Influence of Dry Roasting of Whole Faba Beans (*Vicia faba*) on Rumen Degradation Characteristics in Dairy Cows, II: Starch

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ABSTRACT : Whole faba beans (WFB) were dry roasted at different temperatures of 110, 130 and 150℃ for 15, 30 and 45 minutes (min) to determine the optimal heating conditions to increase bypass starch as glucose source which may be a limiting nutrient in high producing dairy cattle. Ruminant degradation characteristics of starch (St) of WFB were determined using *in sacco* method in 6 dairy cows fed 60% hay and 40% concentrate. Measured characteristics of St were soluble (washable) fraction (S), potentially degradation fraction (D) and the rate of degradation (Kd) of the insoluble but degradable St fraction. Based on measurement of these characteristics, percentage bypass starch (%BSt) and bypass starch (BSt) were calculated. Degradability of starch in the rumen was reduced by dry roasting at temperature of 130 and 150℃ and increased at 110℃. S varied from 50.0% in the raw whole faba beans (RWFB) and 53.7% in 110℃/15 min to 18.2% in 150℃/45 min. D varied from 49.9% in RWFB and 46.3% in 110℃/15 min to 81.8 % in 150℃/45 min. Kd varied from 9.8% in RWFB and 11.0% in the 110℃/30 min to 4.2 in 150℃/45 min. All these effects resulted in increasing %BSt from 22.1% in the 110℃/45 min and 23.9% in RWFB to 49.9% in the 150℃/45 min. Therefore BSt increased from 91.4 g/kg and 98.4 g/kg to 199.9 g/kg respectively. Dry roasting at 110℃ increased the starch rumen degradation. Treatment at higher temperature (130 and 150℃) decreased rumen degradation of starch and seemed to be linear up to highest values tested. No optimal dry roasting conditions of treatment could be determined at this stage. It may be concluded that dry roasting at temperatures of 130 and 150℃ was effective in shifting starch degradation from rumen to intestine to increase bypass starch.

(**Key Words**: Faba Beans, Dry Roasting, Rumen Starch Degradation, *In Sacco*)

INTRODUCTION

Though ruminants have advantages in comparison with monogastric animals, such as the capacity to degrade structural carbohydrates, to produce easily absorbable and highly utilizable volatile fatty acids (VFA), the synthesis of microbial protein, the elimination of many anti-nutritional factors, and the synthesis of B-vitamins, they also have disadvantages. One disadvantage is the degradation of non-structural carbohydrates of which the storage polysaccharide starch is quantitatively the predominant form.

Particularly in highly producing dairy cattle glucose can be a limiting nutrient. If the non-structural dietary carbohydrates (starch) are quantitatively degraded in the reticulo-rumen, the animal has to rely for its glucose supply mainly on glucogenic precursors such as propionic acid and glucogenic amino acids. Under such conditions productivity increases if a part of the dietary non-structural carbohydrates bypasses reticulo-rumen fermentation (Bruchem, 1991). It is advantageous under such conditions to have more starch escape degradation in the rumen and provide a source of glucose in the small intestine (Noeck & Tamminga, 1991) to achieve a higher milk production.

Starch escaping ruminal degradation will not only supply the animal with more glucose, an important precursor for lactose, and possibly conserve amino acids for purposes other than protein synthesis (oxidation and gluconeogensis). It may also prevent fermentation losses in the rumen (Tamminga and Jansman, 1993), alter milk composition, since intestinal digestion of large amount of starch can result in a reduced milk fat content and somewhat enhanced milk protein content (Tamminga and Goelema, 1993). Performance data from growing cattle

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fed processed corn and sorghum grains indicate that starch was used 42% more efficiently if it was digested in the small intestine rather that in the rumen (Owens, 1986)

