

CHEMICAL COMPOSITION AND NUTRITIONAL VALUE OF HEAT-TREATED AND COLD-PRESSED RAPESEED CAKE

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Summary. Chemical composition of locally-produced heat-treated rapeseed cake (n=103) and cold-pressed (n=40) rapeseed cake was evaluated. Cold-pressed rapeseed cake (CPRC) was produced at a temperature 60-70°C and the heat-treated rapeseed cake (HTRC) was processed at 100 °C for 20-25 minutes. CPRC contained less crude protein than HTRC (332 g/kg vs. 363 g/kg) and fewer N-free extracts (282 g/kg and 320 g/kg), but more crude fat (158 g/kg and 111 g/kg), with a higher metabolizable energy content for ruminants (13.9 MJ/kg and 13.0 MJ/kg) and for pigs (15.2 MJ/kg and 14.6 MJ/kg, respectively). Heat treatment decreased glucosinolate concentrations in rapeseed and rapeseed cake – the content of hydroxyglucobrassicin was reduced by 72% and that of glucobrassicin by 75%.

Heat treatment had no effect on organic matter digestibility in pigs.

Ruminal degradability of HTRC protein was slow. Protein solubility of HTRC (fraction A) was 31.0%, while that of CPRC was 70.2%; effective degradability was 53.4% and 89.2%, respectively.

It is concluded that heat treatment of rapeseed improves the protein quality of rapeseed cake.

Keywords: cold-pressed rapeseed cake, heat-treated rapeseed cake, chemical composition, glucosinolates, metabolizable protein, degradability.

KARŠTAI IR ŠALTAI SPAUSTŲ RAPSŲ IŠSPAUDŲ CHEMINĖ SUDĖTIS IR MAISTINĖ VERTĖ

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Santrauka. Rapsų išspaudų pavyzdžiai atrinkti ir tirti 2003–2007 metais. Nustatyta karštai (n=103) ir šaltai (n=40) spaustų rapsų išspaudų cheminė sudėtis. Šaltai spaustų rapsų išspaudos gautos veikiant 60–70°C temperatūra, o karštai spaustų – veikiant 100°C temperatūra po 20–25 minutes. Nustatyta, kad šaltai spaustų rapsų išspaudose žalių baltymų buvo mažiau (atitinkamai 332 g/kg ir 363 g/kg), nei karštai spaustų rapsų išspaudose, nedaug laisvojo azoto (289 g/kg ir 320 g/kg), bet daugiau žalių riebalų (158 g/kg ir 111 g/kg). Tai atrajotojams suteikia 13,9 MJ/kg ir 13,0 MJ/kg, o kiaušinių atitinkamai 15,2 MJ/kg ir 14,6 MJ/kg apykaitos energijos. Karštasis apdorojimas rapsų sėklose ir rapsų išspaudose mažina gliukozinolatų – ypač hidroksgliukobrasicino (iki 72 proc.) ir gliukobrasicino (iki 75 proc.) koncentraciją.

Karštasis apdorojimas kiaušinių organinės medžiagos virškinamumui poveikio neturėjo.

Didžiajame prieskrandyje karštai spaustų rapsų išspaudų baltymai skilo lėčiau. Baltymų tirpumas karštai spaustų išspaudų (frakcija A) buvo 31,0 proc., o šaltai – 70,2 proc., baltymų skilimas atitinkamai buvo 53,4 proc. ir 89,2 proc.

Daroma išvada, kad rapsų išspaudų baltymų kokybė pagerėja, kai rapsų sėklos prieš spaudžiant aliejų buvo apdorotos karščiu.

Aliejaus gavybos iš rapsų sėklų būdas turi įtakos rapsų išspaudų maisto medžiagų kiekybinei ir kokybinei sudėčiai. Išspaudų cheminė sudėtis ir maistinė vertė priklauso nuo daugelio glaudžiai tarpusavyje susijusių veiksnių – perdirbimo technologijos ir sąlygų (aliejaus gavybos būdo, temperatūros, drėgumo).

Raktažodžiai: šaltai spaustos rapsų išspaudos, karštai spaustos rapsų išspaudos, cheminė sudėtis, gliukozinolatai, baltymų apykaita, skilimas.

