HEAT AND MICROWAVE PROCESSING OF OILSEED RAPE: EFFECTS ON PRODUCT QUALITY

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INTRODUCTION

Double low oilseed rape (Brassica napus L. and B. campestris L.) has a high content of oil (40-46%), protein (22-28%) and dietary fibres (DF; approx. 20%) in their seeds. The oil is of high nutritive value, with the fatty acid content dominated by oleic acid (52-58%), linoleic acid (20-25%) and linolenic acid (6-10%). The proteins have a well balanced amino acid composition with a relatively high content of sulfur containing amino acids resulting in a high biological value (BV)(Bille et al., 1983). The digestibility of rapeseed/ rapeseed meal is, however, relatively low for both energy (DE) and protein (TD). This seems to be caused by DF (Bjergegaard et al., 1991). Because of the favourable composition of the whole seeds there is a considerable interest for using whole seeds in diets for animals responding positively on high contents of fatty acids in the feed.

The quality of both oil and protein is strongly correlated with the content of glucosinolates in the seeds and especially products formed as a result of glucosinolate degradation (Jensen et al., 1990). It is thus important to avoid glucosinolate degradation during processing and production of feed, and this requires an efficient inactivation of myrosinases (β-thioglucoside glucohydrolase; EC 3.2.3.1) (Michaelsen et al., 1991). With too vigorous heating or toasting, the quality of the rapeseed/rapeseed meal is reduced (Bille et al., 1983; Jensen et al., 1990). This reduction can be caused by negative effects on the unsaturated fatty acids, amino acids, glucosinolates, aromatic choline esters or other unstable seed constituents, which can be transformed into harmful compounds.

The aim of the present work is systematic investigations of the possibility of processing rapeseed in a cheap process, avoiding formation of too high concentrations of harmful compounds, and eventually with a positive effect on DF for increasing DE and TD. The investigations have been performed both as laboratory scale experiments and industrial scale experiments with a capacity of several ton rapeseed per hour. The processed rapeseed has been tested in balance trials with rats and production trials with mink.

MATERIALS AND METHODS

Rapeseed used in the present work was a Danish grown double low spring rape obtained from Superfos Korn A/S, DK-6971 Spjald, Denmark. The industrial scale processing was performed at Superfos Korn A/S, in an Euro-Therm Plant (drum; length 14 m x 2 m i.d.) with gas heating, regulation of air flow, rotations per minute, and total hold-time resulting in continuous flow of seed through the drum. The amount of water in the seed was adjusted to the wanted level before processing, and determined before and after the processing by standard procedure (ISO 665:1977). The laboratory scale microwave treatment was performed in a Moulinex FM45 Microwave oven, 350 and 700 watt. The laboratory scale heating was performed in an Elektro Helios laboratory oven. The applied combinations of temperature, effect, time and water content (determined as above) are presented together with the results. The laboratory scale experiments were performed with the seeds in open vials or in closed plastic bags.

Details on the applied analytical methods have been described elsewhere; chemical

composition (AOAC, 1980), amino acids (Eggum and Sørensen, 1989), aromatic choline esters (Clausen et al., 1985), HPLC of intact- and desulfoglucosinolates (Sørensen, 1990), and myrosinase activity (Michaelsen et al., 1991). Water binding capacity was determined as weight of extracted rapeseed drained for water in columns (28 x 150 mm). Fatty acid content was determined after esterification with methanol and analysis was performed by gas chromatography (Møller et al., 1985). Balance trials were performed with rats (Bille et al., 1983), and production trials were performed with mink (Henriksen et al., 1987).

RESULTS

Results from laboratory experiments are shown in Figs. 1-3. Heating in oven was performed at 110°C and 140°C for 2, 10 and 30 min. Microwave processing was performed at 350 W and 700 W for 1, 2 and 5 min. All processing conditions were applied to seeds in open vials with 5.8%, 12.1%, 21.9% and 38.0 % water, and a sample size of 4 g. Processed rapeseeds were analysed for myrosinase activity, water binding capacity, glucosinolates (intact and desulfo), sinapine, fatty acid composition and free amino acid composition.

Relative myrosinase activity after processing is shown in Fig. 1. At a temperature of 110°C inactivation of myrosinase required about 30 min. processing time for seeds with the four highest amounts of water. Increasing the temperature to 140°C inactivated myrosinase after 10 min. The results after 2 min. showed that heating seeds containing at least 21.9% water was the most efficient treatment. Microwaves at 350 W inactivated myrosinase after 5 min., and at 700 W, only 1 min. was necessary for myrosinase inactivation in seeds containing 15.5%, 21.9% or 38.0% water, whereas 2 min. was necessary for the seeds with the two lowest amounts of water.

