✲Fractionation of Rapeseed Meal into Flour and Hull Components

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ABSTRACT

Fine-ground rapeseed meal can be fractionated by liquid cyclone processes into flour and hull fractions. The process can be applied to expeller meal or to the marc after solvent extraction. A nonpolar solvent such as hexane is particularly effective because residual oil in the products is also substantially reduced. The flour, obtained in yield of about 66% of the meal, contained over 45% protein and 5-8% of crude fiber. Rapeseed meal is relatively low in digestible energy and the flour fraction would have greater application as a protein supplement in pig and poultry feeds.

INTRODUCTION

Rapeseed is the most important oilseed crop in Canada, the oil content of the seed being about 45%, dry basis. The residual meals contain nearly 40% protein (N x 6.25) but are poor components in animal feeds because of their glucosinolate content, high fiber, low metabolizable energy and poor palatability. The glucosinolate problem is being solved by plant breeding of new cultivars such as Tower, Regent and Candle which contain one-fifth to one-tenth of the original glucosinolate level. The major limitations of low protein/energy levels and poor palatability could be overcome by the mechanical dehulling of the seed or meal. Some decrease in crude fiber level has been achieved by the development of yellow-seeded strains such as Candle, but technological processing would result in additional improvements in the nutritive value of the meal. It is estimated that the economic returns from the sale of the meal would be increased ca. 18% by fractionation of the high and low fiber components in the meal.

Seed Characteristics

The seed coats of *Brassica* seeds adhere very tightly to the cotyledons or meats and are, therefore, difficult to remove without loss of meat fines in the hull fraction. Compared to the meats, the seed coats are relatively thick due, in part, to the small seed size. Generally, the proportions of hulls in turnip rapeseed, rapeseed and yellow mustard of 23, 22 and 18% are associated with their increasing seed size of 2.1, 4.0 and 7.9 mg, respectively. The influence of hull percentage on meal composition is shown in Table I. There is a progressive reduction in crude fiber and ash, and an increase in protein content, with decreases in hull percentage among the three *Brassica* species. Removal of the hulls by hand separation gave marked increases in protein content of the flour and reductions in crude fiber levels. However, there were still characteristic differences in composition of the flour, yellow mustard flour being particularly high in protein content and low in crude fiber. Dehulling served to increase the ash levels in the flour; much of the flour minerals are bound to phytin, and resist aqueous extraction, as well.

Conventional Dehulling Processes

Although rapeseed is crushed in several countries in Europe, Asia, and North and South America, conventional oilseed milling practices are not designed for the separation of hulls. Laboratory and pilot plant studies have demonstrated the feasibility of dehulling before oil extraction (1,2). Unfortunately, the hulls contain ca. 24% of oil, partly a result of contamination with small particles of meats (Table II). This quantity of oil represents ca. 10% of the original seed oil, a prohibitive loss if the hulls are not defatted. Because of the high oil content of the meats, filtration problems also may be encountered during oil extraction. In addition, the yields of flour are comparatively low and the economic benefits of dehulling are inadequate for general adoption by the industry.

Pin milling and air classification of rapeseed meal, after desolventization, into protein-rich and fiber-rich fractions has been proposed (3). The principal drawbacks of this process are (a) the need for double or triple milling to

TABLE I

Proximate Composition of *Brassica* Meals and Flours (% dry basis)

Brassica species	Defatted meal			Dehulled flour		
	Protein	Crude fiber	Ash	Protein	Crude fiber	Ash
Turnip rapeseed	37.6	12.9	7.1	47.5	4.6	8.0
Rapeseed	40.0	11.5	6.5	50.0	3.7	7.2
Yellow mustard	47.1	7.7	5.6	56.0	3.4	5.9

TABLE II

Approximate Yields and Compositions of Products Obtained by Front-End Dehulling of Rapeseed

Product	Yield of products (% of seed)	Oil content (%)	Protein content (% fat-free basis)
Hulls	18-23	24	28
Meats	76-79	54	55
Flour	30-36	1	54-60

obtain a reasonable yield of protein-rich fraction, and (b) the limited protein enrichment which is obtained in the fines fractions.

Liquid Cyclone Process

The process involves two basic steps in which defatted or partially defatted meal is initially disintegrated or fine-ground to pass a 150-mesh (Tyler) screen (4). The grinding may be applied to relatively dry meal after the expeller stage of oil extraction or to the hexane-soaked flakes immediately after solvent extraction.

Partially defatted meal containing no solvent can be fine-ground on a variety of pin, disc or impact mills. Wet milling of marc requires the use of explosion-proof colloidal or stone mills.