Introduction. Global oilseed demand for food and non-food purposes has been increasing recently and it is anticipated to expand further. The driving force is the growing use of oils for biodiesel production. Rapeseed cake is a by-product of biodiesel produced from rapeseed. Currently rapeseed together with soyabean and maize are resources in demand in both the feed and energy markets. Rapeseed has become the second most important oilseed in the world after soybean.

Rapeseed production and use in Europe has substantially increased in recent years and rapeseed oil is now the

primary raw material for processing biodiesel. Rapeseed production has increased in many EU countries including Lithuania, Latvia and Estonia. In Estonia, in 2007 rapeseed production was 132 400 tonnes which was 37.3 % higher than in 2005. Rapeseed production was also 14.5% higher than in the EU over the same period. The increased production of rapeseed meal and cake both in the EU and the Baltic States, is expected to gradually replace soya-bean meal in animal feed rations.

Many articles have been published about the chemical composition and nutritional value of solvent-extracted

rapeseed meal, and the feeding of it to different animal species. Less information is available about the nutritional value of rapeseed cake produced under different production conditions and very little information is available regarding cold-pressed rapeseed cake.

Rapeseed cake has been a widely used protein feed in cattle and pig diets. However, glucosinolates present in rapeseed-cake can reduce the feed value and use in pig and cattle diets due to the formation of toxic degradation products.

Currently 27 different glucosinolates have been detected in rapeseed. The most common are aliphatic glucosinolates such as sinigrin, gluconapin, glucobrassicinapin, progoitrin, napoleiferin and indole. Glucosinolates are hydrolyzed by the enzyme myrosinase into glucose and sulphate, and depending on the conditions, to isothiocyanates, thiocyanates or nitriles (Lambrix et al., 2001). Some products of glucosinolate hydrolysis may be toxic and strumogenic, causing several health disorders in animals. Currently, the glucosinolate content of fat-free dry matter of rapeseed has been reduced by 155-170 $\mu\text{mol/kg}$ to 15-20 $\mu\text{mol/g}$.

Heat treatment degrades 20-25% of glucosinolates (Aumaitre et al, 1989). The degradation products are partially volatilized (Liu et al, 1994; Schöne et al, 1994), but some of them still remain in the cake (Shahidi et al, 1997). Amounts of toxic decomposition products are lower if cold-pressing (50-70°C) technology of rapeseed is used as further hydrolysis continues in the digestive tract (Nugon-Baudon et al, 1990).

Data reported about the use of rapeseeds and rapeseed cakes in pig diets have been contradictory. Several authors have shown that the inclusion of crushed rapeseed at a proportion of 20% in the diets of fattening pigs decreased feed intake (Busboom et al, 1991, Naczka et al, 1998). However, a study conducted by Leming (2005) showed that the incorporation of 11% rapeseed cake in the diet of finishing pigs increased daily gains with no negative effect on meat quality.

In ruminant feeding it is necessary to consider ruminal protein degradability of the protein feed.

Chase (2002) suggests that the ration of high producing cows should contain 60 to 65% ruminally degraded protein (RDP) and 35 to 40% ruminally undegraded protein (RUP) of the total protein. The amount of ruminally undegradable protein is affected by the feed production technology used, chemical composition, kinetics of protein hydrolysis, feeding and level (Cottrill, 1996; Kärt, 1996).

Many methods have been investigated to decrease the rate and extent of ruminal protein degradation. Most of these have involved the use of heat, chemical agents, or a combination of heat and chemical agents (Broderick et al., 1991; Schwab, 1995, Van der Poel et al, 2005). Heat processing decreases rumen protein degradability by denaturation of the proteins (Van Soest, 1994).

Careful control of heating conditions is required to optimize the content of digestible RUP (Schwab, 1995). Under-heating results in only a small increase in digestible RUP. Optimal conditions of heat processing are gen-

erally considered to be those which significantly decrease ruminal protein degradability without adverse effects on postruminal digestion or significant losses of amino acids (Schroeder et al., 1996).

The objective of this investigation was to compare the chemical composition, concentration of glucosinolates and nutritional value of rapeseed cake produced by short-term heat treatment and cold-pressing of rapeseed. Additionally, the digestibility of rapeseed cake in pigs and ruminal degradability of rapeseed cake protein in cows were also investigated.

