Effect of heat treated field beans on the performance of Swedish lactating dairy cows

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Introduction

In organic farming there is a high demand to use locally produced protein feeds for ruminants. However, organic milk production is, in contrast to crop production, a component of farming that has relatively low nitrogen efficiency as only a small part of the nitrogen fed to animals is found in the milk protein. Organic diets for dairy cows are to a large extent based on grasses and legumes with relatively high levels of rumen degradable protein (RDP) (Hedquist & Udén, 2006). On many farms, nitrogen efficiency is unnecessarily low and the cost for protein feed is relatively high due to overestimation of the marginal response to protein supplementation. There are, however, other options to influence quality and concentrations of protein in organic diets by using legumes such as field pea *(Pisum sativum)* and horse bean (*Vicia faba*). They have two advantages: they can be locally produced and can fix atmospheric N. Other benefits with peas are high digestibility and high energy concentration (high starch, low indigestible neutral detergent fibre; NDF) and they are therefore ideal substrates for microbial protein synthesis in the rumen.

One alternative to increase microbial protein (MP) input is using protein-rich feeds that are artificially protected from ruminal degradation. Various physical and chemical treatments have been used to pursue this objective. One of these is a controlled heat application, which allows protein degradation in the rumen to be reduced through denaturation and Maillard reactions, reducing solubility and protein degradation rate in the rumen (Moshtaghi Nia & Ingalls, 1995). There have been studies reporting responses on dairy cows by the use of rumen un-degradable protein (RUP) supplements, such as heat-treated soy protein (Faldet & Satter, 1991). Protein feeds, differing in RUP, showed to have different flows of RUP and total protein from the rumen (Brito & Broderick, 2007). A possibility to increase nitrogen efficiency is to heat-treat the protein feed. Heat-treatment may reduce protein solubility in the rumen and increase the availability of starch. This may then reduce the supply of nitrogen in the rumen and increase the amount of energy available for rumen microbes, as has been shown in international studies using heat-treated dehulled lupines (Barchiesi-Ferrari & Anrique, 2011; Mogensen *et al.*, 2008). The results from the literature show that there is a need for applied studies exploring the possibilities to better utilise nitrogen in organic dairy production by altering the energy and protein concentration in the diets. Utilising locally produced feeds will avoid over-feeding of expensive protein concentrates and unnecessary losses of nutrients to the environment. At farms, a small scale roasting equipment can be used to heat-treat whole seeds. There is, however, a lack of feeding trials to study the effects of such treatment on locally produced protein feeds in Sweden. The first objective of this study was to evaluate if the feeding value of heat-treated field beans (FB) could be improved. The second objective was to compare different protein supplements, which could be used in organic farming, on the performance of lactating dairy cows fed a grass silage based diet.

Materials and Methods

Twenty-four lactating Swedish Red cows 95 days in milk (DIM) and average milk yield of 29.1 kg per day in the beginning of the experiment were used in a cyclic change-over trial with three 21-d experimental periods. Six diets were fed ad libitum as total mixed rations (TMR) and the feed intake was recorded using Insentec intake controlled feeders (Insentec B. V., Marknesse, the Netherlands). The control diet consisted of grass silage and dried rolled barley [60:40, dry matter (DM) basis]. In the experimental diets, barley was replaced with rapeseed expeller (RSE; 104 g/kg diet DM), or isonitrogenous supplements of peas (232 g/kg diet DM), untreated FB (UFB; 140 g/kg diet DM), heat-treated FB (TFB; 140 g/kg diet DM) or heat-treated FB, providing the same dietary MP concentrations as UFB (TFB-MP; 80 g/kg diet DM), (Table 1). The silage was a second cut with 181 g/kg DM of crude protein (CP) and 494 g/kg DM of NDF. Heat-treatment of FB was done with a farm-based roasting equipment (R-100E, Roastech, Blomfontein, South Africa). The machine was electrically (15 kW) heated and consisted of a drum with 3-mm holes. Roasting was conducted at a temperature of 140°C and a turning frequency of 50 Hz which gave a passage time of 7.5-8 minutes. At the outlet of the drum, a cooling container was mounted on the machine to allow air-cooling of the roasted product. The outlet of the machine was directly into bags so the heat treated FB could be collected and processed further.

