Chemical Characterization of Dietary Fiber Isolated from Camelina Sativa

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IFT18
Chicago, Illinois ▪ July 16–18

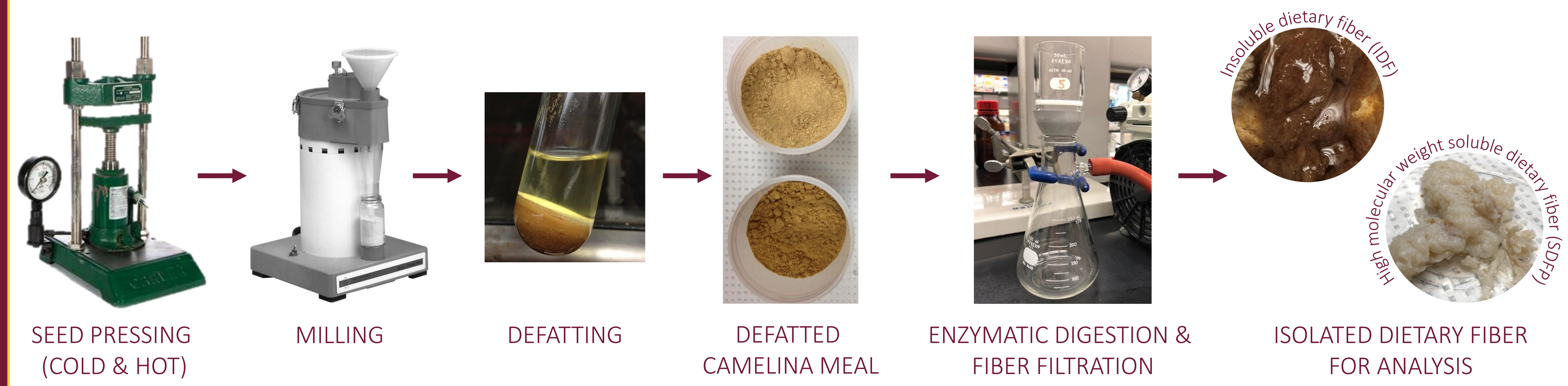
INTRODUCTION

- Camelina sativa, a *Brassica* family oilseed, is a short-season cover crop traditionally grown for biofuel. Camelina is gaining traction in current agricultural systems due to its environmental and industrial benefits (1):
  - Drought resistant
  - Cold weather tolerant
  - Fast growing
  - Increases primary crop production and revenue
- As a food source, camelina holds potential because it aligns with current consumer trends (2):
  - High protein
  - High fiber
  - Non-allergenic
  - Non-GMO
  - Vegetarian, vegan, "flexitarian" compliant
  - Alternative to soy ingredients
- There is a vast gap between the recommended fiber intake (30 g / day) and the average fiber consumption; less than 3% of Americans meet this recommendation. In 2010, the Dietary Guidelines Advisory Committee classified dietary fiber as "an under-consumed nutrient of public health concern" (3).
- Extensive research demonstrates dietary fiber's positive impact on digestive health and prevention of chronic conditions such as cardiovascular diseases, type II diabetes, and obesity (4).
- Currently, dietary fiber is one of the fastest growing segments of the food and beverage ingredient market with an annual growth rate of nearly 9% since 2007 (5).
- Given camelina's agricultural and nutritional characteristics and the demand for novel, plant-based ingredients, dietary fiber isolated from camelina seeds merits further investigation as to its chemical composition and how it can contribute functionality to a food product.
- The objective of this study was to isolate, quantify, and characterize the three dietary fiber fractions—insoluble (IDF), high molecular weight soluble (SDFP), and low molecular weight soluble dietary fiber (SDFS)—from defatted camelina meal (DCM) prepared by two different oil pressing conditions.

METHODS

CHARACTERISTIC	METHOD
Total dietary fiber quantification	Integrated Total Dietary Fiber Assay (AOAC 2011.25) (Megazyme, Wicklow, Ireland) (6)
SDFS identification	Ligand exchange liquid chromatography coupled with electrospray ionization mass spectrometry (LC-ESI-MS) under positive polarity. Oligosaccharide ions detected as mono-sodiated adducts [M+Na]+ at the following m/z values: 365.0 (disaccharides), 527.0 (trisaccharides), and 689.0 (tetrasaccharides) (7)
SDFS oligosaccharide quantification	High performance anion exchange chromatography with pulsed amperometric detection (8)
SDFP & IDF monomer identification	Reduction and acetylation of monosaccharides to alditol acetates measured by gas chromatography with flame ionization detection (GC-FID). Samples were compared against seven monosaccharide standards (9)
SDFP & IDF pectin quantification	Spectrophotometric method measuring galacturonic acid content using *m*-hydroxydiphenyl as the chromogenic reagent (10)
Mono- and Disaccharide identification and quantification	Spectrophotometric method using enzymatic assay kit Maltose/Sucrose/D-Glucose (Megazyme, Wicklow, Ireland)

