considered. The feeding period was of 60 d, plus 15 d for adaptation. Animals were treated against parasites (Ivermectine) and injected with a preparation of vitamins A, D and E. Water was *ad libitum* and the feed was supplied twice daily (9 a.m. and 4 p.m.). Feed consumption was registered daily, and sheep were weighed every 20 d. At the end of the experiment live weight gain and feed consumption was calculated and feed conversion (feed intake/live weight gain) was estimated.

Experimental data for fattening performance of sheep were submitted to analysis of variance in an only one way design. Three treatments with seven replications each were established. One animal was considered as experimental unit (Steel and Torrie 1980). Tukey's test was used for mean comparison. Data were analyzed according to the GLM procedure of SAS (2007).

Results and Discussion

The ruminal digestibility parameters of the diets with increasing levels of polishings are shown in table 2. Rice polishings increased the readily soluble fraction (a). The ration with 22 % increased as average 30.3 % the readily soluble fraction (a), regarding the control and with 11 % polishings rations. These results coincide with the DM increase ($P < 0.01$) disappearing in the rumen in incubation times of 4, 8 and 12 h, as a consequence of the increase of the amount of polishings in the diets (figure 1). According to these results, Zhao *et al*. (1996) reported in cannulated steers that there was a maximum DM disappearance of rice polishings at 24 h, when the highest level was reached. The highest DM disappearance in the diet with higher content of rice polishings is considerable. Belyea *et al*. (1989) in *in vitro* studies with foodstuffs by-products found higher digestion rates for rice polishings (0.102), beet pulp (0.067), distillery's dry grains (0.052), soybean hulls (0.049), maize gluten (0.048) and alfalfa hay (0.052). The whole cottonseed was digested more slowly (0.027). The maize gluten, the distillery's dry grains, the rice polishing and the alfalfa were completely digested at 36 h. The beet pulp was almost completely digested at 18 h. Soybean hulls and cottonseeds were digested at 48 h. In this study was used fatted rice polishings. Similarly, Forster *et al*. (1994) observed greater ruminal DM disappearance for fatted rice polishings and wheat bran than for defatted polishings or maize in short incubations (2 and 4 h), regarding the most prolonged (24 and 48 h). Potential DM disappearance was 88, 100, 83 and 85 % for fatted

Table 2. Ruminal DM degradability parameters of the diets studied

Variables	Rice polishings, %		
	0	11	22
Readily soluble fraction (a)	36.0	37.7	48.0
Soluble fraction (b)	52.8	54.0	42.9
Potential degradability (a+b)	88.8	91.7	90.9
Degradation constant (c)	3.8	2.4	2.9
R^2	96.1	94.3	97.8
SE ±	11.4*	4.6*	6.3*
Effective degradability at flow rate per hour of:			
0.01	77.3	75.8	78.8
0.05	58.3^{b}	55.2^{c}	63.02^{a}
0.10	50.2^{b}	49.0^{b}	57.3^{a}

^{a,b,c}Means in the same line with different letters differ according to Tukey ($P < 0.05$)
SE ± Standard error of estimation *$P < 0.05$