Material and methods. The samples of rapeseed cake were collected and analyzed from 2003–2007. The rapeseed cake originated from two feed factories. The first feed factory used heat treatment for processing rapeseed: purified and crushed oilseeds were treated at 100°C for 20 to 25 minutes and oil was mechanically extracted in a screwpress. Cold-pressing technology for producing rapeseed cake was used in the other factory. The cleaned seeds were connected directly to the mechanical screwpress where the temperature briefly rose to 50–70°C.

Ground rapeseed cake samples were analysed for dry matter, crude protein, crude ash, crude fibre and crude fat contents (AOAC, 2005). For determining crude ash concentration, samples were reduced to ashes in a furnace at 550°C for six hours. Crude protein was analysed by the Kjeldahl method with a Kjeltec 2300 analyser (FOSS Tecator Technology), crude fat by the Soxtec 2042 systems (FOSS) and crude fibre using the Fibretec system (FOSS). The glucosinolate content was determined chromatographically with a liquid-chromatograph. The HPLC method involves single-step extraction of glucosinolates with boiling water and separation of the individual glucosinolates on a Novapack RP-18 column with 0.2 M ammonium sulphate as mobile phase. Peaks were monitored at 229 nm. (Kaushik and Agnihotri, 1999).

The digestion experiments were carried out according to in individual boxes on five castrated male pigs of the Estonian Bacon breed whose mean live weight was 46 kg at the start and 89 kg at the end of the experiment.

Effective degradability of rapeseed cake protein was determined by the *in sacco* method using two fistulated cows. The cows were fed the same ration, providing a stable ruminal environment. Feed samples were incubated in the rumen for 2, 4, 8, 16, 32 or 64 hours. Bags containing samples were put into the rumen at fixed times and were removed simultaneously. Nutrient solubility was determined by rinsing the bags in cold water in a washing machine for 15 minutes. The sample bags were soaked in lukewarm water (35°C) for 30 minutes before putting them into the rumen for the determination of solubility.

Effective degradability of feed nutrients was calculated using the formula described by Ørskov and McDonald (1979):

$$p = a + b(1 - e^{-ct}),$$

where,

p – effective degradability, %,

a – soluble fraction, %,

b – degradable fraction, %,
 c – degradation rate of degradable fraction, %/h,
 t – time of incubation, h.

Passage rate of feed particles was assumed to be 8% per hour.

Results were analysed statistically using computer programmes MS Excel and SAS. The effects of treatment were tested by means of orthogonal contrasts. To analyse the traits containing zero values, ranks of values were

used; other traits were transformed to their logarithmic values.

Results and discussion. Comparative chemical composition of HTRC and CPRC are given (Table 1). There was a great variation in the composition of most nutrients. Mean dry matter contents of all samples were 91.2% and 91.4%, respectively. Significant differences between the cakes were found for crude protein ($P<0.01$), crude ash ($P<0.01$), crude fat ($P<0.001$) and non-nitrogen extractives ($P<0.001$) contents.

Table 1. **Chemical composition and nutritional value of cold-pressed rapeseed cake and heat-treated rapeseed cake**

| Items | CPRC n=40 | | HTRC n=103 | |
|-------------------------------|--------------|------|---------------|------|
| | \bar{x} | s | \bar{x} | s |
| Dry matter, % | 91.4 | 1.7 | 91.2 | 2.1 |
| In dry matter, g/kg | | | | |
| crude protein | 332 | 2.2 | 363** | 2.4 |
| crude ash | 64 | 0.6 | 70** | 0.3 |
| crude fibre | 131 | 1.8 | 136 | 1.7 |
| crude fat | 158 | 4.3 | 111*** | 0.9 |
| N-free extractives | 282 | 3.0 | 320*** | 2.2 |
| Gross energy, MJ/kg | 21.8 | 0.2 | 21.4** | 0.1 |
| Ruminants | | | | |
| metabolizable protein, g/kg | 102 | 5.7 | 166*** | 1.9 |
| ruminal protein balance, g/kg | 174 | 15.5 | 105*** | 13.5 |
| metabolizable energy, MJ/kg | 13.9 | 0.2 | 13.0*** | 0.1 |
| Pigs | | | | |
| metabolizable energy, MJ/kg | 15.2 | 0.2 | 14.6*** | 0.1 |
| digestible protein, g/kg | 259 | 0.6 | 283** | 0.5 |

*** – $P<0.001$; ** – $P<0.01$

Contrary to the variation in most of the nutrients, metabolizable energy content was relatively stable. The difference between minimum and maximum values was 0.6 MJ for HTRC, and 1.5 MJ for CPRC.