Cows were milked twice a day (6 am and 3 pm) and were weighed on three consecutive mornings in the last days of each experimental period. Methane (CH_4) and carbon dioxide emissions were measured with the GreenFeed system (C-Lock Inc., Rapid City, SD, USA). Recordings of feed intake, milk production and gases were made the last 7 days in each period.

The data was analyzed with the MIXED procedure of Statistical Analysis Systems (SAS for Windows, version 9.3, SAS Institute, Cary, NC). The model included fixed effects of period, treatment and random effect of cow. For treatment comparison, the following contrasts were used: control *vs.* others, RSE *vs.* others excluding the control, UFB *vs.* peas, UFB *vs.* TFB-MP and UFB *vs.* TFB. The results are presented as least squares means.

Results

Protein supplementation had no effect ($P>0.05$) on DM intake (DMI); (18.8 vs. 18.2 kg/d), milk yield (23.8 vs. 23.5 kg/d) or energy corrected milk (ECM) yield (25.6 vs. 24.8 kg/d), as shown in Table 2. This was mainly because peas or FB supplemented diets did not increase milk and protein yield compared to the control diet. The RSE treatment increased milk (24.8 vs. 23.6 kg/d) and protein yield (913 vs. 863 g/d) compared to other protein supplements. Heat-treated FB had no effect on DMI, milk or protein yield compared to UFB. Milk nitrogen efficiency (Milk N/N intake) decreased and MUN increased with protein supplementation compared to the control diet (306 *vs.* 265 g/kg and 3.01 *vs.* 3.92 mmol/L, respectively). The RSE supplemented diet tended to decrease ($P= 0.09$) CH_4 production compared to other protein supplements (383 vs. 399 g/d) as given in Table 2.

Table 1 Ration ingredients and chemical composition (g/kg DM unless otherwise noted)

	Ration[1]					
Item[2]	CON	RSE	Pea	UFB	TFB	TFB-MP
Grass silage	600	600	600	600	600	600
Barley	400	296	168	260	260	320
Pea	0	0	232	0	0	0
Rapeseed	0	104	0	0	0	0
Field bean not-heat treated	0	0	0	140	0	0
Field bean heat treated	0	0	0	0	140	80
DM, g/kg of fresh matter	347	349	349	348	349	349
CP	159	187	187	181	183	176
Crude fat	26	33	24	25	25	25
NDF	400	415	365	395	390	393
iNDF	45	56	37	40	40	41
ME, MJ/kg of DM	11.8	11.8	12.1	11.9	12.0	11.9

[1]CON = control, RSE = rapeseed expeller, UFB = field bean not heat-treated, TFB = field bean heat-treated, TFB-MP = field bean heat-treated same metabolizable protein as UFB.
[2]DM = dry matter, CP = crude protein, NDF = neutral detergent fibre, iNDF = indigestible NDF, ME = metabolizable energy.

Discussion

In a meta-analysis conducted by Huhtanen *et al.* (2011), based on digesta flow and rumen metabolism studies, it was found that the effect of chemical and physical treatments to reduce crude protein CP degradability do not result in expected improvements in CP supply to the small intestine. Our study is in line with the findings of Huhtanen *et al.* (2011) since the performance of the dairy cows did not change by heat treating FB. Results from an organic farming study with high-yielding dairy cows indicate that toasting decreases effective rumen protein degradability for diets including toasted lupins, barley and soybeans (Mogensen *et al.*, 2008). They reported that toasting of lupins tended to increase milk yield compared to the untreated lupins, whereas toasting of soybeans did not show any improvements. Our findings did not show any improvements on milk yield or ECM when FB was heat treated compared to the UFB diet. In agreement with our findings, several other experiments have shown that heat treatment does not affect milk fat (Pires *et al.*, 1996) or milk protein content (Bertilsson *et al.*, 1994). The discrepancy between studies on the effect of heat treatment of feeds and performance of dairy cows and supply of MP under organic farming conditions can vary among feeds. In an *in vitro* evaluation Vaga *et al.* (2014) found that treatment method (autoclave *vs.* oven), temperature and the length of treatment affected the concentration of utilizable CP. It should be noted that increasing temperature and treatment period will increase processing costs and may decrease the concentrations of essential amino acids and decrease intestinal digestibility of undegraded CP. Further studies are therefore required before making any definite conclusions.