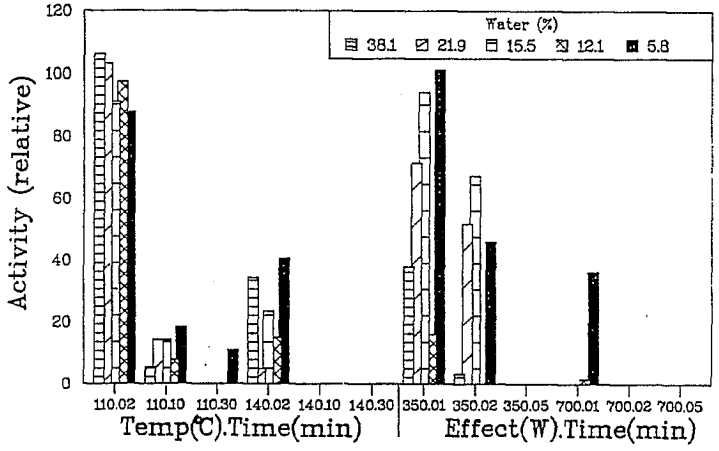

Fig. 1. Relative myrosinase activity in seeds after processing.

Water binding capacity of seeds from all treatments was high, and varied from 240% to 360% of dry weight. Reduction in water binding capacity was only seen for the treatment at 700 W for 5 min.

Amounts of glucosinolates in the seeds were determined both as intact and desulfoglucosinolates. Results from analyses of 4-hydroxyglucobrassicin in the seeds are shown in Fig. 2. A temperature of 110°C for 30 min and 140°C for 10 and 30 min. caused a reduction in the amount of 4-hydroxyglucobrassicin of approx. 20%, 30%, and 85%, respectively, with no influence of the water content present in the seeds before processing. An effect of 700 W for 2 or 5 min. caused a reduction in the amount of 4-

hydroxyglucobrassicin of approx. 45% and 95%, respectively, with no clear influence of water content in seeds. Total glucosinolates were reduced with treatments at 140°C for 30 min., 700 W for 2 min. and 700 W for 5 min. resulting in reductions of approx. 30%, 15% and 70%, respectively.

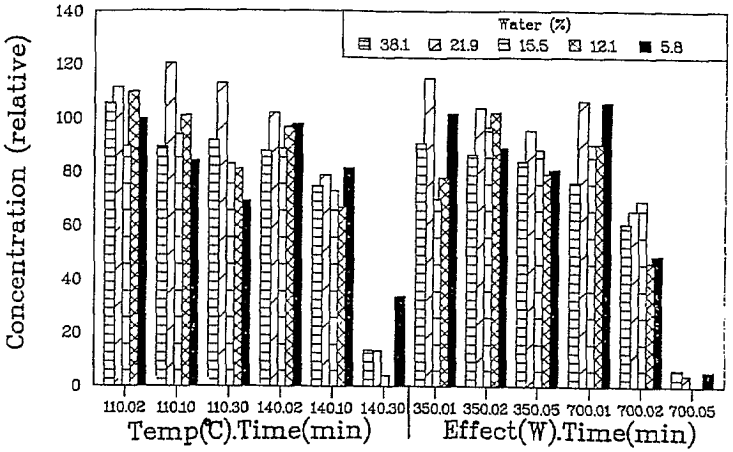

Fig. 2. Effect of process treatments on the concentration of 4-hydroxyglucobrassicin in the seeds.

The amount of sinapine in seeds after some of the process treatments is shown in Fig.3. A temperature of 110°C or an effect of 350 W did not lower the content of sinapine whereas 140°C for 30 min. decreased the level, especially for seeds with the highest water content. Microwave treatment at 700 W for 2, and especially 5 min. also decreased the sinapine level irrespective of water content in the seeds.

