Bull. Fac. Agr. Shimane Univ., 28 : 119—124, December 20, 1994

Effect of Heat Treatments on the Effective Degradability of Soyabean Crude Protein in the Rumen

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Abstract To evaluate the effect of heat treatments on the effective degradability of soyabean crude protein in the rumen, we conducted the nylon bag incubations and rumen passage rate estimates for raw and heated soyabean. Three types of heated soyabeans were prepared by roasting rolled raw soyabean at 400°C for 30, 60 and 120sec. The rumen degradation characteristics and passage rate constant for each soyabean were determined *via* the nylon bag technique and the marker pulse dose procedure. The nylon bag incubations and ruminal passage rate estimates of the soyabeans were conducted using three rumen fistulated weathers and four Holstein lactating cows, respectively. The results obtained were as follows; 1) The soluble portion (%), degradable portion (%) and degradation rate constant (/h) of crude protein for raw soyabean, heated for 30, 60 and 120sec were 55, 45, 0.06; 19, 81, 0.04; 11, 89, 0.05 and 10, 83, 0.06, respectively. 2) The ruminal passage rate constant (%/h) for raw soyabean, heated for 30, 60 and 120sec were 1.94, 3.04, 2.26 and 3.18, respectively. 3) The effective ruminal degradability of crude protein (%) for raw soyabean, heated for 30, 60 and 120 sec were 86.4, 63.2, 69.5 and 61.6, respectively, and was significantly higher ($P<0.05$) for raw compared to heated soyabeans. There was no statistically significant differences in the effective ruminal degradability among the heated soyabeans.

Key words: Rumen degradability; soyabeans; heat treatments; nylon bag technique.

Introduction

The protein value of feeds presently is assessed by the amount of amino acid absorbed in the small intestine from dietary protein which escapes ruminal degradation and from microbial protein synthesized in the rumen. Meeting amino acid requirements of high producing dairy cattle may require feedstuffs containing protein sources which are degraded slowly and/or lowly-degradable in the rumen to increase amino acid supply to the small intestine. Soyabean is commonly used for dairy cattle feeding as a protein supplement source. Heat treatments of protein supplements have been generally used to reduce the rumen degradation.

Since direct measurement of dietary protein degradation in the rumen using fistulated animals is not easy, alternative method have been developed. The nylon bag technique is the method most commonly used (Nocek, 1988; Orskov, 1991). The present study was conducted to determine ruminal crude protein degradation including

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an information on rumen retention time for heated soyabeans.

Materials and methods

Animals and feeding: Three rumen fistulated wethers (mean body weight 37 kg) and four intact early lactating Holstein cows (mean body weight 583kg) were used. The wethers and dairy cows were, respectively, used for measuring nylon bag degradation and rumen passage rate constant of soyabeans. The animals were individually tied in a pen and had free access to water and mineral blocks. The wethers were fed a mixed diet, consisting of 50% chopped hay and 50% concentrate at levels ranging from that sufficient to supply the energy requirement for maintenance (ARC, 1980). The dairy cows were fed a ration (TDN 75%, CP 17%) to meet requirements for milk production and maintenance.

Experimental feed: Rumen degradation characteristics and ruminal passage rate constants were determined for three types of heated soyabeans (120s, 60s and 30s) and raw soyabean (RS). All soyabeans were similally rolled. The 120s, 60s and 30s were prepared by roasting RS in a hot-sand roaster for 120, 60 and 30sec, respectively.

Nylon bag measurement: The rumen degradation values of the soyabeans were determined *via* nylon bag technique (Orskov and McDonald, 1979). Nylon bags (5× 10cm, 45μm pore size), containing about 5g sample (ground to pass a 2-mm screen), were placed in the rumen and two of the bags were removed from the rumen of each wether at 2, 4, 6, 12, 24 and 48h after incubation. After removal, bags were rinsed thoroughly with running-tap water until the wash-out water had become clear for several hours. After being washed, the bags were dried at 60°C for 48h. The dried residues were determined gravimetrically for dry matter (DM) and crude protein (CP) *via* the method of A. O. A. C. (1980). The proportion of DM and CP lost from initially incubated samples at each incubation time (t, h) were described by an exponential model, $P_{(t)}=a+b(1-e^{-ct})$ (Orskov and McDonald, 1979). The constants a, b and c were estimated using an iterative least square method.