Whole faba beans (WFB), a widely available legume seed, are particularly high in crude protein and are also a good source of lysine, and starch (Cerning-Beroard, 1977). They have attracted attention in recent years as possible homegrown feeds in a large area (temperate and subtropical zone) and appear to be the protein source and starch source best suited to the ecological and climatic condition of many countries. However the rapid fermentation of the starch fraction in the rumen limits their use in an unprocessed form in ruminant diets because little starch escapes fermentation, and volatile fatty acids (VFA) are generated sufficiently rapidly to cause a decrease in ruminal pH, to levels at which cell wall degrading bacteria are inhibited. The effects can be large enough to disturb rumen fermentation (Cone, 1990), inhibiting the degradation of cell walls of roughage component of the diet and causing an imbalance between feed digestion and microbial cell growth. High contents of easily degradable concentrates in the diet may also lead to the production of lactate, which is less easily absorbed from the rumen, leading to rumen acidosis and possibly eventually resulting in the so-called off-feed syndrome and a concurrent atony of the rumen. Therefore these seeds like cereal grains are to be used with caution.

One of the possibilities to reduce rumen degradation is heat treatment. The intensity of the effect is a function of time of exposure and temperature reached (Stern et al., 1985; Pene et al., 1986; Annexstad et al., 1987; Waltz and Stern, 1989). Particle size and moisture during processing also influence the possible effects of processing. The decrease in rumen starch degradation should lead to an increasing intestinal availability of starch. Under conditions of high concentrate intake, treatments that would lead to even a small improvement in the nutritive value of legume seeds could be of significant economic consequence. A number of publications (Pene et al., 1986; Annexstad et al., 1987; Tamminga, 1993, Waltz and Stern, 1989 and Yu, 1995) indicated that heat treatment does effect rumen degradation. But optimal heating conditions have not been found for each legume seed till now. Heating above the optimal temperature may overprotect starch so that starch is neither fermented in the rumen nor digested in the small intestines (Stern et al., 1985). Also prolonged treatment with high temperature could lead to adverse reactions (Maillard reaction) between carbohydrate and amino acid.

Dry roasting is a technology to improve the nutritive value of legume seeds. Literature on the nutritive value of dry roasting WFB for ruminants is scarce. The aim of the present experiment was to determine the effect of dry roasting of faba beans on ruminal degradative kinetics and fermentation characteristics of starch for high yielding dairy cows in order to decrease rumen degradation, increase the amount of bypass starch and optimize fermentation in the rumen by shifting of starch digestion from rumen to intestines and therefore reduce unnecessary starch losses from rumen.

MATERIALS AND METHODS

Feedstuffs

Whole faba beans (WFB) (*Vicia faba*) were obtained from the commercial company (Peter Gibbs Stock Feeds in Australia). Contamination in WFB, mainly peas, was less than 0.2%. The chemical composition of whole faba beans seeds is presented in table 1.

Table 1. Dry matter and chemical composition (g/kg) of RWFB

Chemical composition	Content (g/kg)
Dry matter	885.9 ± 0.60
Starch	364.1 ± 0.85
Crude protein	281.1 ± 1.67
Organic matter	855.1 ± 0.73
Ash	30.8 ± 0.13

Technological treatments

Raw whole faba bena (RWFB) were dry toasted at 3 different temperature (110, 130 and 150℃) for periods of 15, 30 and 45 minutes in the design as shown in the table 2. The number of total treatments (10) included RWFB. For each treatment, about 1.5 kg was roasted in the lab oven (Qualtex Solidstat. universal series 2000 designed in Australia by Watson Victor LTD). After dry roasting, faba beans were cooled down to ambient temperature, then were ground through a 3 mm screen (Hemmer mill AEG TYP AM80N* 2). The conditions of processing are shown in table 2.

Animals and animal diets

Six dry Holstein Friesian cows, aged between 56 and 135 months, liveweight between 580 and 746 kg and about 8 months pregnant, were previously equipped with a rumen cannula with an internal diameter of 10 cm (Silicon rubber, handmade) for measured rumen degradability, and were kept at Kyabram Dairy Center (Victoria, Australia) in the feedlot.

