A non-organic solvent process for the efficient recovery of canola oil

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Abstract

Conventional processing of canola (*Brassica napus*) generally uses either, a combination of seed expelling plus organic solvent based oil extraction, or non-organic solvent processes that are based solely on expelling of the seed. Organic solvent based oil extraction is highly efficient (>96% oil recovery) in comparison to non-organic solvent based expeller only processes (generally 80% oil recovery). As such solvent extraction processes tend to dominate. However, environmental and safety concerns with the use of organic solvents are such that non-organic solvent based processes would be preferred if the efficiency of oil recovery approached that of organic solvent extraction. MCN BioProducts Inc. has developed a proprietary non-organic solvent process for high efficiency recovery of canola oil in the form of free oil and oil contained in a high valued concentrate of insoluble protein. The process uses expellers for a front end mechanical de-oiling as typical for conventional non-solvent processes. The cake containing the residual oil is then slurried in water and processed through an aqueous fractionation scheme that generates a fibrous fraction, a concentrate of insoluble protein and a liquid stream. Conditions are set such that 20% of the residual oil in the expelled cake is directed to the low valued fibrous production, 20% to the high valued insoluble protein concentrate and 60% to the liquid stream. The liquid stream is then processed through an oil-water separation with the generation of free oil that is mixed with expelled oil. The net result is 92% recovery of whole seed oil as free oil plus 4% recovery of oil within the high valued protein concentrate product. As such the combination of conventional oilseed expelling plus aqueous oil extraction results in a net oil recovery as high valued products that approaches that of organic-solvent based extraction processes.

Introduction

Historically, canola (Brassica napus) has been grown primarily for the oil. The oil comprises approximately 40% of the seed weight, however, the high value of the oil relative to the low value of the meal are such that the oil provides 70% or higher of the revenues generated from a commercial seed crushing and solvent extraction process. As such crushing operations have focused on maximizing the efficiency of oil recovery. A typical pre-press plus solvent extraction process can provide >96% oil recovery. This compares favorably to the 80-90% oil recovery that is typically obtained with a non-solvent expeller only based process. This substantial difference in oil recovery has lead to the predominance of solvent extraction plants for the processing of canola seed. However, safety, environmental and product quality concerns associated with the use of organic solvents are such that non-solvent based processes would be preferred provided that oil recovery are not overly compromised.

One approach to improve the efficiency of oil recovery from a non-solvent expeller process is to process the oil-expelled cake through an additional aqueous fractionation process designed to generated high valued protein concentrates. Such a process has the potential to facilitate recovery of additional oil in the form of valued free oil or valued oil-containing protein concentrate. MCN BioProducts Inc has developed a proprietary process for the aqueous fractionation of non-solvent expelled canola cake to generate a high valued protein concentrates. To improve the overall efficiency of oil recovery from whole seed starting material, an oil-water seperation step was integrated into the basic aqueous fractionation scheme. By quantifying the crude fat contents of the various streams generated by the process it was possible to measure the flow of oil to these streams and thus quantify the efficiency of oil recovery as high-valued outputs.

Materials and Methods

Whole seed canola was obtained from a local supplier near Saskatoon, Saskatchewan Canada. The seed was transported to the pilot oilseed processing facilities of Agricultural Research Center of the USDA in Peroria Illonios USA. The seed was conditioned for 15-20 minutes at 85-90°C (French Oil Mill Machinery Model 324 – 3 deck 24 inch diameter) and the expelled through a pilot scale full press (French Oil Mill Machinery Model L-250 3.5 inch barrel). The press cake was returned to the process development centre of MCN BioProducts in Saskatoon.

The press cake was initially slurried in water and then processed through the proprietary MCN aqueous fraction process. The core process outputs 3 intermediate streams consisting of a low value hull-enriched by-product stream, a high valued insoluble protein concentrate, and a solids-free liquid stream in the form of an oil-in-water emulsion.

The liquid stream was then processed through a 3-phase disk-stacked oil separating centrifuge (Westfalia) to separate the free oil from the oil-in-water emulsion.

Dry matter and crude fat mass flows were monitored through the process. Dry matter was determined by weight differential upon evaporation of moisture using an HB43 Halogen Automated Moisture Analyzer. Crude fat was determined by solvent extraction using an Ankon XT20 automated fat analyzer.

Results

Oil Expelling. A total of 22 replicate runs of seed conditioning and expelling were conducted using the pilot scale equipment at USDA in Peoria. The mean residual oil content of the full press cake obtained from 22 replicate runs was 9.39±1.09% of cake dry matter. This calculates to an 86.9±1.71% oil expelling efficiency from the starting seed.

Aqueous Fractionation. Water is added to the press cake to generate a slurry that is then processed through the core proprietary fractionation scheme. The process generates a first fraction enriched in hull fragments, a second fraction enriched in insoluble protein and a third fraction consisting of a solids-free liquid stream. Table 1 summarizes dry matter, protein and crude fat flux through the core fractionation process.

Table 1. Dry matter, protein and crude fat flows through the aqueous fractionation process*.

	Composition (% of d.m.)		Mass flows (% of starting cake)		
	Protein	**Crude fat**	**d.m.**	**Protein**	**Crude fat**
Starting cake	39.8	12.4			
Hull fraction	31.8±1.0	6.25±0.9	26.3±1.7	21.3±1.4	14.5±1.0
Protein concentrate	61.9±1.1	10.0±0.8	36.2±4.6	55.5±7.3	33.2±6.6
Liquid stream	13.1±0.4	12.0±1.0	36.9±3.1	11.9±1.0	40.4±6.4
Total % recovery			99.4	88.7	88.1

*Results are expressed as the mean and standard deviation obtained from triplicate runs of the proprietary fractionation process.

