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Rumen degradability of protein in field beans after heat treatment or ensiling

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Introduction

The production of organic milk is increasing in Sweden. In 2012 it made up 12.7% of total milk delivered. One constraining factor in the production is the scarcity of protein- rich feedstuffs. The price of protein- rich concentrates certified as organic is high, creating a growing interest in home-grown protein- rich feeds. Field beans, *Vicia faba*, is an attractive crop for organic cultivation and should have the potential to add valuable protein to diets for ruminants. Being a legume, field beans can fix atmospherics nitrogen and are also appreciated as a preceding crop in the crop rotation system due to its deep root system. However, rumen solubility of the protein fraction in field beans is high, as in most other home-grown crops. When feeding a diet based on grass-clover silage and concentrates based on wheat, barley or oats, all feeds consist of easily degrade protein. A protein supplement with higher resistance towards rumen degradation combined with a high total digestibility would be desirable.

Heat treatment has been used to reduce solubility of the protein fraction of other feeds, e.g. rape seed meal. This is used commercially in the production of ExPro® (AAK Ltd, SE-374 82 Karslhamn, Sweden), where effective protein degradability (EPD) is depressed from 72% to 35% by treating rapeseed meal with heat and steam (Spörndly, 2003A). Treating field beans with heat was proposed by Lund et al (2004). It decreased protein solubility but maintained total digestibility resulting in an increased metabolizable protein, calculated as amino acids absorbed in duodenum (AAT). The primary aim of the present study was to estimate rumen degradability of the protein fraction in whole, dry field beans after treatment in a farm-based roaster at three different temperatures.

Field beans require a comparatively long growing season. In some years, this can result in low DM content at harvest. As an alternative to drying the beans after harvest, crimping and ensiling is sometimes practiced for safe preservation and storage. The beans are then crushed at approximately 60-70% DM and packed into airtight plastic tubes where an ensiling process takes place. This process will have an effect on protein degradability and a pilot study was also performed to evaluate the effect ensiling on rumen protein degradability.

Materials and Methods

Field beans harvested 2011 were dried and stored at a commercial feed factory. In the autumn of 2012, these intact beans were treated in a farm based toaster at 165, 185 and 205°C for 5.5 minutes. The toaster (Roastech; Roastech Ltd, Bloemfontein,South Africa) used a forced convection roasting technique where the beans maintained in a rotating tunnel with electrically heated walls for 5.5 minutes at selected preset temperature. At unloading, the beans were subjected to moderate cooling by forced air ventilation at ambient temperature. The capacity of the machine was 100 kg per hour.

Parallel to this study, field beans harvested in 2012 were ensiled with the crimping technique. Propionic acid, 6-7 L per tonne, was used as silage additive (Perstorp AB, SE-284 80 Perstorp, Sweden).

After heat treatment the beans were milled through a 1.5 mm sieve and rumen degradable protein was analysed by the rumen *in situ* technique. Ensiled beans were pre-dried at 60°C before milling. The degradability was estimated using three dry cows according to Åkerlind et al. (2011). The standard diet of cows contained 12% crude protein (CP) and consisted of 67% hay and 33% concentrate during an adaptation period of 21 days before the trial started.

The two batches of field beans for heat treatment and crimping were of comparable nutrient quality. The content of dry matter (DM), CP, neutral detergent fiber (NDF), starch, ether extract and ash are shown in Table 1, analyzed by conventional wet chemistry methods. Table 1 also shows the fermentation products and microbial composition in the silage.

Table 1 Basic nutrient composition of field beans used for roasting and crimping respectively and fermentation products for crimped beans. Number of samples per crop =1

	Dry matter, g/kg	CP, g/kg DM	NDF, g/kg DM	Starch, g/kg DM	Ether extract, g/kg DM	Ash, g/kg DM
Field beans for roasting	851	307	114	425	15	34
Field beans for crimping	637	303	117	419	17	37

		% of DM							Log CFU/g	
	pH	Lactic acid	Acetic acid	Propionic acid	Butyric acid	Formic acid	2,3-butane-diole	Ethanol	yeast	mold
Ensiled crimped field beans	5.0	1.26	0.2	0.22	<0.02	<0.02	<0.02	0.08	6.2	0

Results and Discussion

Results show that the roasting had the intended effect. The effective protein degradability (EPD) decreased with increasing temperature (Table 2) and EPD for the highest temperature was 10% lower than for the untreated control. Under the assumption that duodenal digestibility is unchanged, , this difference would give 13% more AAT per kg DM in the field beans treated at 205°C. The EPD, AAT and PBV values in Table 2 are calculated according to the classical method described by Madsen et al (1995) and Spörndly (2003B) using a passage rate of 8% h^{-1} and 80% duodenal degradability of rumen undegraded feed protein. The ensiling process of the crimped field beans had the opposite effect on protein degradability resulting in 7% higher EPD value compared to the dried beans.

The protein degradation fitted to an exponential curve, as practiced in NorFor (Åkerlind et al, 2011) is illustrated in Figure 1. The two field beans batches differed in protein solubility; after 2 h in the rumen, 65% was degraded in the untreated batch designated for heat treatment while 72% was degraded in the untreated batch for ensiling. In both treatments, the impact on EPD was

Table 2 The effect of increasing temperatures or ensiling of field beans on in situ measured efficient protein degradability (EPD). Metabolizable protein (AAT) and rumen protein balance (PBV) are calculated using the classical method used in Sweden (Spörndly, 2003B)

		Heat treated			Untreated	Ensiled
	Untreated		Heat treated	Heat treated		
Temperature, °C		165	185	205		
Crude protein, g/kg	303	303	303	303	307	307
EPD[a],%	79	76	74	72	84	87
AAT[b], g /kg dry matter	95	101	104	108	86	80
PBV[b], g /kg dry matter	121	113	108	102	135	143

[a]Calculated according to Madsen et al (1995) using 8% h^{-1} passage rate and 80% duodenal digestibility; [b]Amino acids absorbed in the duodenum (AAT) and protein balance in rumen (PBV) calculated as described by Spörndly (2003B).