Table 2 The effect of diet treatments on feed intake, milk yield and nutrient consumption of dairy cows

	Ration[1]							Contrasts (P – value)[2]				
Item	CON	RSE	PEA	UFB	TFB	TFB-MP	SEM[3]	C vs. O	R vs. O	UFB vs. PEA	UFB vs. TFB-MP	UFB vs. TFB
DMI, kg/d	18.2	19.0	19.0	18.7	18.7	18.6	0.37	0.13	0.33	0.58	0.80	0.98
CP intake, kg/d	2.90	3.55	3.44	3.35	3.32	3.15	0.072	<0.01	<0.01	0.33	0.04	0.79
NDF intake, kg/d	7.11	7.66	6.94	7.23	7.23	7.26	0.154	0.31	<0.01	0.17	0.90	0.99
AAT, kg/d	1.66	1.85	1.78	1.75	1.75	1.71	0.035	<0.01	<0.01	0.51	0.40	0.96
ME, MJ/d	219	224	231	223	223	222	4.50	0.18	0.98	0.17	0.87	0.97
Milk, kg/d	23.5	24.8	23.0	23.7	23.8	23.8	0.90	0.49	0.02	0.30	0.90	0.85
ECM, kg/d	24.6	26.6	24.9	25.8	25.8	25.3	0.91	0.18	0.17	0.40	0.97	0.62
Milk fat, g/kg	43.3	44.8	45.4	46.1	45.5	44.1	1.63	0.70	0.17	0.72	0.71	0.30
Milk protein, g/kg	37.6	37.3	36.6	36.9	36.9	37.5	0.53	0.07	0.049	0.29	0.44	0.07
Milk urea, mmol/L	3.01	3.79	3.94	3.90	4.42	3.57	0.154	<0.01	<0.01	0.16	0.80	0.03
FE[4], kg/kg	1.35	1.40	1.32	1.34	1.37	1.36	0.046	0.77	0.14	0.60	0.62	0.52
MNE[5], g/kg	306	264	250	255	266	288	8.95	<0.01	0.82	0.42	<0.01	0.09
CH_4, g/d	390	383	397	389	403	406	9.6	0.53	0.09	0.45	0.12	0.20
CH_4, g/DMI	21.4	20.4	21.0	20.8	21.6	22.0	0.57	0.71	0.11	0.78	0.10	0.22
CO_2, kg/d	11472	11839	11986	11786	12095	11716	217.0	0.03	0.75	0.40	0.76	0.19
CH_4/CO_2	0.034	0.033	0.033	0.033	0.033	0.035	0.0006	0.44	0.19	0.91	0.03	0.62

[1]CON = control, RSE = rapeseed expeller, UFB = field bean not heat-treated, TFB = field bean heat-treated, TFB-MP = field bean heat treated same MP as UFB, [2]C vs. O = CON vs. other diets, R vs. O = RSE vs. other diets excluding CON, [3]SEM = standard error of mean, [4]FE = feed efficiency (kg ECM) / (kg DMI), [5]MNE = milk nitrogen efficiency (milk protein yield × 6.38) / (protein intake × 6.25).

Conclusions

This study suggests that in organic farming no improvement on lactation performance of dairy cows were achieved by the inclusion of heat treated FB or peas as compared to a control diet without any protein supplement, provided that RDP requirements are met. Only RSE supplementation resulted in an improvement in animal performance compared to the control diet.

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