All cows received a diet consisting of 3.5 kg/day commercial pelleted concentrate (Barastoc Hi-Lac-Hi-E Dairy Pellets, Ridley Agriproducts PTY. LTD, table 3) and 5.4 kg/day (83.7% DM) sub-clover hay purchased locally. Water was always available. The cows was individually fed twice daily at 08:00 and 16:00, 2.7 kg sub-clover hay and 1.75 kg pellets. The feeding level was according to the requirements of dairy cow requirements calculated by Ruminant 3.3 (Dept. of Agriculture, Reading University, UK). A 12 day period of adaptation was allowed. The animal used in these experiments were cared for in accordance with the guidelines established by Australian Council of Animal Care.

Table 2. Treatments (1 control + 9 treatment) and the dry toasting condition of WFB (Where, each treatment measured at least 4 times)

Treatments	Dry roasting		
	Temp. (℃) (Mean and SD)		Time (min.)
RWFB			
110℃/15 min	110.0	0.00	15
110℃/30 min	111.3	1.21	30
110℃/45 min	110.9	1.55	45
130℃/15 min	130.0	0.00	15
130℃/30 min	129.8	0.45	30
130℃/45 min	130.0	0.00	45
150℃/15 min	149.5	0.71	15
150℃/35 min	150.0	0.00	30
150℃/45 min	150.0	0.00	45

Table 3. The chemical analysis* of commercial pelleted concentrate of dairy cows

composition	content
Dry matter	87.6%
Total Crude Protein	12.0%
Crude protein	10.7%
Non protein N	1.3%
Urea	0.5%
Crude fat	2.0%
Crude fiber	15.0%
Max. added salt	1.0%
Max. fluorine	0.02%
Vitamin A	6,000 IU/kg
Vitamin D_3	500 IU/kg

* The date provided by manufacturer, Ridley Agriproducts PTY. LTD, except DM content.

Starch degradation *In sacco* method

Starch degradation characteristics of WFB in the rumen of the 6 dairy cows were determined using the *in sacco* method. Incubation of all treatments in the rumen was with 5 g dry matter in nylon bags (10 × 17 cm) with the pore size of approximately 44 μm (Switzerland 1807710014 I 044 Nytal ASTM 325-44) as described by Tamminga et al. (1990). The rumen incubations were performed according to the 'gradual addition/all out' schedule. Incubations were carried out for 48, 24, 12, 8, 4 and 2 hours; bags were inserted at 21:00 (first day), 21:00 (second day) and on the third day at 09:00, 13:00, 17:00 and 19:00; all were removed at 21:00 hours on the third day. All treatments were randomly allocated over all cows and the whole incubation period.

After incubation, the bags containing the residues were rinsed under a cold stream of tap water to remove excess ruminal fluid and free or loosely attached microbes on the surface, to stop microbial activity, then washed with cool water without detergent in a commercial washing machine (Fisher & Paykel, Smart Drive 500) for 55 minutes. The bags were drained and blotted without spin drying and subsequently dried at 60℃ for 24 hour in a force draft oven. The 0 hour incubation samples were put directly into the washing machine under the same conditions. Dry samples were stored in a cool room (4℃) until analysis. The residue was ground through a 1 mm screen and analyzed for chemical composition.

Chemical analysis

Analyses for feed and for rumen residues at 0, 2, 4, 8, 12, 24 and 48 hours of all treatments were DM, Ash, N, Starch (St). DM was determined by drying at 105℃ to constant weight. Ash was determined by ashing at 550℃ to constant weight. N was analyzed by NCS instrument (NA 1500 NCS FISONS), and CP content was calculated as N * 6.25. Starch was determined according to the AGS-DG method (Yu, 1995), the analytical principle being Removal of dextrin and lower sugars by extraction with ethanol, gelatinization of the starch, hydrolysation of starch by the enzyme amyloglucosidase (AGS) to glucose at pH 4.8 (a); Glucose is phosphorylated to glucose-6-phosphate (G-6-P) by adenosine-5'-triphosphate (ATP) in the presence of the enzyme hexokinase at pH 7.6 (b); In the presence of the enzyme glucose-6-phosphate dehydrogenase (G6P-DH), glucose-6-phosphate is oxidized by nicotinamide-adenine-dinucleotide-phosphate (NADP+) to gluconate-6-phosphate under formation of NADPH (c); The amount of NADPH formed is stoichiometric with the amount of glucose. NADPH is determined by means fo its absorbency at 334, 340 or 365 nm (d).