The second stage involves suspending the fine-ground marc or meal in additional hexane or other nonpolar fluid medium and fractionating the hulls and flour using liquid cyclone, liquid or sludge centrifugation or other gravity separation devices. It is necessary to maintain a uniform feed of ground marc to the liquid cyclone. To avoid settling of the denser particles, which is characteristic of the hulls fraction, a mixing tank was used in the laboratory to maintain the marc in suspension but an in-line mixer could be developed for that purpose. A short contact time of ca. 20 sec in the mixer will reduce the residual oil level in the meal from 2-5% to less than 1%. Longer residence time in the mixer is required for partially defatted meal from the expeller which may contain 15-20% of residual oil.

The minimum ratio of fine-ground rapeseed meal to solvent has been found to be 1:5. That is, for prepress rapeseed meal containing no solvent, 5 parts of hexane were required for effective fluidization or suspension (and soaking of the meal) and cyclone operation. For marc which contained 1.7 parts of hexane, 3.3 parts of additional hexane were added to provide the desired 1:5 ratio. After filtration, the marc may contain as little as 40% hexane, and proportionately more hexane is required.

Repeated experiments have shown that the presence of water in the solvent seriously interferes with liquid cyclone fractionation. Therefore, dehydrated solvent should be used. Solvent containing oil (miscella) is satisfactory for cyclone fractionation but the ability to defat the marc and remove residual oil is impaired to the extent of oil contamination in the solvent. Fresh, oil-free solvent reduces residual oil to as low as 0.1-0.5% in flour and hulls, and would be the preferred solvent.

The fine-ground (150-mesh) meal, fluidized with 1:5 of hexane, is pumped from the mixing vessel and forced through a liquid cyclone at pressures of 0.2 to 1.0 kg/cm^2. The pump must be explosion-proof and preferably with positive pressure features.

A wide range of liquid cyclones ranging in length from 15 to 70 cm were found to be effective in hull-flour fractionation, requiring only appropriate adjustment of pump pressures and valves to control inlet, overflow and underflow rates. From the data collected, it was possible to recommend that the cyclone have the following dimensions for fractionation of rapeseed meal components: (a) ratio of interior diameter to length of cyclone = 1:4; (b) overflow opening should be about one-half of the interior diameter of cyclone and two times larger than the inlet diameter; (c) ratio of the overflow opening to underflow outlet must be not less than 2:1.

Application in the Crushing Plant

The flow chart in Figure 1 illustrates the introduction of the wet-grinding step after the marc leaves the filter in an all-solvent type of oilseed plant. Hexane is blended with the

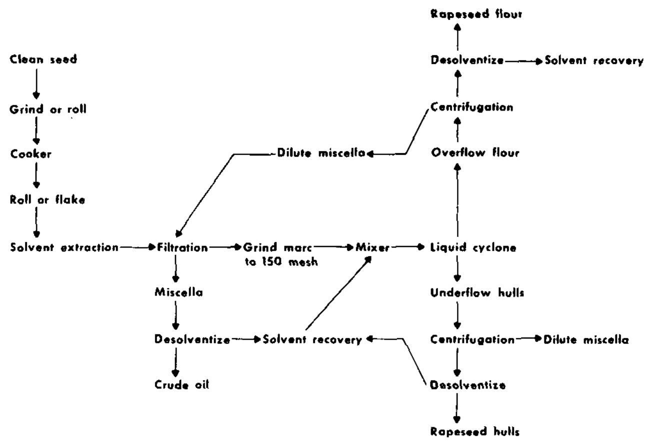

FIG. 1. All-solvent extraction plant incorporating wet milling and liquid cyclone fractionation after oil extraction and marc filtration.

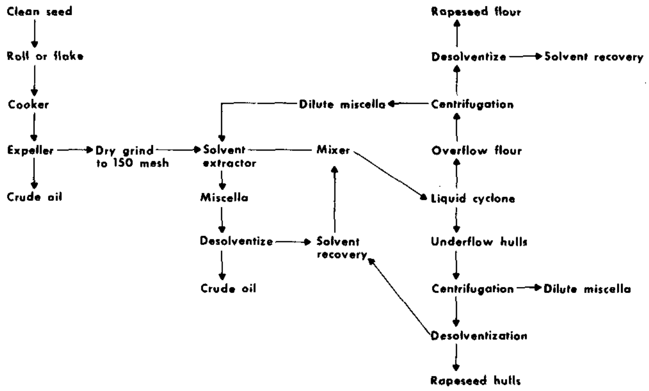

FIG. 2. Prepress plus solvent extraction plant using dry fine-grinding before oil extraction and liquid cyclone fractionation after solvent extraction.

fine material in the mixing chamber before pumping through the cyclone. Decanter centrifuges would be effective in removing the solvent from the flour and hull products. In each case, the dilute miscella, containing a low proportion of seed oil, could be reintroduced into the extraction system.

