Detoxification of Rapeseed Meal by Extrusion with an Added Basic Salt[1]

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ABSTRACT

A commercial, high-glucosinolate, rapeseed meal with no added salt or mixed with 2, 5, or 10% NH_4HCO_3 was extruded under different processing conditions using the Wenger TX-52 twin-screw extruder. Male Wistar rats were fed 13 diets containing 15% rapeseed meals (including nonextruded) or a casein-based control diet. After six weeks, blood samples were taken, and serum was analyzed for thyroid hormones. Extrusion processing under all salt and steam conditions tested reduced glucosinolate levels in the meal, but no significant correlation was found between intensity of the treatment conditions and glucosinolate reduction. Higher weight gains, feed efficiencies, and thyroid hormone profiles were observed with use of the extruded meals; but no treatment completely detoxified the meal. Histopathological evaluation showed that thyroid and other tissue abnormalities occurred in all animals except those fed the casein diet. Antinutrients, including glucosinolates and probably volatile nitriles, in the meal were reduced by extrusion processing under the basic conditions of this experiment.

Many cruciferous seeds, such as rapeseed (*Brassica napus* or *B. campestris*), are valuable for their high oil content, which is often >40%. In some cases, the oil contains as much as 45% erucic acid (C22:1, Δ13-14), which is used in manufacturing plastics and high-grade lubricants (Erickson and Bassin 1990).

The meal remaining after oil removal has potential for use in the diets of monogastric animals because it contains 20–40% high-quality protein. However, such use is limited because the meal also contains compounds that reduce its nutritional value and make it unpalatable as well as goitrogenic. Glucosinolates, one type of antinutrient in the meal, have suppressed thyroidal uptake of iodine in rats, which resulted in lowered levels of the thyroid hormones T3 (triiodothyronine) and T4 (thyroxine) (Duncan 1991). Goitrin (5-vinyl oxazolidine thione), thiocyanates, isothiocyanates, and nitriles are toxic compounds that can result when glucosinolates are hydrolyzed by an endogenous enzyme (Duncan 1991).

Athough several methods, including the use of heat, steam, and chemicals, have been tested in attempts to detoxify cruciferous seed meals and make them palatable for monogastric animals (Keith and Bell 1984, Naczk et al 1986, Shahidi and Gabon 1989), they have attained only limited success.

The objective of this study was to improve the nutritional quality of a commercial, high-glucosinolate rapeseed meal by treatment with a basic salt and extrusion processing under different conditions. Nutritional quality of the products was tested in a feeding study of rats.

MATERIALS AND METHODS

Extrusion

High-glucosinolate pressed rapeseed meal (*B. napus*), obtained from Montana Vegetable Oil Co., Great Falls, MT, with no added salt or mixed with 2, 5, or 10% NH_4HCO_3, was extruded using a Wenger co-rotating twin screw (TX-52) extruder. A nine-head screw configuration was used with mixing and forward-conveying shear locks as described by Wang et al (1993). Shaft speed was 325 rpm. Steam was added to the conditioning cylinder at 10 kg/hr; temperature in the cylinder was 90°C. Steam was not used or was applied to the extruder barrel at 5 or 10 kg/hr, and barrel temperatures just before the die were 50°C, 80°C, and 110°C, respectively, for the three steam conditions. Steam and ammonia (from decomposition of the NH_4HCO_3) were vented at head 6 and at the die. A three-hole die with 5/32 in. (3.97 mm) holes and a 1-in. (2.54 cm) first die spacer were used. After a steady-state was attained for each treatment, the extruded pellets were conveyed by a pneumatic system to an oven dryer and dried at 105°C for 25 min.