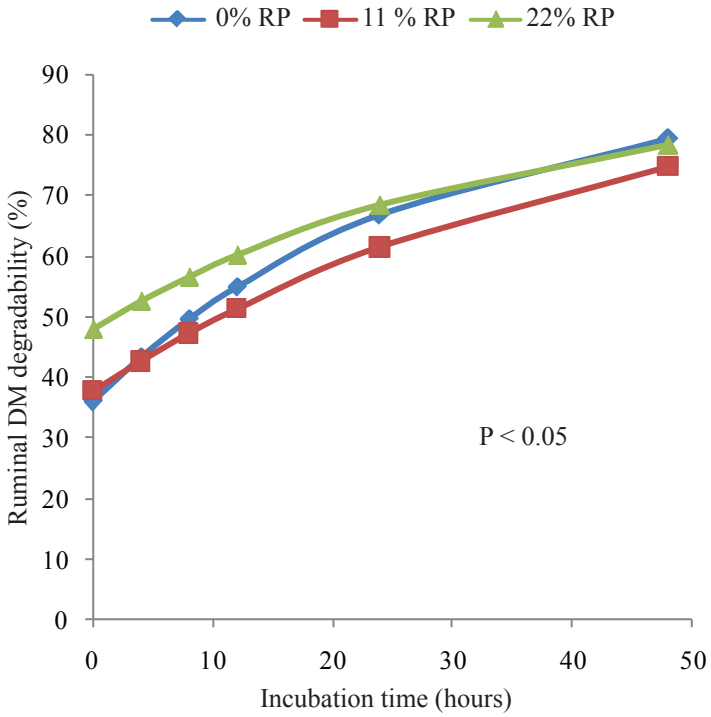

Figure 1. Ruminal DM degradability in rations with different rice polishings levels

rice polishings, maize, wheat bran and defatted rice polishings, respectively. Results from these authors also suggested lower NDF digestibility for fatted rice polishings. The lowest disappearance at 0 h and highest at 48 h for maize regarding the by-products, implies that the factors affecting the digesta stay time in the rumen have greater effect on the long ruminal digestion of maize.

In this research was studied the ruminal DM disappearance of totally mixed rations, formulated for the same content of protein and energy. The control diet included higher amount of sorghum grain, soybean meal and beef tallow, while in rations with rice polishings these ingredients were reduced. Nonetheless, sugar cane molasses, urea and wheat bran, which are of readily ruminal disappearance, were increased. In the 11% polishings ration, those ingredients increased to a lesser extent, while in the ration with 22 % rice polishings, the inclusion of molasses, urea and wheat bran was in greater proportion. Forster *et al*. (1994) noticed lower ruminal disappearance at few hours of incubation in the rumen for maize, compared to rice polishings. Ruminal fermentation of starch is determined by the fermentation rate and the retention time of starch in the rumen. These factors vary with the species, type of grain and other elements (Nocek *et al*. 1991 and Huntington 1997). Sorghum grain shows lower starch digestion rate (Spicer *et al*. 1986 and Herrera-Saldaña *et al*. 1990). From these considerations, for this study the control diet was based on grain sorghum, with which lower ruminal DM disappearance can be expected.

The ration with 22 % of polishings reduced as average 24.5 % the soluble fraction (b) respecting the control or with 11 % rice polishings rations. The level of rice polishings did not affect the potential degradability (a + b) or the degradation constant (c). This is due to the fact that rations with higher value in the fractions readily soluble (a) showed lower value in the degradative fraction (b), and vice versa. The ration with the highest content of polishings was readily degraded in the rumen, but its soluble fraction (b) was lower, whereas in the ration without polishings (control), it was found lower value of readily soluble fraction (a), but greater in the soluble fraction (b). These results agree with those of Zhao *et al*. (1996), who reported greater ruminal disappearance of the unprocessed polishings than in the processed, without fat, during the first 24 h of incubation. However, in the followings was greater in defatted rice polishings. In other studies it was also found that a feed is degraded in the rumen in lesser amount at the beginning, but in the following hours its disappearance is increased, regarding other ingredients. The rice polishings showed high ruminal DM degradability. In this sense, Forster *et al*. (1994) reported lower DM disappearance rate at 0 h of incubation for maize, rice polishings and other by-products, while at 48 and 72 h was the highest ruminal disappearance for maize. The rice polishings readily disappear from the rumen. In spite of its low carbohydrate content of easy digestion (starch), shows high rate of ruminal degradation. This is similar to that of yucca (Manihot esculenta C.) tuber flakes with high starch content of easy digestion (Wanapat *et al*. 2012).

In this study the effect of the rice polishings level on the effective degradability at ruminal exchange rate of 1 % per hour ($P > 0.10$) was not confirmed. However, at ruminal exchange rates of 5 and 10 % per hour, there was higher effective degradability in the diet with 22 % of rice polishings. The effective degradability in high concentrates rations present ruminal exchange rates, from 5 to 10 % per hour. Regarding the diet without polishings, the diet with 11 % had lower substitution of ingredients. The diet with 22 % notably changed the composition of ingredients, decreased the sorghum grain and the soybean meal. However, ingredients of high rate of ruminal degradability, as urea, molasses, when bran and rice polishings were increased considerably. Besides the high ruminal solubility of the ration with 22 % of polishings, the particle size can also contribute to a rapid passage rate. On the matter, Zhao *et al*. (1996) reported that the particle size of the polishings is small, and leads to a fast passage rate from the rumen of non-amylaceous non-structural polysaccharides. According to these criteria, Elliot *et al*. (1977) observed that supplementation with polishings increased the ruminal exchange rates.