Comparing the nutrient content of the two different types of cake on a dry matter basis, the values for crude protein and crude fat were the most significant differences. CPRC contained 3.1% less crude protein (332 g/kg vs. 363g/kg) and 4.7% more crude fat (158g/kg vs. 111g/kg), and the metabolizable energy per 1 kg dry matter was 0.6 MJ higher for pigs and 0.9 MJ higher for ruminants (Table 1).

Dry matter and crude protein contents in CPRC were similar to those found by Barneveld (2000) and Kaldmäe et al (2006).

Dry matter, crude protein and crude fat contents in CPRC analysed in this study were in good accord with the results of Geier (2004).

In contrast to fat and energy content in CPRC, crude protein content was much lower than in HTRC. All major differences in chemical composition between two cake types are most likely to be connected to the efficiency of oil removal in the different extraction methods. The higher the fat content in the cake, the less proportionally

is the content of other nutrients. However, the chemical composition of rapeseed cake is affected by many other factors. The results of the study demonstrate great variation in the nutrient content of rapeseed cake. Therefore, prior to diet formulation, it is recommended to evaluate the chemical composition of any new batch of rapeseed cake purchased.

Mean dry matter and protein contents in HTRC were in good accord with the data presented by Barneveld (2000). However, compared to the results of the present study, the fat content was higher by 2.6% in the report of Barneveld (2000); 13.7% vs. 11.1%. Fat content in the cake analysed in the present study was found to be similar (12.5% in dry matter) to the results from another investigation (Allan *et al.*, 2000) but were different in protein content (318 g/kg vs. 363 g/kg) from that investigation. It appears that the chemical content is roughly similar compared to corresponding results from other investigators, but there is some difference in the content of one or more nutrients. Greatest differences are often seen in protein and fat content. These differences are most likely caused by specific pressing technologies and conditions that are used in a particular oil plant or in a particular region. Pressing conditions influence the effectiveness of oil re-

moval and thereby also the nutrient content and value of produced rapeseed cake (Homolka et al, 2007).

Table 2 presents the glucosinolate contents of rapeseed and HTRC cake analysed.

Table 2. Content of glucosinolates in rapeseed and rapeseed cake (n=3)

| Item | Rapeseed | Rapeseed cake | The effect of heat treatment on the content of glucosinolates, % |
|-----------------------------------|----------|---------------|------------------------------------------------------------------|
| Glucosinolates, $\mu\text{mol/g}$ | 17.9 | 9.5 | -47 |
| Progoitrin | 6.9 | 4.7 | -32 |
| Napoleiferin | 0.4 | 0.3 | -25 |
| Gluconapin | 2.7 | 1.9 | -30 |
| 4-OH-glucobrassicin | 6.7 | 1.9 | -72 |
| Glucobrassicinapin | 0.8 | 0.5 | -38 |
| Glucobrassicin | 0.4 | 0.1 | -75 |

Analysis revealed that 4-hydroxy-glucobrassicin, progoitrin and gluconapin constituted about 90% of all glucosinolates detected in the RS and HTRC.

The study results revealed that heat treatment reduced the content of total glucosinolates in fat-free dry matter by almost 50%. Treatment had the strongest effect on the content of glucobrassicin and 4-hydroxy-glucobrassicin, reducing their level by 75% and 72%, respectively.

The study indicated that the glucosinolate content of rapeseed (00 varieties) and rapeseed cake is currently relatively low – 17.9 $\mu\text{mol/g}$ and 9.5 $\mu\text{mol/g}$ in fat-free dry matter, respectively. Data published by Jensen et al (1995) and Shahidi et al (1997) have also shown that 4-hydroxy-glucobrassicin, progoitrin and gluconapin constitute the majority of glucosinolates in rapeseed.

Heat treatment affected most significantly the contents of 4-hydroxy-glucobrassicin and glucobrassicin, reducing the level of each of them by more than 70% in fat-free dry matter. Treating rapeseed at 100°C for 15, 30, 60 and 120 minutes, the content of 4-hydroxy-glucobrassicin decreased by 36%, 70%, 93% and 97%, respectively Liu et

al (1994) have reported that glucosinolates content was reduced by 60% when heated at 100-110 C for 60 to 80 minutes.