Nutritional Evaluation

Male Wistar rats weighing 101 ± 3 g were obtained from Charles River Breeding Lab, Wilmington, MA. Fourteen groups of 10 animals each were fed diets containing 15% rapeseed meal or a casein-based control diet. Diets were formulated to be nutritionally balanced and contained 20% protein and 7% fat (Table I). Diet 1 contained the pressed rapeseed meal as it was received from the supplier. Diets 2–13 contained rapeseed meal extruded under the different processing conditions of steam and added NH_4HCO_3. Diet 14 contained no seed meal and had casein as the protein source. Rats were housed individually and fed ad libitum for six weeks. The experimental design was a complete random block.

Glucosinolate Analysis

Total glucosinolates in the meals were determined by the method of McGregor and Downey (1986). Glucosinolates were removed from oil-extracted meals with boiling water. Interfering materials were removed from the aqueous extracts by precipitation with a barium-lead acetate solution (0.375*M*) followed by centrifugation. Aliquots of the supernatents were carefully placed on small (4 × 33 mm) DEAE Sephadex A-25 (pyridine-acetate form) separation columns, which were then washed with a 30% formic acid solution, then water. Glucosinolates were eluted from the columns with 0.3*M* K_2SO_4 solution. Glucose was hydrolyzed from the glucosinolates in the eluate with 77% H_2SO_4. It was then colorimetrically measured after reaction with thymol (1% in ethanol), using a Milton Roy Spectronic 1001 spectrophotometer at 505 nm.

Thyroid Hormones and Histopathology

After six weeks, blood was withdrawn by cardiac puncture from ether-anesthetized rats, and radioimmunoassay was performed on the serum to determine total triiodothyronine (T3) and thyroxine (T4). Rats were sacrificed by exposure to an ether atmosphere, and kidney, thyroid, liver, and heart tissue samples were obtained. All tissues were fixed in 10% neutral buffered formalin, embedded in paraffin, sectioned at 6 µm, and stained with hematoxylin and eosin (H&E), then processed in an Autotechnicon before histopathological examination.

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Statistical Analysis

Data were analyzed using Proc ANOVA and Proc Corr (SAS 1989). Means were compared using Duncan's multiple range test.

RESULTS AND DISCUSSION

Effects of Extrusion on Glucosinolates in Rapeseed Meal

Table II shows that the extrusion conditions tested did not destroy most of the glucosinolates in the commercial rapeseed meal. The original meal contained 132 μmol glucosinolates/g of sample. Maximum reduction (28%) occurred with 10% added salt and 10 kg/hr steam added to the barrel. A 20% reduction in glucosinolates occurred under the milder conditions of 2–5% salt and no steam added to the barrel. No significant correlation was found between intensity of treatment conditions and glucosinolate destruction.

Rat Weight Gains and Feed Efficiencies

Animals fed extrusion-processed rapeseed meals (Diets 2–13) gained more weight than those fed the commercial rapeseed meal (Diet 1), although the difference was not always significant (Table III). Weight gains of animals in all groups fed the extruded meal were not statistically different from gains of animals fed the casein diet. Animals fed the casein diet (Diet 14) did not gain significantly more weight than those fed the commercial rapeseed diet. A negative correlation existed between dietary glucosinolate levels in the processed rapeseed meals and rat weight gain ($r = -0.607$, $P = 0.028$) (Fig. 1)

Diet 1 containing the nonextruded rapeseed meal was less efficient than any other diet (Table III). All diets containing extrusion-processed rapeseed meals were as efficient as the casein-based diet.

Serum Thyroid Hormones

Animals fed the nonextruded rapeseed meal (Diet 1) had the lowest T3 levels (Table III). Overall, extrusion processing of rapeseed meal resulted in increased serum T3 to levels that were equal to those of animals fed the casein diet (Diet 14), although increases were not always significant. Higher serum T3 levels in animals fed extruded meals were strongly correlated with higher weight gains ($r = 0.8177$, $P = 0.0006$) (Fig. 2). That suggests that improvement in the nutritional quality of the meals was the result of the reduction of thyrotoxic agents. T4 levels also tended to be higher in animals fed the extruded meals as compared to the commercial meal, but all rapeseed-fed animals had lower T4 levels than those fed the casein diet (Table III).