Statistical analysis

Important degradation characteristics of starch are: the soluble (washable) fraction (S) which is assumed to be degraded rapidly and completely; the fraction which is not soluble, but potentially degradable (D); the fractional rate of degradation (Kd) of the fraction D (Van Straalen and Tamminga, 1990). Part of starch could be washed out of the bags without incubation in the rumen. This proportion (S) was considered to be degraded very rapidly and completely. The remaining proportion (D) was degradable, but insoluble, can be calculated as 100-S. The fractional rate of degradation of this proportion was called Kd. The lag time (T0) and U fraction in starch are neglected (Tamminga, 1989) due to the fast and complete starch degradation

Results of *in sacco* incubations were calculated using the NLIN procedure of the statistical package SAS (SAS, 1991) using iterative least squares regression by the following equation (Ørskov and McDonald, 1979):

$R(t) = U + D * \exp^{-Kd*(t)}$

Where: R(t) stands for residue (in %) of the amount of incubated material after t hours of rumen incubation. Percentage of bypass starch (%BSt) was calculated according the following formula (Tamminga, 1994)

$\% BSt = D * Kp / (Kp+Kd) + 0.1 * S.$

Bypass starch was calculated as:

$BSt = Starch (g/kg) * \%BSt /100$

Where: Passage rates (kp) of 0.06/h was adopted based on international data (Tamminga et al., 1994); BSt and St in g/kg, DM; %BSt in %;

Analysis of variance was carried out using Proc GLM (SAS). The following linear model was used for data analysis:

$Y = \mu + Temp_i + Time_j + Temp*Time_{ij} + e_{ij}$

where: Y = degraded fraction; i = 1,2,3,4; j = 1,2,3,4

Comparison of temperature or time effects on degradation characteristics were carried out by Tukey's studentized range test (HSD)

Since the determination of degradation characteristics, yielded one result per treatment, no statistical test of comparison of each treatment (time and temperature combination) for %BSt, BSt, Kd, D and S) in the rumen was carried out.

RESULTS

Total starch and CP composition and rumen starch disappearance (%) of WFB are presented in table 4. Dry roasting at 110℃ increased rumen disappearance but at 130 and 150℃, it decreased the washable fraction and decreased the rumen disappearance. After 24 h rumen incubation, rumen disappearance was high (more than 90%) for all treatments except 150℃/45 min. In RWFB only 3.6% of starch remained undegraded, indicating that dry roasting has effects on starch disappearance during short rumen incubation time, but after a long incubation, the effects tended to disappear.

Table 5 presents ruminal degradation of starch in WFB as described by means of the exponential equation and based on the best fit of data to the model. RWFB showed a high soluble fraction (50.1%), high degradation rate (9.8%/h) and less escape starch to intestines (23.9%).

Table 4. Starch disappearance (%) of faba beans dry roasted at different time and temperature, as a function of time of incubation in nylon bags incubated in the rumen of dairy cows

Temp. (℃)	Raw	110			130			150		
Time (Min.)	Raw	15	30	45	15	30	45	15	30	45
DM (g/kg)	885.9	895.6	900.7	910.2	919.0	920.6	923.4	924.1	935.3	941.0
CP (g/kg, DM)	317.3	317.5	319.9	318.8	323.0	324.3	318.2	322	320.4	310.4
Starch (g/kg, DM)	364.1	371.8	371.2	382.7	371.7	370.2	376.5	370.7	369.5	377.1
Starch rumen disappearance (RD %)										
Incubation time (h)										
0	50.1	53.7	52.0	52.5	42.4	40.5	36.1	30.8	25.5	18.2
2	48.9	56.6	56.7	56.7	45.8	47.5	38.9	33.3	26.7	20.4
4	59.6	63.4	65.7	68.2	56.8	55.7	50.2	43.6	36.4	21.3
8	80.2	82.6	83.0	82.2	77.8	75.0	70.2	64.9	54.0	33.7
12	89.9	88.6	89.9	89.9	87.3	86.0	84.4	81.9	74.0	49.2
24	96.4	95.8	94.8	94.3	93.5	94.1	92.1	93.1	91.6	81.1