SAMPLE PREPARATION



RESULTS

DEFATTED CAMELINA MEAL

Table 1. Percent IDF, SDFP, and SDFS found in DCM samples

	IDF (%)	SDFP (%)	SDFS (%)	Total Dietary Fiber (%)
Cold Press DCM	49.1$^{a\wedge}$	2.00^{b}	1.20^{a}	**52.3^{a}**
Hot Press DCM	45.3^{a}	5.98^{a}	1.11^{a}	**52.4^{a}**

Table 2. Percent glucose, sucrose, and maltose present in DCM as determined by spectrophotometric enzymatic assays

	Glucose (%)	Sucrose (%)	Maltose (%)
Cold Press DCM	0.35$^{a\wedge}$	3.42^{a}	0.00^{a}
Hot Press DCM	0.17^{b}	3.33^{a}	0.00^{a}

Table 3. Total pectin in DCM as percent of DCM

	Total Pectin in DCM (% of DCM)
Cold Press DCM	3.33$^{b\wedge}$
Hot Press DCM	4.22^{a}

INSOLUBLE DIETARY FIBER

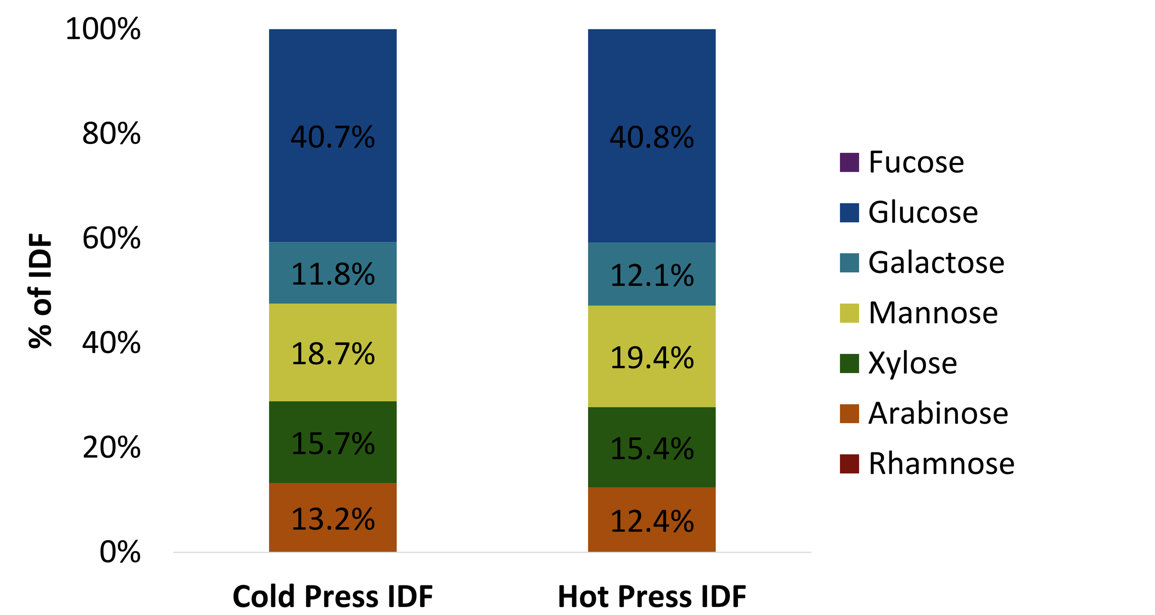


Figure 1. Monosaccharides present in IDF fraction (% monosaccharide of fiber fraction) as determined by alditol acetate derivatization measured by GC-FID

Table 4. Percent pectin present in IDF fractions as percent of DCM

	Pectin by Fiber Fraction (% of DCM)
Cold Press IDF	2.85$^{a\wedge}$
Hot Press IDF	2.61^{a}

Statistical Analysis. ^ Means in each column with different lowercase letters indicate significant differences among the different extracts according to the Tukey-Kramer multiple means comparison test (P ≤ 0.05).

