Grinding levels and extrusion effects on the nutritional value of lupin seed for cattle

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Introduction

In 2004, the self-sufficiency in plant protein production (except forages) of the European Union (EU) reached only 24% and more that 30 10^6 tons of soybean meal were imported to assure a well-balanced feed for the European livestock. This situation complicates the traceability of animal production, the assurance of GMO-free livestock diets and increases the economic dependency of EU towards American markets. Several solutions should be encouraged in the future to improve our self-sufficiency, for instance: to optimize the utilization of good forage quality, to valorise the increasing part of by-products from bio-fuel industry and also to improve the utilization of main protein crops that could be grown in EU, specifically pea (*Pisum sativum*), lupin (*Lupinus albus*, *Lupinus angustifolius*) and faba bean (*Viscia faba*). This study referred to the third solution and concerned specifically the lupin seed, containing more protein than pea and faba bean and being more adapted to cattle feeding due to its low content in starch, often supply in a sufficient amount by cereals. Our aims were:

1) to determine the optimal grinding level of lupin seed to limit the rumen degradability of proteins and to maximize the supply of digestible protein in the small intestine and
2) to wonder if nutritional standards, established on fine ground samples, evaluate correctly the nutritional value of lupin seed.

Material and methods

Five double-muscled Belgian Blue (dmBB) bulls (311 ± 27 kg) received 5 diets (table 1) in 2 similar meals, at an intake level of 90 g/kg$^{0.75}$, according to a 5×5 Latin square design experiment. Diets only differed by the presentation form of lupin seed, fed on a raw form, with median particle sizes (d_{50}) of 0.5 mm, 2.0 mm, 4.2 mm, 6.0 mm, or extruded (180°C, 30 sec.). The diet '0.5 mm' supplied a digestible protein to net energy ratio of 90 g DVE/1000 VEVI, estimated to be optimal for growing dmBB bulls (Froidmont, 2001). After 5 d of adaptation to diets, each experimental period was composed by 7 d for urine and feces collection, 1 d for duodenal and ileal contents sampling, 1 d for bacteria isolation in duodenal contents and 1 d for fluid rumen sampling. Chromic sesquioxyde (10 g/meal, in the rumen) and purines were respectively used as DM and bacteria tracers.

Table 1. Composition and nutritional value of raw and extruded diets

g/kg DM	Diets 'raw lupin'	Diet 'extruded lupin'
Ingredients		
Hay	220.0	220.0
Wheat	200.0	200.0
Lindseed meal	108.4	108.4
Raw lupin	321.6	-
Extruded lupin	-	321.6
Sugar beet pulp	125.0	125.0
Minerals and vitamins	25.0	25.0
Nutritional value[1]		
Crude protein	205.0	209.0
VEVI	1182.8	1188.9
DVE	105.8	106.3
OEB	39.4	42.9

According to Dutch feeding standard, VEVI = net energy, DVE = digestible protein in the small intestine, OEB = difference amongst rumen microbial protein synthesised with available N and with available energy.

Results and discussion

One animal was discarded from the experiment after the first period due to acute diarrhoea and important refusals. The results presented are least square means calculated with the data of 4 animals.

Rumen parameters

Extruded lupin induced the larger pH fluctuation in rumen liquid that could be explained by an increase in rapidly degradable nutrients due to matter expansion and, consequently, a better accessibility of micro-organisms to matter (Daccord, 2004). The decrease of rumen pH tended to be negatively correlated to the mean particle size, except for the '4.2 mm' grinding level, probably due to a larger heterogeneity in the particle size distribution for this treatment (data not shown). A significant difference (P = 0.011) appeared 2 hours after the meal, amongst the 6.0 mm grinding level (pH = 6.31) and the extruded lupin (pH = 6.05). A delay in the appearance of the post-prandial N-NH_3 concentration peak in rumen liquid was observed with coarse grindings compared to finer ones and extruded lupin.