Treatment temperatures have significantly effects on starch rumen disappearance during a short time incubation of 0, 2, 4, 8 and 12 ($p < 0.05$). Treatment times have not significantly effects on starch rumen disappearance ($p > 0.05$).

Table 5. Effect of dry roasting on rumen degradation characteristics (RDC) and Bypass (Bst) of starch in WFB

Temp. (℃)	Raw	110			130			150		
Time (Min.)	Raw	15	30	45	15	30	45	15	30	45
DM (g/kg)	885.9	895.6	900.7	910.2	919.0	920.6	923.4	924.1	935.3	941.0
CP (g/kg, DM)	317.3	317.5	319.9	318.8	323.0	324.3	318.2	322	320.4	310.4
Starch (g/kg)	364.1	371.8	371.2	382.7	371.7	370.2	376.5	370.7	369.5	377.1
Starch Rumen Degradation Characteristies (RDC)										
S	50.09	53.72	51.95	52.45	42.42	40.51	36.06	30.81	25.53	18.18
D	49.91	46.28	48.05	47.55	57.58	59.49	63.94	69.19	74.47	81.82
Kd	9.82	9.88	10.97	10.96	10.14	10.03	9.04	8.54	7.05	4.21
%BSt	23.94	22.86	22.18	22.07	25.65	26.32	29.11	31.63	36.79	49.90
Mean S (SD)		52.71 (0.91)			39.66 (3.26)			24.84 (6.34)		
Mean D (SD)		47.29 (0.91)			60.34 (3.26)			75.16 (6.34)		
Mean Kd (SD)		10.60 (0.63)			9.73 (0.61)			6.60 (2.20)		
Mean (%BSt) (SD)		22.37 (0.43)			27.03 (1.84)			39.44 (9.42)		

Note: %BSt = D * Kp/(Kp + Kd) + 0.1 * S; Bst = Starch (g/kg) * %BSt/100 (Kp = 6%/h).
Treatment temperatures had significantly effects on the parameters of S, D ($p < 0.01$) Kd, %BSt, BSt ($p < 0.05$).
Treatment times had significantly effects on S, D ($p < 0.05$) but no significantly on Kd, %BSt, BSt ($p > 0.05$).

Dry roasting changed WFB soluble fraction, degradation fraction and Bypass starch.

S varied from 53.7% in 110℃/15' to 18.2% in 150℃/45'. The effects of treatment time and temperature were strongly significant ($p < 0.01$). Averages of S of dry roasting at 110, 130 and 150℃ were 52.7, 39.7 and 24.8% respectively. S was increased at 110℃ by 5%, then reduced by 21 and 50% at 130℃ and 150℃ respectively. All the results are discussed later.

D varied from 46.3% in 110℃/15' to 81.8% in 150℃/45'. The effects of treatment time and temperature were strongly significant ($p < 0.01$). With increasing temperature from 110 to 150℃, D was decreased by 5% at 110℃, then increased by 21% and 50% at 130 and 150℃ respectively.

Kd fraction varied from 10.9% in 110℃/30' to 4.2%/h in 150℃/45'. Treatment temperature had significant effect on Kd ($p < 0.05$) but the effect of treatment time was not significant ($p > 0.05$). Compared with RWFB, Kd of 150℃/15', 150℃/30' and 150℃/45 was rapidly reduced by 13.0, 28.2 and 57.1%/h, respectively.