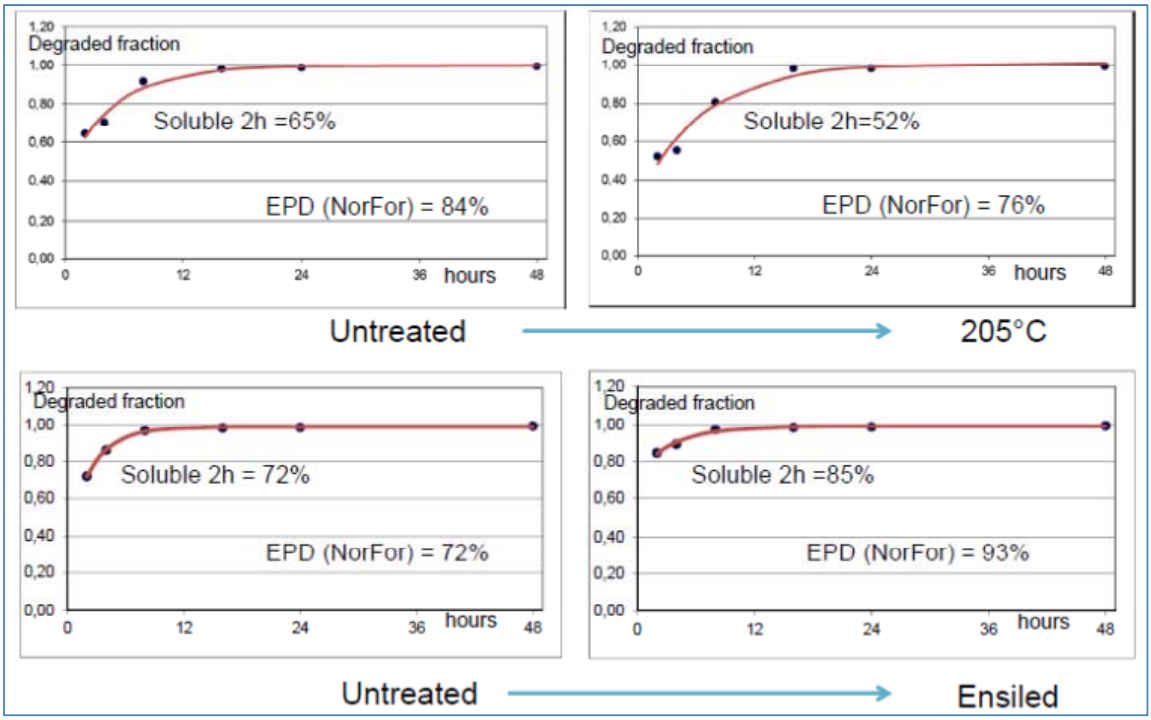

Figure 1 The effect on protein degradability when subjecting field beans to heat or ensiling. Exponential function fitted to degradation measured at 2, 4, 8, 16, 24 and 48 hours. Efficient protein degradability (EPD) calculated at 8% passage rate (Åkerlind et al, 2011).

most marked at the initial phase, decreasing and increasing the EPD at heat treatment and ensiling, respectively. At 24 h, close to 100% degradability was obtained in all treatments. This also indicates that the total protein digestibility was not affected. In Table 3, the parameters used in the Nordic feed evaluation system NorFor (Åkerlind et al, 2011), computed from the exponential degradation curve, are presented. By inserting the parameters in the ration formulation program 'IndividRAM', AAT and PBV used in that system were calculated. A uniform content of CP, NDF and starch was used in order to equalize the comparison.

Table 3 Calculated protein value of untreated and heat treated and untreated or ensiled field beans according to the NorFor system (Åkerlind et al, 2011)

	Field beans untreated	Filed beans Heat treated, 205°C	Field beans untreated	Field beans Ensiled
Crude protein, g/kg	303	303	303	303
Soluble protein, g/kg protein[b]	447	303	410	736
Indigestible protein, g/kg protein	1	0	11	11
Degradation rate,% h^{-1}	19.5	14.7	38,7	26,7
AAT[a], g /kg dry matter	121	135	109	107
PBV[a], g /kg dry matter	139	122	153	155

[a]Metabolizable protein (AAT) and rumen protein balance (PBV) calculated at a standard diet at 20 kg DMI using NorFor application IndividRAM 5.8b (Svensk Mjölk AB, Stockholm, Sverige) 2012).

The NorFor system generally estimates a higher metabolizable protein content than AAT by the classical Swedish system does. The increase due to the heat treatment though, is of the same magnitude in the two systems. The decrease in AAT caused by ensiling is however of a lower magnitude when calculated in the NorFor system compared with the classical system.

Conclusions

Heat treatment of field beans (*Vicia faba*) with the farm based bean roaster using a rotating tunnel with electrically heated walls made the protein fraction less rapidly degraded in the rumen of dairy cows. Roasting the beans at 205°C for 5.5 minutes resulted in an increase in AAT of 11-13%. On the contrary, ensiling crimped beans at a DM content of 63% with propionic acid as additive increased rumen degradability and resulted in a slight decrease in AAT.

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