Digestive parameters

The lupin form did not influence the appetence of the diets. In accordance with Benchaar et al. (1991) and Aufrère et al. (2001), apparent rumen degradability of DM, OM and N tended to be higher with the 0.5 grinding level, inducing a lower apparent digestibility of these nutrients in the small intestine.

Even if differences amongst diets did not reach the significant threshold, probably due to the missing animal, microbial N at the duodenum was lower with the 0.5 mm grinding level (table 2), while dietary N was maximized with the 4.2 mm grinding level and the extrusion treatment. The 6.0 mm grinding level supplied a lower amount of dietary N than the other treatments. One explanation could be that the particle size was not sufficiently fine to enable their outflow without additional rumination. Total digestible N supply was lower with the 0.5 mm grinding level. The interest of extrusion in term of digestible N supply was limited compared to 2.0 and 4.2 mm grinding levels.

Table 2. Origin of duodenal N flows, digestible N supply and efficiency of rumen proteosynthesis according to lupin treatment

	Treatment					SEM	P
	0.5	2.0	4.2	6.0	Extr		
Duodenal flows (g/d)							
Microbial N	95.8	123.3	108.8	124.0	128.6	3.9	0.162
Non microbial N	73.7	74.5	85.3	68.1	81.6	2.9	0.443
Dietary N	60.9	62.2	72.9	55.6	68.9	4.0	0.452
Endogenous N	12.8	12.3	12.4	12.5	12.7	0.1	0.642
Non NH_3 N	169.5	197.8	194.1	192.1	210.2	5.0	0.268
NH_3 N	11.1	12.3	13.1	12.4	11.8	0.4	0.583
Digestible N flow (g/d)	125.8	148.9	151.0	140.60	159.6	4.4	0.274
Microbial synthesis,							
g N/kg apparent FOM	32.5	48.8	41.3	45.7	50.5	3.1	0.473
g N/kg true FOM	23.1	31.4	27.7	30.0	32.5	1.4	0.352

By assuming that lupin was the only feedstuff responsible from the variation observed in dietary N flow, we could calculate the degradability of lupin protein in the rumen as to be 78 (standard value), 74, 65, 82 and 70% for 0.5, 2.0, 4.2, 6.0 mm grinding levels and extruded lupin. So, in our experimental conditions, the average size of 4.2 mm appeared to be optimal for limiting the rumen degradability of lupin protein. On the basis of protein flows observed *in vivo* and by considering that lupin of treatment 1 corresponded to feeding standards, we also tried to re-define DVE and OEB values for lupin seed according to treatments (table 3).

Table 3. Effect of lupin treatment on the OEB and DVE values lupin seed according to DVE/OEB system based on *in vivo* measurements

	Treatment				
	0.5	2.0	4.2	6.0	Extr
OEB value (g/kg DM)	151	152	126	168	128
DVE value (g/kg DM)	143	206	202	186	220

These results confirmed that a coarse grinding [4.2 mm or slightly lower (until 2.0 mm)] assure to optimize the nutritional value of lupin seed for cattle. Our results confirmed the study of Sauvant (2000), suggesting that the daily chewing time is considerably reduced for cattle when the dietary particle size is below 3-4mm.

Nitrogen balance

Fecal N excretion was significantly lower with the 0.5 mm grinding level compared to the 2.0 mm grinding level ($P < 0.005$) but the difference was excreted via urines and was not valorised by animals. Total N retention did not differ amongst treatments and reflected the 0.5 mm grinding level satisfied already the animal’s requirements.

Conclusions

The trends observed in this experiment suggested that an average particle size of 0.5 mm for lupin seed is not adapted to cattle feeding, and has a negative impact on the microbial proteosynthesis in the rumen and the digestible protein flow. The extrusion treatment and the 4.2 mm grinding level maximized the dietary protein flow at the duodenum while particles from the 6.0 mm grinding level were probably too large for leaving the rumen without being ruminated, inducing a more intense protein degradability in the rumen. These results suggest that feeding standards should consider the influence of the grinding level in the determination of the protein value of legume seeds. On an economic point of view, a coarse grinding or a flattening are recommended because they are less expensive than extrusion.

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