Percentage of BSt varied from 22.1% in 110℃/45' to 49.9% in 136℃/45' as present in table 5. It decreased by 6.5% at 110℃, then increased by 13.0% at 130℃. When temperature reached 150℃, it tremendously increased by 64.7%. Compared with control, %BSt of the treatment of 150℃/45' was increase two times. The effect of temperature was strongly significant ($p < 0.05$) but time effect was not significant ($p > 0.05$)

The changes of BSt had the same pattern as %BSt. It varied from 98.38 in RWFB and 91.4 in 110℃/30' to 200.0 g/kg in 150℃/45' as shown in figure 1. The effect of temperature was significant ($p < 0.05$). It decreased by 5% at 110℃, increased by 11.2% at 130℃. when temperature reached 150℃, it increased by 60.0%. BSt of 150℃/45'

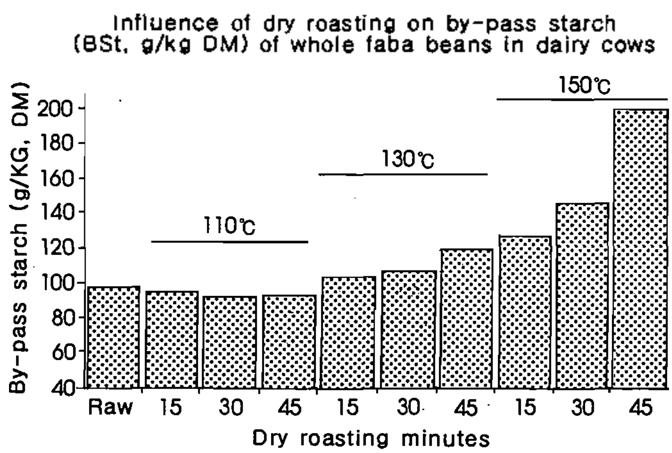

Figure 1. Effect of dry toasting on rumen bypass starch (BSt) of whole faba beans in dairy cows.

DISCUSSION

The results in this experiment indicate that starch of RWFB had a high rate of degradation (9.8%/h), very high soluble fraction (50.1%) and low potentially degradable fraction (49.9%), which all can contribute to very high degradability (76.1%) after being incubated in the rumen.

Only 23.9% of starch entered the intestines as a glucose source. Excessive amounts of soluble or rapidly degradable carbohydrates may give rise to an excessive VFA production resulting in a low pH, which will slow down the degradation of structural carbohydrates and also result in excessive NH_3 production followed by urea excretion.

The portion of starch of horse beans escaping from reticulo-ruminal degradation was estimated by Tamminga (1989) as 22% that Water solubility (S) is 44%, rate of degradation (Kd, %/h) of the non-soluble fraction of starch is 8.0. Yu (1995) reported 71.9% disappearance of starch at kd=4.9%/h for raw horse beans (*Vicia faba cv Alfred*). These results are very close to the results obtained in the present experiment.

Whether dry roasting of WFB shifts more starch from rumen to intestines depends on temperature. At lower temperature (110℃), dry roasting resulted in increased rather than decreased rumen starch disappearance; more starch was fermented than with raw faba beans. Higher temperatures (130 and 150℃) decreased the starch degradation and increased proporsion of starch resisting degadation to the intestines, thus potentially available for flow. Yu (1995) also reported that using a laboratory scale pressurized toaster, the bypass starch dincreased ramatically from 27.6% to 31.7, 40.0, 48.7% at pressure temperature of 100, 118, 136℃

Heat treatment had a variable effect on starch degradation. Whether it increased or decreased starch fermentation depended not only on temperature and time but also on the heating methods, feed type and species. Dry roasting at 110℃ decreased bypass starch but pressure toasting at 100℃ (Yu, 1995) increased bypass starch although the heat temperature was similar. The reasons for this are not clear but results indicate that processing methods have different effects on starch characteristics or feed particle characteristics that influence degradation. Also results indicate that moisture during heating (pressure toasting) can play an important role. During the heat treatment not only is the physical form of the feed changed, but also its chemical structure may be affected. When the temperature and pressure are high enough, starch granules are disrupted and starch gelatinizes (amylose and amylopectin molecules are irreversibly changed in structure). During the process of faba beans digestion, in the intestines the processes allow a better and quicker penetration of amylase into the starch fraction, which results in an improved digestibility (Tamminga, 1993).

