Carbohydrates and Dietary Fiber Components of Yellow- and Brown-Seeded Canola

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Meal samples derived from a number of yellow- or partly yellow-seeded varieties/lines of canola were analyzed for carbohydrate and dietary fiber content and shown to contain 8–10% sucrose, 2–3% oligosaccharides, 20–22% nonstarch polysaccharides (NSP), and 5–8% lignin and polyphenols. The sucrose content was positively correlated ($r = 0.66$) with the percentage of yellow seeds in canola samples and was higher by 3–4 percentage points in fully yellow-seeded cultivars as opposed to brown-seeded varieties. Approximately 15 and 40% of the NSP fractions were found to be soluble in water and neutral detergent fiber (NDF) solution, respectively. Due to the high solubility of NSP in the NDF solution and because of a low content of lignin and polyphenols, the NDF values for yellow-seeded canola averaged only 19% as compared to 26% for brown-seeded canola. The total dietary fiber, however, was found to be 27% on average which is only slightly lower than that estimated for brown-seeded canola (30%). On average in comparison to brown-seeded canola, yellow-seeded canola was shown to contain more sucrose and much less lignin and polyphenols. Although the digestibility values were low, the digestibility of NSP from yellow-seeded canola meal was higher than that for brown-seeded canola meal (8.6 vs 3.4%) when measured with laying hens fed semipurified diets. Dry matter and amino acid digestibilities also tended to be higher for yellow-seeded canola meal.

INTRODUCTION

Canola meal contains a relatively high amount of fiber due to the high content (30%) of hull in the meal (Bell and Shires, 1982). As indicated by Pusztai (1989) attempts have been made to improve the nutritional value of the meal by increasing the digestibility of the hull and/or reducing the hull proportion in the meal. Hulls from yellow-seeded rapeseed have been reported to be lower in fiber than those from brown-seeded types (Stringam et al., 1974), and plant selection programs have been directed toward increased yellow seed content to decrease the fiber content and thereby increase the nutritive value of the meal. In this regard, studies were conducted to characterize the carbohydrate components in yellow-seeded canola and through comparison with brown-seeded canola to assess the potential for improvement in nutritive quality by increasing the content of yellow seeds.

EXPERIMENTAL PROCEDURES

Plant Materials. Canola samples representing 14 partly yellow-seeded or fully yellow-seeded lines/varieties and four brown-seeded varieties of canola were provided by Dr. P. McVetty (Department of Plant Science, University of Manitoba, Winnipeg, Canada), Dr. B. Uppstrom (Svalof AB, Svalov, Sweden), and Dr. K. Downey (Agriculture Canada Research Station, Saskatoon, Canada). In preparation for analysis, the samples were crushed and extracted with *n*-hexane for 2 h in a Soxhlet apparatus. Following drying, the samples were ground to pass a 1-mm sieve and re-extracted with hexane for 4 h.

Samples of commercial canola meal originating from brown- or yellow-seeded canola were obtained from local crushing firms. A laboratory-prepared heat-treated sample of commercial meal was obtained by autoclaving the brown-seeded meal sample at 127 °C with a steam pressure of 117 kPa for 15 min.