Histopathology

Tissues of animals fed the casein diet had normal-appearing cells. Kidneys had no swollen seminiferous tubules and no calcification. Thyroid follicles were regular in size and filled with col-

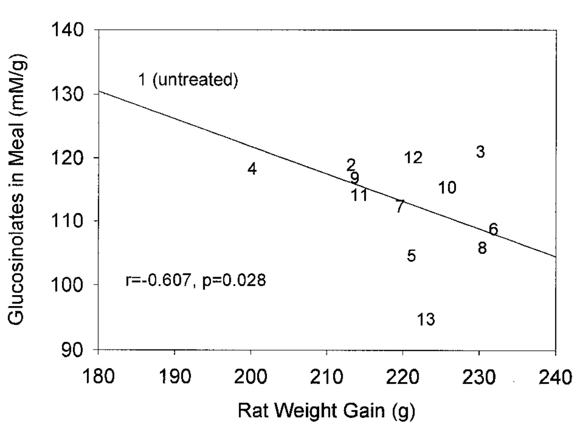

Fig. 1. Glucosinolate content of the meals negatively correlated with animal weight gains. Numbers correspond to dietary treatments (Table III).

TABLE I
Composition (%) of Rat Diets[a]

Ingredient	Diets 1–13 (Rapeseed)[b]	Diet 14 (Casein)
Casein[c]	17	25
Rapeseed meal	15	0
Corn starch	46	48
Sugar	10	10
Soybean oil	6	7
Vitamin mix[d]	2	2
Mineral mix[e]	4	4
Cellulose[f]	0	4

[a] All diets contained 20% protein and 7% fat.
[b] Diet 1, commercial pressed meal; diets 2–13 extruded meal. Proximate contents (%): protein, 34.9; moisture, 6.26; crude fat, 6.79; ash, 7.48, crude fiber, 12.4.
[c] From bovine milk, essentially vitamin-free, extracted with ethyl alcohol.
[d] AIN Vitamin Mixture 76.
[e] U.S.P. XVII Salt Mixture.
[f] Alphacel, nonnutritive bulk.

TABLE II
Effects of Extrusion Conditions on Glucosinolates in Rapeseed Meal

	Extrusion Conditions		Glucosinolates	
RapeseedMeal	% Salt	Steam (kg/hr)	μMol/ g of Meal	% Reduction After Extrusion
Nonextruded[a]				
1	. . .	. . .	132	. . .
Extruded[b]				
2	0	0	118	11
3	0	5	122	8
4	0	10	119	10
5	2	0	105	20
6	2	5	110	17
7	2	10	112	15
8	5	0	105	20
9	5	5	117	11
10	5	10	115	13
11	10	0	114	14
12	10	5	120	9
13	10	10	95	28

[a] Montana Vegetable Oil Co., Great Falls, MT.
[b] Wenger TX-52 extruder and different conditions of NH_4HCO_3 and steam.

TABLE III
Effects of Extrusion Conditions on Overall Rat Weight Gains, Feed Efficiencies, and Serum Thyroid Hormones (T3 and T4)

Diet	Salt/Steam (kg/hr)	Wt. Gain (g)	Feed Efficiency[a]	T3 (nMol/L)	T4 (nMol/L)
Nonextruded rapeseed[b]					
1	. . .	186b[c]	0.253b	1.44e	43.6gh
Extruded[d]					
2	0/0	213ab	0.292a	1.64b–e	44.5f–h
3	0/5	230a	0.306a	1.73a–d	54.0b–d
4	0/10	200ab	0.286a	1.53ef	47.5d–h
5	2/0	221a	0.291a	1.63b–e	56.0bc
6	2/5	232a	0.305a	1.81ab	57.6b
7	2/10	220a	0.292a	1.81ab	52.3b–e
8	5/0	230a	0.299a	1.80ab	48.7c–g
9	5/5	214ab	0.292a	1.55d–f	40.9h
10	5/10	226a	0.299a	1.86a	42.3gh
11	10/0	214ab	0.295a	1.73a–d	51.3b–f
12	10/5	221a	0.292a	1.60c–e	47.9d–h
13	10/10	223a	0.287a	1.68a–e	46.8e–h
Casein					
14	. . .	213ab	0.285a	1.75a–c	64.6a