The hull fraction contained 6.3% crude fat on a dry matter basis and accounted for an average of 14.5% of crude fat in the starting expelled cake. The protein concentrate contained 62% protein and 10% crude fat on a dry matter basis and accounted for 33% of the starting expelled cake crude fat. The clarified liquid stream is the remaining fraction and this stream contained an average of 40% of the crude fat originating from the starting cake.

Crude Fat Recovery form the Liquid Stream. The clarified liquid stream contained an average of 41% of the crude fat in the starting press cake which is equivalent to 5.4% of the crude fat in the whole seed starting material. The liquid stream had the appearance of a solids-free cloudy milk-like material. Inspection of the liquid stream under light microscopy revealed an oil-in-water emulsion (Fig 1). Oil droplet size varied between 1-15 microns. Based on the distribution of droplet sizes an estimated 90% of the oil is contained in droplets of greater than 8 microns in diameter.

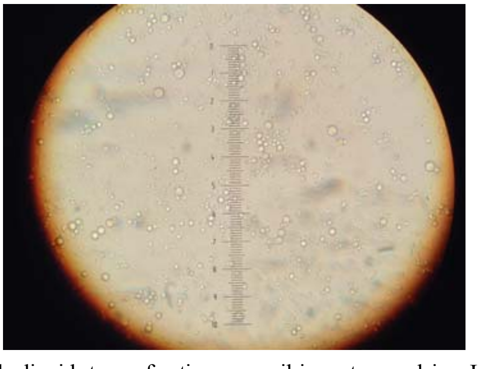

Fig 1. Light microscopy image showing the liquid stream fraction as an oil-in-water emulsion. Units are 23 μm and subunits are 2.3 μm.

Table 3 summarizes the result obtained in processing the oil-in-water liquid stream through a 3-phase disk-stacked centrifuge. The light out phase from the centrifuge averaged 40.8% crude fat, 5.3% non-oil dry matter in solution and 53.9% water. This stream accounted for 84.8% of the crude fat in the original feed to the centrifuge. The heavy out liquid phase was a largely aqueous stream with an average of 4.07% non-oil soluble dry matter and 0.13% crude fat. This stream accounted for an estimated 13.6% of the crude fat in the feed to the centrifuge. The sludge component of the 3-phase separation accounted for the remainder of the crude fat, water and non-fat dry matter.

Table 3. 3-Phase Disk-Stacked Centrifuge* Separation of Liquid Stream from Aqueous Fractionation of Expelled Canola

Fraction	% Dry Matter	% of total Volume	% crude fat		% crude fat recovery
			% as-is	% of d.m.	
Liquid stream input	4.62	100	0.77	16.78	
Light phase	46.1±9.8	1.6	40.8±3.2	88.5±0.53	84.8
Heavy phase	4.20±0.06	75.3	0.13±0.23	3.06±0.38	13.6
Sludge phase	7.17	7.4	0.45	6.25	4.3
Total % of input	95.9	84.3			102.7

*Continuous flow 3-phase separation on disk-stacked centrifuge. Dry matter and crude fat contents of light phase and heavy phase liquid outputs shown as the mean±S.D. of samples taken at the early, middle and late stages of the run. Volumes of light phase, heavy phase and sludge phase determined at the end of run. Sludge sampled at end of the run.

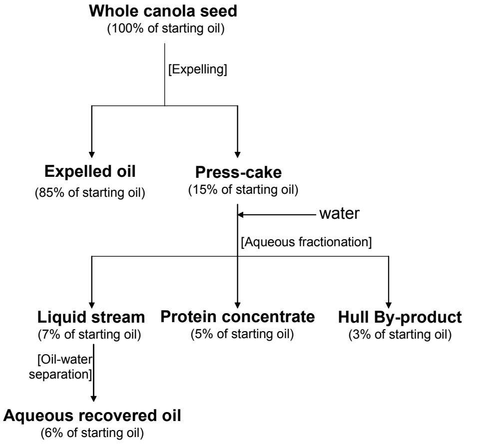

Fig 2. Projected oil flows through a non-solvent expeller plus aqueous fractionation and oil recovery process. Estimated recovery of oil as valued free oil plus protein concentrate = 96%.

Discussion

Current alternatives to solvent extraction for the processing of whole seed canola are disadvantaged by an 80-90% oil recovery relative to the near complete oil recovery obtained in solvent based oil extraction. To be competitive, a non-solvent process must provide comparable recovery of oil in the form of high valued products.

This paper described the flow of oil from expeller cake to the 3 fractionations that are produced by a novel proprietary aqueous fractionation process. In the process 15% of the crude fat in the expelled cake was directed to the low valued hull stream. The oil associated with the insoluble protein concentrate will have a comparable value to free oil given the high value of the protein in this stream while the majority of the oil in the liquid stream can be readily recovered by established oil-water separation processes. Figure 2 provides a projected oil mass balance for the integrated process. The net result is an overall 96% efficiency of oil recovery in the form of valued free oil plus oil within a high valued protein concentrate. As such oil recovery in this process is comparable to a conventional solvent based process.