Experiment II. The effect of increasing level of rice polishings on sheep performance during fattening is set out in table 3. The highest daily feed consumption was in sheep of 22% of rice polishing, and the lowest in those of 11% ($P < 0.05$). Animals of the control showed similar ($P > 0.05$) feed consumption than those of 11% and 22%. The highest daily weight gain was in sheep of the control group, and the lowest in 11% ($P < 0.05$). Animals of 22% presented similar weight gain than those of control and 11%. The best feed conversion was that of sheep of the control group, and the lowest corresponded to those of 22% ($P < 0.05$). Animals of 11% had similar feed conversion than those of the control and 23%.

According to these results, Tabeidian and Sadeghi (2009) noticed adverse effects on growth or feed conversion of sheep with the substitution of barley grain high levels of rice polishings (45 or 60 %). These results were attributed to lower feed consumption in animals with high levels of rice polishings. In this experiment, the ration with highest level of rice polishings attained higher feed consumption. Ruiz *et al*. (2005) in sheep fed diets based on Saccharina, in substitution of 0, 10, 20 and 30 % rice polishings, reported an increase in feed consumption with higher levels of rice polishings.

Table 3. Productive performance of sheep in feeding trial

Variable	Rice polishings, %			SE ±
	0	11	22	
Animals	7	7	7	
Initial LW	20.07	19.50	20.43	
Final LW	34.07	30.07	32.57	
Daily LW gain (g)	233.00[a]	176.00[b]	202.00[ab]	14.7
Daily DM intake (g)	981.00[ab]	882.00[b]	1074.00[a]	45.4
Feed conversion	4.23[b]	5.12[ab]	5.41[a]	0.25

[a,b]Means in the same line with different letters differ according to Tukey ($P < 0.05$)

In this study, sheep fed rations with rice polishings reached better daily live weight gain and feed conversion, compared to the research of Tabeidian and Sadeghi (2009) in rations with 0, 15, 30 and 45 % of rice polishings. These differences are attributed to the composition of the diet. For this investigation were used ingredients of lesser ruminal degradability, while in the studies of Tabeidian and Sadeghi (2009), the high levels of rice polishings affected the ruminal function through the increase of degradability. Oliveira *et al*. (2012) did not find effect on confined sheep production, when maize meal was substituted by rice polishingss in the diets. According to these authors, the advantage of using rice polishings is its cost, which is 30 % cheaper than maize.

In this study the correspondence between the high ruminal degradability in diets with rice polishings and poorer growth and feed efficiency of fattening sheep was confirmed with these diets regarding the control diet, without rice polishings. Rations with lower levels of molasses and wheat bran, which are of high ruminal degradation, generate better productive performance of fattening sheep, fed diets with 18 % rice polishings and beef tallow (Salinas-Chavira *et al*. 2008).

It is concluded that according to the conditions of this study, in rations high in concentrates with rice polishings there is high DM rumen degradability, and lower productive performance of fattening animals. Respecting the control diet, in the 22% diet, with the inclusion of rice polishings, the sorghum grain was reduced by 56 % and soybean meal by 55 %. However, molasses, urea and wheat bran were increased for maintaining the energy and protein balance in the diets. The 22% diet, with the inclusion of available ingredients in the region, the cost decreases, since soybean and sorghum are imported in Mexico in variable amounts. From these criteria, it can be stated that rice polishings can be included in rations for sheep fattening in moderate amounts (less than 20 %), the same as other ingredients of high ruminal degradability, in low proportions. Search for nutritional alternatives must be made allowing the maximum use of available ingredients in the region, without affecting ruminal function and production of fattening sheep.

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