[a] Expressed as g of wt. gain/g of feed.
[b] Montana Vegetable Oil Co., Great Falls, MT.
[c] Means in the same column not followed by the same letter are significantly different at $P \leq 0.05$.
[d] Wenger TX-52 extruder and different levels of NH_4HCO_3 and steam.

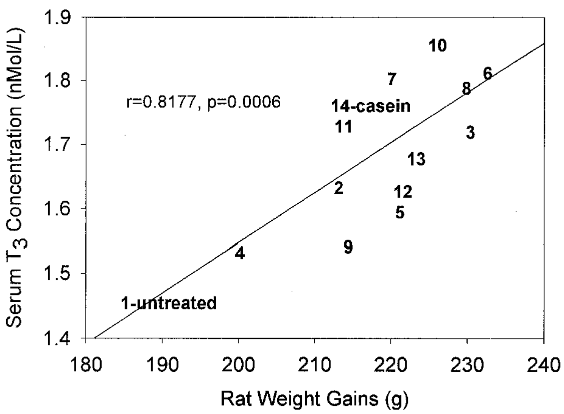

Fig. 2. Improved weight gains associated with improved serum T3 levels in extruded meal diets. Numbers correspond to dietary treatments (Table III).

loid; liver and heart tissues were normal. Tissues of rats fed the nonextruded rapeseed meal showed extensive tissue damage, exhibited in the kidneys as swollen, irregular, and convoluted tubules. Thyroid colloid follicles in those animals were mostly small, irregularly shaped, and frequently scrambled in appearance, and some were collapsed. There were a few very large follicles filled with colloid, which was nonuniformly deposited. All animals fed the diets containing extruded meal showed moderate to severe damage in kidney and thyroid tissue, but not as extensive as the damage observed in tissues from rats fed the nonextruded meal. Severity of damage did not seem to be associated with different salt or steam treatments. Animals fed Diet 8 containing meal extruded with minimal treatment (no salt, no steam) showed tissue abnormalities similar to those of animals fed Diet 4 (maximum conditions, 10% salt and steam at 10 kg/hr).

CONCLUSIONS

Although glucosinolates remained in all the processed meals, extrusion under any of the salt or steam conditions tested improved the feed efficiency of the commercial pressed rapeseed meal to a level equal to that of the casein diet. Weight gains in animals fed the extruded rapeseed meals tended to be higher than those of animals fed the nonextruded meal. A negative correlation existed between dietary glucosinolate levels and rat weight gains. Thyroid hormone levels, especially T3, were improved in almost all groups fed the extruded meals versus the nonextruded rapeseed meal. However, tissue abnormalities were observed in all animals except those fed the casein diet. Considerable evidence indicates that nitriles are the predominant and most toxic hydrolysis products of glucosinolates in natural environments (Duncan 1991). Extrusion processing with added NH_4HCO_3 should have destroyed any nitriles present in the rapeseed and driven off the resulting ammonia (Furniss et al 1989), thereby improving the nutritional quality of the meal:

$$RC \equiv N + \text{Heat} + \text{Base} \rightarrow R\overset{\overset{\displaystyle O}{\|}}{C}\text{–}NH_3 + \text{Heat} + \text{Base} \rightarrow R\overset{\overset{\displaystyle O}{\|}}{C}\text{–}OH + NH_3\uparrow$$

Our data indicated that improved nutritional quality of the extruded rapeseed meal was the result of reduced thyrotoxicity.

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