Hung (1995) reported that rumen starch degradabilities were higher for diets with autoclaved maize than for raw maize in Taiwan native goat. Benchaar (1994) reported that with faba beans, extrusion at 195℃ increased the apparent ruminal digestion of starch from 58 to 72% though total tract apparent digestibility of starch was not affected. Walhain et al (1992) reported degradation of starch in peas was increased after extrusion. Research by Tamminga et al. (personal communication) has shown that pelleting in different concentrate decreased amount of starch bypassing rumen degradation (%BSt). The decreased BSt% varied from 15 to 43%. Goelema (personal communication) found that grinding method didn't affect %BSt, but technological treatments affected %BSt. Compared with the control sample (concentrate meal), cold pelleting increased Kd by 3.2% and decreased %BSt by 3.9%; steam pelleting increased Kd 3.1% and decreased %BSt by 4.3%; expander treatment increased Kd by 3.6 and reduced % BSt by 7.9%; expander/pelleting treatment had the largest effects on Kd and %BSt, increased Kd by 29.5% and decreased by 13.5%. Arieli (1995) reported that the degradation rate of starch was reduced in expanded wheat and barley. Effective degradation of starch in the rumen was considerably lowered in expanded grains by 34 %, 27%, 14% and 9% in wheat, barley, sorghum and corn, respectively. Extrusion also resulted in comparable reduction in effective degradation of starch in these grains by 27%, 27%, 17% and 6%, respectively.

Therefore starch degradability in the rumen differs among feeds in the response to processing. Such heterogeneity may be related to a divergence in the crystallinity of the starch source and/or the association between starch and the protein matrix surrounding the starch granules (Theurer, 1986). Differences in degradative behavior of starches can also be caused by several other factors such as their amylose and amylopectin content, crystallinity, particle size and the presence of enzyme inhibitors (Cone & Wolters, 1990). Starch may be locked in granules, in size varying between 0.010 (maize, rice, wheat) to 0.050 mm (field bean, potato, pea), surrounded by a protein-containing layer (Cone, 1991). The amylose / amylopectin ratio may also influence the susceptibility of non structual polysaccharide to enzymatic degradation. The later ratio ranges from 1 to 4 (Cone & Wolters, 1990).

These data do not reveal effects on the total tract disappearance and the intestinal digestibility of rumen undegraded starch of faba beans. These may differ among treatments and the possibility of an overprotection effect will be further investigated in studies of intestinal digestibility using a mobile bag technique (De Boer, 1987).

CONCLUSIONS

Dry roasting of whole faba beans at temperatures of 130 and 150° has potential for increasing the supply of bypass starch and improves the nutritional quality of faba beans by reducing degradation in the rumen and thus by increasing the amount of starch supplied to the small intestine, which could be a benefit to high yielding dairy cows. In our experiment, although bypass starch was increased with higher temperature, no optimal combination of time and temperature was found at these stage. But among the 10 treatments, the treatment of 150℃/45 min seems the best with BSt increased twice compared with RWFB. To determine the optimal treatment, the digestibility of starch in the intestines for all treatments also should be measured.

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REFERENCES

Annexstad, R. J., M. D. Stern, D. E. Otterby, J. G. Linn and W. P. Hanaen. 1987. Extruded soybeans and corn gluten meal as supplemental protein sources for lactating dairy cattle. J. Dairy Sci. 70:814-822.

Arieli, A., I. Bruckental, O. Kedar and D. Sklan. 1995. In sacco disappearance of starch nitrogen and fat in processed grains. Anim Feed Sci. & Tech. 51:287-295.

Benchaar, C., M. Vernay, C. Bayourthe and R. Moncoulon. 1994. Effects of extrusion of whole horse beans on protein digestion and amino acid absorption in dairy cows. J. Dairy Sci. 77:1360-1371.