Passage rate measurement: The rumen passage rate constant for each soyabean was determined *via* labeled-soyabean dosing technique. The 120s, 60s, 30s and RS was, respectively, labeled with ytterbium, lanthanum, dysprosium and samarium following the procedure outlined by Mader *et al.* (1984). A pulse dose of the labeled soyabeans (500g, respectively) were performed *via* feeding to the dairy cows. After dosing, a total of 24 rectal feces samples were taken over 5-d collection period from each animal. Fecal samples were dried at 60°C in a forced-air oven, ground (1 mm screen) and wet-ashed before rare-earth analysis. The rare earths concentrations in the fecal samples were determined by inductively coupled argon plasma emission spectrophotometry. Rumen passage rate constant for each soyabean was calculated as described by Grovum and Williams (1973).

Effective rumen degradability: Effective rumen degradability (DG) of crude protein for each soyabean was calculated using the rumen degradation constants weighted against rumen passage rate constant. The DG value was calculated following an exponential equation,

$$DG = a + \frac{bc}{c+k}(1 - e^{-(c+k)T}) \quad \text{(Orskov and McDonald, 1979)}$$

where a, b, and c are parameters obtained from nylon bag study, k is rumen passage rate constant and T is rumen retention time (h, reciprocal value of k).

Statistical analyses: Results were subjected to a one-way layout design with the heating treatments as a factor. Statistical analyses were conducted by analysis of variance and regression. Statistical differences in the mean values between soyabean were tested using Duncan's multiple range test.

Results and discussion

The CP disappearance of soyabeans from the nylon bags at each ruminal incubation time are illustrated in Fig. 1. An asymptotic CP disappearance pattern was observed for each soyabean. There were large differences in the ascending part of CP disappearance from the bags between RS and heated soyabeans (HSB), but not among HSB. The CP disappearance ratio of initial CP at 3 to 24h after incubation was significantly higher for RS than for 120s, 60s, and 30s ($P<0.05$). Ruminal degradation parameters were calculated by fitting the ruminal degradation curves to the exponential equation (Orskov and McDonald, 1979), in which a represents the immediate soluble fraction which ferments rapidly, b represents the insoluble but fermentable fraction and c represents the rate constant of degradation of b. The values of ruminal degradation parameters in terms of DM and CP are shown in Table 1. The values showed that RS contained greater rapidly degradable portion than did HSB. Inversely, the insoluble but degradable portion for RS was lower than for HSB. The potentially degradable portion ($a+b$) and degradation rate constant did not differ significantly among soyabeans. Since CP content (% DM) of soyabean is markedly high (average value, 45%), degradation rate constant did not differ between CP and DM for each soyabean. The b value for 30s, 60s and 120s was significantly greater

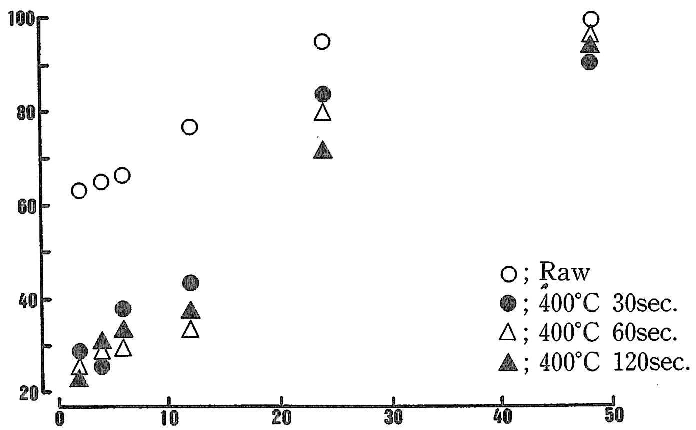

Fig. 1. Crude protein degradation of Raw and heated soyabeans as determined by the nylon bag technique (means of three observations at each time).

Table 1. Ruminal degradathion characteristics for raw soyabean and heated soyabeans according to the equation $P(t)=a+b(1-e^{-ct})$.