Determination of Carbohydrate and Dietary Fiber Components of Canola Meal. Galactooligosaccharides, raffinose and stachyose, were extracted from 0.1 g of canola meal with 5 mL of 80% ethanol containing 0.1 mg mL^{-1} of *myo*-inositol (internal standard). The samples were shaken for 5 h at room temperature and centrifuged at 3000 rpm. One milliliter of clear supernatant was then transferred into a 4-mL silylation vial. Following drying under a stream of nitrogen at 30 °C, the samples were derivatized at room temperature by adding 100 μL of pyridine, 50 μL of *N*-methyl-*N*-TMS-trifluoroacetamide, and 15 μL of trimethylchlorosilane (Pierce, Rockford, IL) to each vial; the vials were then capped and the contents mixed well prior to gas chromatographic analysis (Varian Vista 6000). A glass column (1.2 m × 2 mm i.d.), packed with 2% OV-7 on Chromosorb W (HP), was used with helium gas at a flow rate of 40 mL min^{-1}. The oven temperature was programmed from 170 to 320 °C at 6 °C min^{-1}. Injection port and detector temperatures were 280 and 320 °C, respectively. Sucrose was determined similarly to the oligosaccharide procedure utilizing the extraction of 0.1 g of canola meal with 5 mL of 80% ethanol containing 1 mg mL^{-1} of *myo*-inositol (internal standard) for 2 h. Following centrifugation, 0.2 mL of supernatant was transferred into a vial. The samples were then dried and derivatized, and the sucrose was analyzed according to the gas chromatographic procedure for oligosaccharides with the exception that the oven temperature was programmed from 170 to 245 °C at 5 °C min^{-1}. Nonstarch polysaccharides (NSP) were determined by gas–liquid chromatography (component neutral sugars) and by colorimetry (uronic acids) using the procedure described by Englyst and Cummings (1984) with minor modifications (Slominski and Campbell, 1990). In addition, polysaccharides were divided into water-soluble and water-insoluble NSP. Solubility in water was determined by extraction of canola meal samples in Tris-HCl buffer (0.1 M, pH 7.5) at 40 °C for 4 h. The method of Goering and Van Soest (1970) was used to determine neutral detergent fiber (NDF). The NDF procedure was modified to exclude the use of decalin and sodium sulfite (Mascharenhas Ferreira et al., 1983). The contents of NSP, protein (Kjeldahl nitrogen), and ash in NDF residues of canola samples were also measured. The values for lignin plus polyphenols were calculated by difference [NDF − (NSP + protein + ash)]. Neutral-detergent-soluble polysaccharides (NDSP) were calculated as total sample NSP minus NSP present in the NDF residue, and total dietary fiber was determined by summation of NDF and NDSP values. Kjeldahl nitrogen and ash were assayed according to standard procedures (AOAC, 1984).

In addition to the oligosaccharide analyses described above, an attempt was made to assess the presence of any fructosyl or galactosyl derivatives of sucrose with a degree of polymerization greater than that for stachyose (DP > 4). The fully yellow-seeded variety, Parkland, was used for this analysis. Seventy milligrams

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Table 1. Composition (Percent) of Canola Meal Diets

ingredient and analysis	brown-seeded canola	yellow-seeded canola
brown-seeded meal	46.4	
yellow-seeded meal		48.6
cornstarch	37.8	35.1
vegetable oil	5.0	5.5
calcium carbonate	8.0	8.0
calcium phosphate	1.0	1.0
vitamin premix[a]	1.0	1.0
mineral premix[a]	0.5	0.5
chromic oxide	0.3	0.3
calculated analysis		
CP, %	17	17
ME, kcal/kg	2748	2743
Ca, %	3.5	3.5
available P, %	0.4	0.4

[a] Added to meet the nutrient requirements of laying hens as specified by National Research Council (1984).

Table 2. Carbohydrate Content (Percent Dry Matter)[a] of Defatted Meals Derived from Yellow- and Brown-Seeded Lines/Varieties of Canola

component	type of sample: yellow-seeded (n = 14)	type of sample: brown-seeded (n = 4)
sucrose	9.8 ± 0.6[a]	7.7 ± 0.8[b]
oligosaccharides[b]	2.4 ± 0.4	2.5 ± 0.4
soluble NSP[c]	2.0 ± 0.3[a]	1.5 ± 0.1[b]
insoluble NSP[c]	19.4 ± 0.4[a]	16.4 ± 1.2[b]
NSP component sugars[d] (%)		
rhamnose	1.0 ± 0.1	1.1 ± 0.1
fucose	1.2 ± 0.2	1.2 ± 0.1
arabinose	25.7 ± 1.8	25.2 ± 0.9
xylose	9.1 ± 0.3	9.0 ± 0.7
mannose	2.1 ± 0.1	2.2 ± 0.1
galactose	8.6 ± 0.3	9.3 ± 0.5
glucose	28.5 ± 1.2	27.8 ± 2.8
uronic acids	23.8 ± 2.3	24.2 ± 2.9

[a] Mean ± SD; values within a row with no common superscript differ significantly ($P < 0.01$). [b] Includes raffinose and stachyose. [c] NSP, nonstarch polysaccharides; solubility was determined by extraction in Tris-HCl buffer (pH 7.5; 40 °C) for 4 h. [d] Component sugar analyses were similar for soluble and insoluble NSP.

of meal was extracted for 30 min with water at 40 °C with the aid of an ultrasonic cleaner. Following centrifugation, the clear supernatant was filtered using a nylon 0.22-μm syringe filter. Sample volume of 10 μL was injected onto the column through a Rheodyne injection valve. Separation of carbohydrates was performed on a stainless-steel Rezex 4% oligosaccharide (Phenomenex, St. Torrace, CA) column (200 × 10 mm i.d.) after passage through a guard column (60 × 10 mm i.d.) filled with the same material as the main column. Carbohydrates were eluted with degassed deionized water at the flow rate of 0.3 mL min^{-1} at 60 °C. The HPLC equipment (Shimadzu) consisted of and LC600 pump, an RID-6A refractive index detector, a CTO-6A column oven, and a C-R4A Chromatopac integrator. Carbohydrates were identified by comparison of retention times with those of standard compounds.