Bruchem, J. van. 1991. Physiology of the Gastrointestinal Tract. Wageningen Agricultural University. pp. 6-17.

Cerning-Beroard, J. and A. Filiatre. 1977. Characterization and distribution of soluble and insoluble carbohydrates in legume seeds: horse beans, peas, lupines. p. 65 in Protein Quality from Leguminous Crops. Com. Eur. Commun. Brussels, Belgium.

Cone, J. W. 1991. Degradation of starch in feed concentrates by enzymes, rumen fluid and rumen enzymes. J. Sci. Food Agric. 54:23-34.

Cone, J. W. and M. G. E. Wolters. 1990. Some properties and degradability of isolated starch granules. Starch/Starke, 42:298-301.

De Boer, Murphy, J. J. and J. J. Kenelly. 1987. Mobile nylon bag for estimating intestinal available of rumen undegradable protein. J. Dairy Sci., 70:977-982.

Hung, Y., Y. Li, J. Hsu, Y. C. Hung, Y. T. Li and J. Hsu. 1995. Effect of protein and starch degradation rates on rumen metabolism in Taiwan native goat. Proceedings of the National Science Council, Part B Life Sci. 19:2, 99-104.

Nocek, J. E., and S. Tamminga. 1991. Site of digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. J. Dairy Sci., 74:3598-3629.

Ørskov, E. R. and I. McDonald. 1979 The estimation of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. J. Agricultural Sci., Cambridge, 92. 499-503.

Owens, F. N., R. A. Zinn and Y. K. Kim. 1986. Limits to starch degestion in the ruminant small intestine. J. Anim. Sci., 63:1634-1648.

Pena, F., H. Tagari and L. D. Satter. 1986. The effect of heat treatment of whole cottonseed on site and extent of protein digestion in dairy cows. J. Anim. Sci., 55:395.

SAS User's Guide: Statistics, Version 6 Edition, 1991. SAS Inst., Inc., Cary, NC.

Stern, M. D., K. A. Santos and L. D. Satter. 1985. Protein Degradation in rumen and Amino Acids absorption in the small intestine of lactating dairy cattle fed heat-treated whole soybeans, J. Dairy Sci., 68:45-56.

Tamminga, S. 1989. In: Physiology of the Gastrointestinal Tract. 1991. edited by J. van. Bruchem. Wageningen Agricultural University. pp. 6-20.

Tamminga, S., A. M. van Vuuren, C. J. van der Koelen, R. S. Ketelaar and P. L. van der Togt, 1990. Ruminal behavior of structural carbohydrates, non-structural carbohydrates and crude protein from concentrate ingredients in dairy cows. Netherlands J. Agric. Sci., 38:513-526.

Tamminga, S. and A. J. M. Jansman. 1993. Animal Nutrition. Wageningen Agricultural University. p. 30.

Tamminga, S. and J. O. Goelema. 1993. Feed processing as a means to improve feed utilization by ruminants. WIAS course at Wageningen Agricultural University.

Tamminga, S., W. M. Van Straalen, A. P. J. Subnel, R. G. M. Meijer, A. Steg, C. J. G. Wever and M. C. Block. 1994. The Dutch Protein Evaluation System: the DVE/OEB-system. Livestock Prod. Sci., 40:139-155.

Theurer, C. B. 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci., 63:1649-1662.

Van Straalen, W. M. and S. Tamminga. 1990. Protein degradation in ruminant diets. pp. 55-72.

Walhain, P., M. Foucart and A. Thewis. 1992. Influence of extrusion on ruminal and intestinal disappearance *in sacco* of pea proteins and starch. Anim. Feed Sci. Tech. 38:43-55.

Waltz, D. M. and M. D. Stern. 1989. Evaluation methods for protecting soybean protein from degradation by rumen bacteria. Anim. Feed. Sci. Tech., 25:11-122.

Yu, P. 1995. Influence of pressure toasting on rumen degradation characteristics of horse beans in lactating dairy cows. MSc. Thesis. Wageningen Agricultural University.