HIGH MOLECULAR WEIGHT SOLUBLE DIETARY FIBER

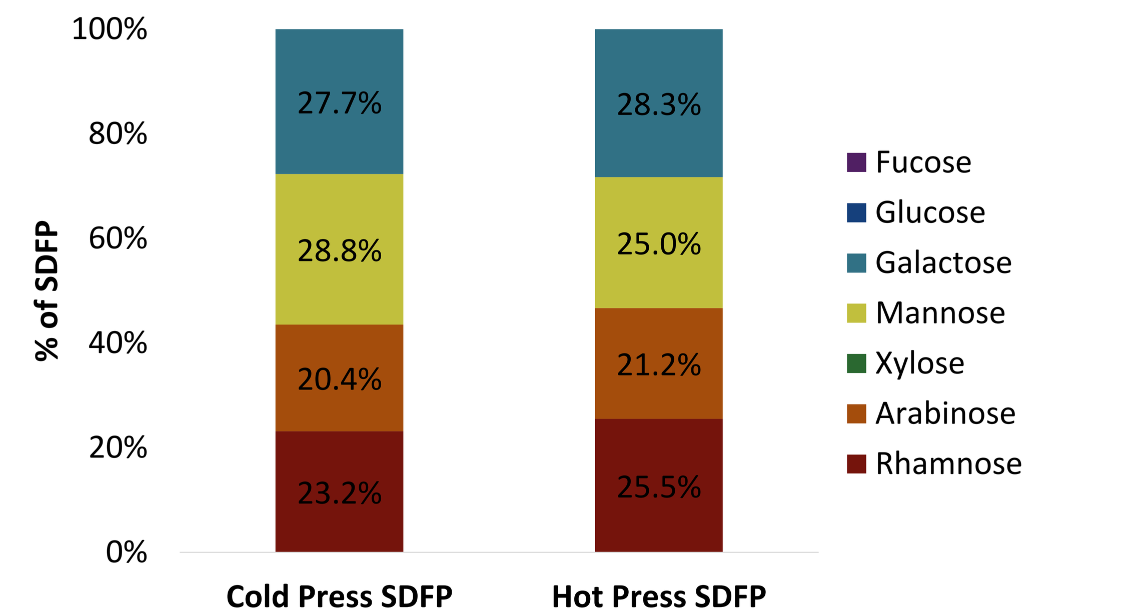


Figure 2. Monosaccharides present in SDFP fraction (% monosaccharide of fiber fraction) as determined by alditol acetate derivatization measured by GC-FID

Table 5. Percent pectin present in SDFP fractions as percent of DCM and degree of methylation of pectin as determined by ^{1}H NMR spectroscopy

	Pectin by Fiber Fraction (% of DCM)	Degree of Methylation (%)
Cold Press SDFP	0.48$^{b\wedge}$	12.5^{b}
Hot Press SDFP	1.61^{a}	14.5^{a}

LOW MOLECULAR WEIGHT SOLUBLE DIETARY FIBER

Table 6. Saccharides in SDFS fractions as percent of DCM

	Glucose (%)	Fructose (%)	Sucrose (%)	Raffinose (%)	Stachyose (%)
Cold Press DCM	1.83$^{a\wedge}$	1.02^{a}	2.02^{a}	0.27^{b}	0.93^{a}
Hot Press DCM	1.45^{b}	0.74^{b}	1.88^{a}	0.38^{a}	0.73^{b}

DISCUSSION

- SDFP was significantly higher in the hot press samples (Table 1). This may be due to the heat treatment applied to the seeds prior to hot pressing (held at 50°C). While too low to inactivate natively present enzymes, the mild heat treatment could have had an activating effect, causing some of the IDF to be cleaved into smaller, more soluble polysaccharides, contributing to a higher SDFP total for hot press DCM.
- Sucrose was the main disaccharide present (Table 2), a finding that has also been reported for *Brassica* crops canola, mustard, and cabbage.
- Hydrocolloids in camelina lend it strong gelling properties, which can partially be attributed to pectin (Table 3). Most of the pectin was found in the IDF fraction (Table 4) rather than the SDFP (Table 5), a trend that has been reported in *Brassica* vegetables. Pectin from camelina was mostly low methoxyl (LM) pectin, indicating that its gelling behavior requires divalent cations. Degree of methylation in the SDFP pectin was confirmed to be <50% (the cutoff for LM pectin classification), which allows it to be a good gelling agent, producing firmer gel networks in the presence of cations.
- The main monomer of IDF was glucose (Fig 1), whereas SDFP had roughly even ratios of galactose, mannose, arabinose, and rhamnose (Fig 2). These percentages are on par with related *Brassica* crops such as broccoli, although camelina contained greater amounts of mannose.
- Fiber types can be inferred based on monosaccharide composition. Possible polysaccharides in IDF and SDFP include:
  - Mannose backbone + galactose branching = *galactomannans*

  Specific to IDF:
  - Xylose backbone + arabinose substitutions = *arabinoxylans*
  - Xylose + glucose + mannose + galactose = *hemicellulose*
  - Glucose backbone = *cellulose*

  Specific to SDFP:
  - Galacturonic acid backbone + rhamnose branching = *pectin*
- SDFS contained raffinose and stachyose (Table 6), which are commonly found in beans and legumes but have yet to be reported in camelina. These are fermentable fibers that are associated positive health benefits.

CONCLUSION

- Camelina contains high amounts of dietary fiber, including appreciable levels of soluble fiber and pectin. These fractions are of particular interest for use as functional ingredients in foods such as fortified cereals, meat analogues, or sauces.
- Glycosidic linkage analysis of camelina dietary fiber is underway to confirm speculated polysaccharide types.
- This is the first comprehensive study on camelina dietary fiber, lending opportunity for further exploration as to how camelina dietary fiber can be incorporated into a food product.

ACKNOWLEDGEMENTS

This project was generously supported through a research grant from General Mills Inc. We would also like to acknowledge Dr. Senay Simsek at North Dakota State University for her help with HPAEC and ^{1}H NMR analyses.

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