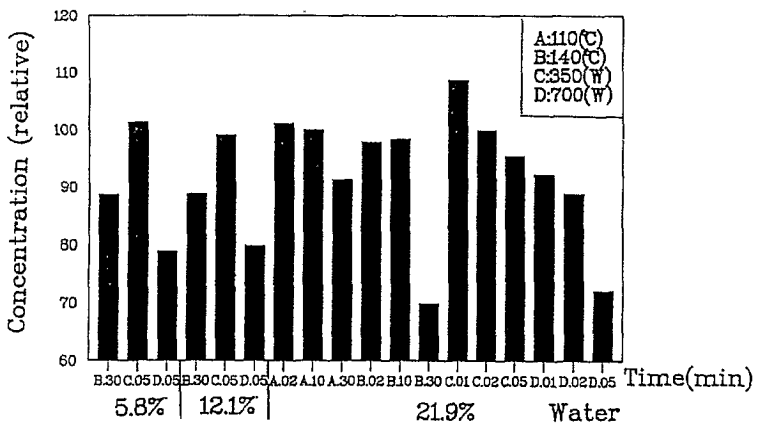

Fig. 3. Effect of some of the proces treatments on the concentration of sinapine in the seeds.

The amount of free amino acids after processing was determined in some of the seed samples. The results showed that intense heating reduced the total amount of amino acids compared to the amounts in control samples. The amount of different amino acids were not equally reduced by the process treatments, and the different processing conditions did not reduce specific amino acids to the same level. This indicated diverse effects depending

on amino acids and process conditions.

Laboratory experiments were scaled to production of processed rapeseed for balance trials with rats and production trials with mink. Processing larger amounts of seeds showed the necessity of measuring the temperature of seeds immediately after processing instead of temperature in the oven or processing chamber. Process treatments and results obtained from analyses of the content of 4-hydroxyglucobrassicin and progoitrin in the rapeseed used in trials with rats are shown in Table 1. All treatments resulted in complete myrosinase inactivation. Preliminary results from determination of the relative amounts of stearic acid, oleic acid, linoleic acid and linolenic acid did not reveal any changes in relative amounts towards more of the saturated fatty acids.

Table 1. Process treatments of rapeseed used in balance trials. Laboratory (L): 120 g and industrial (I): continuous flow.

Group	Temp. or Effect	Time min.	Water %	Seed temp. °C	L or I	4-Hydroxy-glucobras-sicin[3]	Progoi-trin[3]
1-2						100	100
3-4	120°C	10	9.6	98[1]	L[2]	103.5	107.6
5-6	120°C	10	20.3	95[1]	L[2]	98.2	103.8
7-8	160°C	40	9.6	143[1]	L	15.8	41.2
9-10	700 W	8	9.6	168[1]	L	10.3	27.5
11-13	90°C	5	24.7	90[1]	I	78.7	86.0
14-15	105°C	5	22.7	105[1]	I	74.7	93.0
16-17	>140°C	5	14.4	-	I	0	8.1

[1]. Measured in seeds immediately after processing
[2]. Processed in closed plastic bags.
[3]. Relative concentrations of the glucosinolates in the seeds after processing.

Preliminary results from balance trials with rats fed processed rapeseeds are shown in Table 2. The balance trials revealed differences in true protein digestibility (TD), biological value (BV), net protein utilization (NPU), and digestible energy (DE) as a result of the process treatments. Balance trials are, however, not likely to show great differences as a result of the various degrees of myrosinase or heat induced glucosinolate degradation at the lowest levels of glucosinolates in the diet (0.6-2.4 μmol/g) and the short period of trial. Inclusion of 7.5%, 15% and 30% of rapeseed resulted in 19.1%, 38.4% and 76.6%, respectively, of protein coming from rapeseed. Control diets without rapeseed resulted in TD, BV, NPU, and DE values of 95%, 99%, 95%, and 91%, respectively.

The processing conditions of rapeseeds for groups 3-4, 5-6, 11-13 and 14-15 were sufficient and optimal for destruction of myrosinase, and TD, BV, NPU and weight gain were not reduced for these groups compared to group 1-2. This indicated that no negative effects on the protein quality had occurred. More intense processing conditions (groups 7-8, 9-10, and 16-17) resulted, however, in appreciable reductions of TD, BV and NPU. Weight gains were lower for groups 9-10 and 16-17. There was a reduction of DE for groups 8,10,16, and 17. The increased liver weight as percent of body weight observed for groups 1-2 indicated the presence of harmful products from myrosinase catalysed glucosinolate breakdown.

Table 2. Results from the balance trials with young growing rats fed processed rapeseeds. Group refers to Table 1.