A similar wet-grinding system could be incorporated into a prepress plus solvent plant after the solvent extraction step. However, there are certain advantages in dry-grinding to achieve the 150-mesh particle size. In addition to a reduction of explosion hazards, a more uniform grind can be achieved. In the second flow chart (Fig. 2), the partially defatted meal from the expeller is dry-ground, before solvent extraction and liquid cyclone fractionation. If the expeller reduces the oil level to 14 or 15% of the meal, the liquid cyclone is effective in removing the remaining oil to a residual level of 1-2% which is within the range of present commercial plants. In this way, the cyclone can essentially replace the traditional solvent extraction system.

Pilot Plant Experiments

The yield and composition of the flour and hulls obtained from the fractionation of marc from an all-solvent plant are given in Table III. After grinding the marc, the hexane:meal ratio was made up to 5:1. The ratio of flour to hulls varied slightly during the run, but averaged 66:34. The flour was essentially free of hulls, but the hull fraction contained ca. 2% of flour. Crude protein and fiber in the original meal were 39.6 and 11.8%, respectively, at the 3.1% oil level.

TABLE III

Yield and Composition of Liquid Cyclone Fractions Obtained after Fine Grinding of Commercial Meals

Type of oil extraction plant	Meal-to-hexane ratio	Fractionated products[a]	Yield ratio	Protein (%)	Oil (%)	Fiber (%)	Ash (%)
All-solvent	–	Meal	100	39.6	3.1	11.8	6.8
	1:5	Flour	65	46.9	1.0	5.7	6.9
		Hulls	34	27.0	0.9	24.1	6.5
Prepress + solvent	–	Meal	100	37.6	3.1	14.7	6.8
	1:5	Flour	66	45.1	1.1	8.2	7.2
		Hulls	34	25.9	0.5	29.3	6.3
	1:3	Flour	67	42.4	1.3	10.3	7.0
		Hulls	33	29.2	0.5	25.0	6.8

[a]The marcs were desolventized before analyses; values reported are on a dry basis.

About two-thirds of this residual lipid was extracted during mixing and cycloning to give flour and hull products with only 1% of residual oil. Protein enrichment was only 7.5 and fiber reduction 6.0 percentage units. However, the fractionation removed one-third of the meal as a 24% crude fiber fraction so that the metabolizable energy in the flour should be greatly enhanced over that of the meal.

Marc from an expeller plant gave similar yields of flour and hulls (Table III). At the 1:5 ratio, the protein enrichment was also 7.5%, but the gain was only 5.0 percentage units when a 1:3 ratio of meal to hexane was employed. In the 1:3 experiment, many hulls were observed in the flour, and the crude fiber level exceeded 10.0%. Feeding trials need to be conducted on these samples to determine if this level of contamination can be tolerated in these processed products. Obviously, there would be savings in processing costs at the lower solvent:meal extraction ratio. The relatively efficient fractionation of the meal components resulted from their differential densities. The weight ratio of hulls to flour was ca. 1.6:1 on the basis of a hull density of 0.55 g/cc and the flour density of 0.34 g/cc.

Both products were very fine in particle size and difficult to handle. Firm, hard pellets could be produced by tempering to 15-18% moisture for the flour and 20-22% moisture for the hulls.

It should be noted that the proposed process for rapeseed does not fractionate the flour components into protein-rich and protein-depleted products as occurs when the liquid cyclone process is applied to dehulled cottonseed flour (5). In the process of removing pigment glands from cottonseed, a "protein concentrate" containing 66-69% protein was obtained. In our application of the liquid cyclone technique, rapeseed flour is recovered as a single fraction. On a seed basis, the yield of flour is ca. 36% (Tables II and III) and further yield reductions associated with protein concentration would be undesirable and, probably, uneconomical. The yield of flour from yellow mustard, which has a lower oil content and less hull, would be ca. 50-55% of the seed weight. The flours obtained by cyclone separation would contain glucosinolates and phenolic compounds which would detract from food uses of the product. Therefore, the proposed uses for both fractions are in animal feeds, the flour having particular application in nonruminant rations.

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