	RS[1] Non-heated	Heated (400°C)		
		30sec	60sec	120sec
Dry matter				
a, %	49.4[2),A)]	28.7[B)]	28.2[B)]	31.1[B)]
b, %	50.6[A)]	69.2[B)]	71.8[B)]	68.8[B)]
c, %/h	0.06	0.05	0.06	0.05
Crude protein				
a, %	54.8[A)]	18.7[B)]	11.3[B)]	10.3[B)]
b, %	45.2[A)]	81.2[B)]	88.7[B)]	83.4[B)]
c, %/h	0.06	0.04	0.05	0.06

1) Raw soyabean.
2) Mean values for three sheep.
A) and B) Means within the same row with different superscripts differ (P<0.05).

(P<0.05) than RS for both DM and CP. The degradation of the incubated protein supplement could be a measure of the degree of rumen microbes attack and consequently of different rumen microbes activities associated with the nature of fermentability of dietary protein. In the present study, the heat-treatments of the soyabean did not affect the CP degradation rate but did its rumen solubility and potentially degradable portion.

As can be seen in Table 2, ruminal passage rate constant of soyabean increased by heat treatments. The HSB had 50% greater (P<0.05) rate constant than RS. No significant difference was found for passage rate constant among HSB. Poppi *et al.* (1980) have reported that the particle size of ingesta particles strongly affected the ruminal passage rate, however, the physical form of soyabeans did not differ between RS and HSB. Therefore, the difference in ruminal passage rate constant between RS and HSB should not be attributed to the particle size of ingested soyabeans. Since the rapidly fermentable portion for RS was markedly higher than for HSB, fermented gas portion, attaching gas bubbles and floating property of the soyabean particles in the rumen appeared to be greater for RS than for HSB. As reviewed by Sutherland (1988), the specific gravity of buoyant particles in the rumen should be lower than the optimum value required for rumen passage (about 1.2 to 1.4). Specific gravity of the

Table 2. Ruminal passage rate constant[1] for raw soyabean and heated soyabeans.

	RS[2]	Heated (400°C)		
		30sec	60sec	120sec
	%/h			
Rate constant	1.94±0.41[3),a)]	3.04±0.36[b)]	2.26±0.25[b)]	3.18±0.55[b)]

1) Calculated *via* the mathematical model presented by Grovum and Williams (1973).
2) Raw soyabean.
3) Mean values with the standerd deviations for four cows.
a) and b) Means within the same row with different superscripts differ (P<0.05).

rumen particles closely relate to the location in the rumen and the transport from the rumen raft materials which consisted of large-sized forage particles (Ewing *et al.* 1986; Faichney, 1980). Accordingly, it is inferred that the difference in ruminal passage rate constant between RS and HSB could be ascribed to the difference in the ruminal floating status which was carried out *via* fermentation of the easily fermentable portion between RS and HSB. Blaxter *et al.* (1956) suggested that the ruminal digestibility of feed was affected by ruminal retention time. As shown in Table 2, soyabean heat treatments greatly reduced ($P<0.05$) the ruminal retention time of soyabean. In order to estimate the *DG* value of soyabean CP considering its ruminal retention time, we combined the nylon bag incubation data with the ruminal passage rate constant. The values for each soyabean is listed in Table 3. The *DG* of HSB averaged 64.8% and was 25% lower compared to RS. However, potentially degradable portion of CP did not differ among the soyabeans, while differences in the rumen retention time between soyabeans affected appreciablly the *DG* value. However, the effect of soyabean heating time on ruminal degradation was not cleared.

Table 3. Effective ruminal degradability (*DG*) of crude protein for raw soyabean and heated soyabeans.

		Heated (400°C)		
	RS[1)]	30sec	60sec	120sec
	%			
DG[2]	86.4±1.5[3),a)]	63.23±2.8[b)]	69.49±7.5[b)]	61.62±6.8[b)]

[1)] Raw soyabean.

[2)] $DG=a+\frac{bc}{c+k}(1-e^{-(c+k)T})$; a, b, c are ruminal digradation parameters for each soyabean (see Table 1), k=rumen passage rate constant for each soyabean (see Table 2) and T=ruminal retention time (100/k, h).

[3)] Mean values with their standerd deviations for three sheep.

[a) and b)] Means within the same row with different superseripts differ ($P<0.05$).

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