Group	Inclusion % of DM	TD %	BV %	NPU %	DE %	Weight gain g	Liver % of weight
1	15	93.0	95.0	88.3	88.7	15.4	5.2
2	30	87.5	92.8	81.2	85.7	12.2	5.2
3	15	92.5	93.3	86.2	88.1	13.7	4.3
4	30	88.9	95.0	84.5	85.6	12.3	4.7
5	15	94.7	96.7	91.6	88.7	13.9	4.1
6	30	87.4	90.3	78.9	86.8	13.9	4.5
7	15	90.4	92.4	83.5	88.1	14.3	4.8
8	30	85.4	88.2	75.3	85.1	11.7	4.5
9	15	85.3	96.6	82.4	88.0	11.1	
10	30	70.9	89.1	63.2	84.8	7.5	
11	7.5	97.4	96.1	93.5	91.3	13.8	4.5
12	15	91.5	94.7	86.7	88.3	13.1	4.6
13	30	88.6	94.7	83.9	86.6	12.7	
14	15	93.1	95.3	88.7	87.9	12.2	
15	30	86.9	96.7	84.2	85.7	13.7	
16	15	70.5	96.1	67.8	86.1	8.5	
17	30	44.9	82.4	37.0	81.0	0.0	

DISCUSSION AND CONCLUSION

Inactivation of myrosinase is critical for possible use of intact rapeseed in feed. Therefore the first parameter to analyse for is remaining myrosinase activity in seeds after processing. Dry heat (oven heating) showed that a relatively high temperature and long processing time was necessary to inactivate myrosinase compared to microwave treatment (Fig.1). Furthermore a water content above 20% in seeds was preferable, using oven as well as microwave heating. Not only high amounts of water in the seeds are necessary, but also high humidity in the processing chamber is of great importance. This was seen from oven heating of rapeseeds containing the same amount of water and heated in open vials or closed plastic bags. It was also found in an experiment by Jensen et al. (1990), where myrosinase inactivation was not obtained by heating rapeseed meal in open vials at high temperatures and for long periods of time. Ensuring complete myrosinase inactivation, the next step is to determine whether compounds such as glucosinolates, aromatic choline esters, unsaturated fatty acids and amino acids are thermally degraded, transformed or bound into potentially harmful or unavailable compounds.

Processing conditions required and optimized to inactivate myrosinase did not give any degradation, transformation or binding of the above mentioned compounds, but more intense heating and microwave treatments did. The relatively unstable 4-hydroxyglucobrassicin was most affected by processing and therefore accounting for most of the reduction in total amount of glucosinolates in seeds. More stable alifatic glucosinolates (e.g. progoitrin and gluconapin) were degraded only when heated in oven at 140°C or by microwaves at 700 W. The amounts of sinapine and free amino acids were only decreased by the most intense heating conditions. Analyses of D-L amino acids are in progress, and these are expected to reveal whether intense heating will result in racemization of amino acids.

Processing by too intense heating lower the quality of protein in the diet (Table 2). Reasons could be: effects from glucosinolate degradation products, phenolics (lignanes), lower availability of amino acids caused by Maillard reactions (Öste et al., 1987) condensation products of free amino acids, and destruction of special amino acids (Bille et al., 1983; Eggum and Sørensen, 1989; Jensen et al., 1990 and refs. cited therein).

There was no increase in DE and TD, that could be a result of a positive effect on DF caused by heating seeds even for those containing high levels of water. Processing conditions sufficient for inactivation of myrosinase probably also inactivates lipoxygenase. This is important to avoid oxidation of polyunsaturated lipids during storage of whole and crused seeds in feed stored for long periods (Meshehdani et al., 1990).

In conclusion, the investigations now performed have revealed various requirements to satisfactory processing of whole rapeseeds. The most promising results were obtained with heating of whole rapeseeds containing 20-24% of water to a seed temperature (measured immediately after processing) of 90-95°C with continuous flow and a total pass time of 5 min. in the Euro-Therm plant. In the laboratory scale 10 min. at 120°C in closed plastic bags using a laboratory oven and sample sizes of 120 g could be used. These processing conditions inactivated myrosinase, gave no heat induced degradation of glucosinolates or sinapine and gave no negative effect on protein quality as shown by balance trials with young growing rats. Long term feeding in production trials with mink are now in progres. Heat processing by the Euro-Therm plant is furthermore a simple, cheap and high capacity processing method, and can eventually give a product of sufficient high quality for the less sensitive animals (Sørensen, 1988).

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