Digestibility in pigs. Digestibility analyses of CPRC and HTRC are shown in Table 3. CPRC used for the digestibility trial contained 89.4% dry matter 306 g/kg crude protein, 194 g/kg crude fat and 15.8 MJ/kg in DM metabolizable energy, but in HTRC these were 89.5%; 376 g/kg; 111 g/kg and 14.8 MJ/kg respectively. The results showed that dry matter and organic matter and energy of rapeseed cake produced using different technologies were similar. Digestibility of crude protein was the higher by 70.4% in the diet where HTRC had 100 °C processing temperature and lower by 68.4% CPRC was used in the diet. The processing temperature of rapeseed cake improved the digestibility of protein for pigs as reported by Leming and Lember (2002), whose data indicated the highest digestibility of CP (74%) in pigs where processing temperature was the highest (112°C). Berot et al (2005) explain the better digestibility of CP of rapeseed cake with heating on the effect on globulins.

Table 3. Digestibility of CPRC and HTRC in pigs

| Item | CPRC | HTRC |
|------------------|------|-------|
| Dry matter,% | 74.0 | 73.2 |
| Organic matter,% | 76.9 | 76.2 |
| Crude protein,% | 68.4 | 70.4* |
| Gross Energy,% | 75.1 | 74.1 |

* P<0.05

Protein degradability of rapeseed cake. Ruminal kinetics of protein degradability of various rapeseed products are presented (Table 4). The chemical compositions of HTRC (n=6) and CPRC (n=6) were DM 97.7% and 86.0% and crude protein 371 g/kg and 341 g/kg, respectively. Assessment of protein degradability of rapeseed cake indicated that it was affected by the temperature used during the pressing of rapeseed. The ruminal degradability of CPRC protein was rapid – in two hours 80.9% of protein was degraded, while for HTRC the value was 37.3%. Protein solubility of HTRC (fraction A) was 31%, while that of CPRC 70.2%; effective degradability was 53.4% and 89.2, respectively. Studies of

ruminal degradation of protein of heat processed feed-stuffs using the *in sacco* approach indicate reductions in fraction A (soluble fraction), but increases in fractions B (degradable fraction) and C (undegradable fraction), and decreases in the fractional rates of degradation of the B fraction (Goelema et al. 1999; Prestlökken, 1999, Kaasik et al. 2002).

Earlier studies have also indicated that heat treatment of rapeseed can decrease the effective ruminal degradability of rapeseed cake protein. Kass et al. (2005) have showed that at a treatment temperature 98°C, the effective degradability of protein was 57% while at 112°C it was 43%.

Table 4. Protein degradability (%) of rapeseed cake processed under different conditions

| Time of degradability, h | CPRC | | HTRC | |
|----------------------------|-----------|-----|-----------|-----|
| | \bar{x} | s | \bar{x} | s |
| 2 | 80.9 | 0.6 | 37.3 | 0.1 |
| 4 | 83.1 | 0.7 | 42.6 | 0.7 |
| 8 | 90.0 | 0.6 | 44.6 | 0.5 |
| 16 | 93.0 | 0.4 | 67.5 | 1.1 |
| 32 | 94.2 | 0.2 | 75.5 | 0.9 |
| 64 | 94.4 | 0.1 | 86.9 | 0.5 |
| Effective degradability, % | 89.2 | 0.3 | 53.4*** | 3.0 |
| Solubility, % | 70.2 | 1.8 | 31.0*** | 0.7 |

*** – P<0.001

In the diets of cows it is recommended that the effective degradability of rapeseed cake does not exceed 55%. Strudsholm et al. (1995) suggested that the effective degradability of rapeseed cake is 55%; according to Tuori et al (1996) this value should be 65%. The heating method of rapeseed processing has been reported Homolka et al, (2007) to affect the degradability of crude protein in rumen of ruminants and their further digestibility in the intestine.

Conclusions. Heat treatment (at 100°C for 20 to 25 minutes) of rapeseed increases the metabolizable protein content of rapeseed cake in the diet for ruminants and the digestible protein for pigs.

Heat treatment of rapeseed improves the nutritive value and the protein quality of rapeseed cake.

Chemical composition and the nutritive value of rapeseed cake depend on processing conditions.

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