Dry Matter, Nonstarch Polysaccharide, and Amino Acid Balance Trial with Laying Hens. Ten hens individually housed in cages (25 × 40 cm) were randomly allotted to each of the experimental treatments. Semipurified diets (Table 1) containing commercial brown- and yellow-seeded canola meals and chromic oxide as an internal marker were fed for 1 week, and excreta collection was made on day 7 as described by Slominski et al. (1987). The excreta samples were freeze-dried and ground prior to analysis for chromium, nonstarch polysaccharides (NSP), and amino acids (AA). Chromic oxide analysis was done by atomic absorption spectrometry (Williams et al., 1963). Amino acids were analyzed according to the procedure of Andrews and Baldar (1985) with some modifications (Mills et al., 1989). NSP and AA digestibilities were calculated according to the indicator method

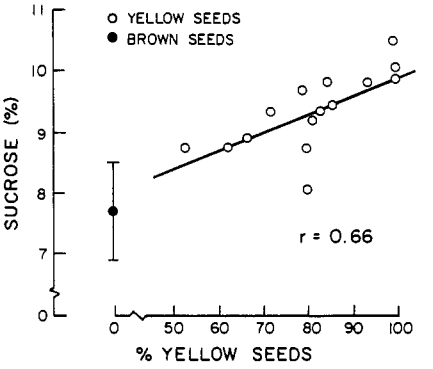

Figure 1. Relationship between the sucrose content of selected lines/varieties of canola and percent yellow seed coat content.

Table 3. Influence of the Commercial Crushing Process and Autoclave Treatment on the Sucrose Content of Canola

sample	sucrose content[a] (% DM)
yellow-seeded canola	
defatted seed, cv. Parkland	10.7 ± 0.1
commercial meal[b]	8.7 ± 0.1
brown-seeded canola	
defatted seed, cv. Westar	7.8 ± 0.1
commercial meal[b]	6.7 ± 0.0
commercial meal, autoclaved[c]	4.0 ± 0.0

[a] Mean ± SD. [b] Origin of the canola for commercial meal samples was Parkland for the yellow-seeded type and unknown but presumed to be Westar for the brown-seeded type. [c] The meal was autoclaved at 127 °C with a steam pressure of 117 kPa for 15 min.

(Crampton and Harris, 1969). Statistical analyses were performed according to the procedure of Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

The content of major carbohydrates including NSP component sugar analysis for yellow- and brown-seeded canola is shown in Table 2. Yellow-seeded canola contained more sucrose than brown-seeded canola, while both types of canola had similar values for oligosaccharides. The concentrations of sucrose and oligosaccharides in brown-seeded canola determined in this study are almost identical with those reported by Theander et al. (1976), Finlayson (1977), and Bach Knudsen and Li (1991). As indicated in Figure 1, the sucrose content of yellow-seeded samples was positively correlated with the percentage of yellow seeds in the samples and was higher by 3–4 percentage points in some fully yellow-seeded lines/varieties as compared to brown-seeded varieties.

Since values obtained for the sucrose content of canola meal tended to be lower than those noted for defatted canola seed samples (Slominski, unpublished results), further work was done to substantiate this finding. The results presented in Table 3 for the sucrose contents of defatted seed and commercial meal are indicative of some destruction of sucrose during canola seed processing. In addition, the fact that mild heat treatment (127 °C for 15 min) resulted in a further reduction of the sucrose content of a sample of brown-seeded commercial canola meal further substantiates this supposition. In this regard, literature data on the sucrose content of canola should be interpreted with consideration of the influence of the commercial processing procedure.

The total amount of NSP tended to be higher for yellow-seeded canola (Table 2), which is in agreement with previous results from this laboratory (Slominski and Campbell, 1990). The higher level of NSP in the yellow-seeded samples was reflected in a proportional increase in component sugar content rather than in qualitative

Table 4. Fiber Content (Percent Dry Matter)[a] of Defatted Meals Derived from Yellow- or Brown-Seeded Lines/Varieties of Canola

type of sample	NDF[b]	NDSP[c]
yellow-seeded (n = 14)	18.8 ± 1.6[b]	8.4 ± 0.8[a]
brown-seeded (n = 4)	25.7 ± 1.0[a]	4.4 ± 0.3[b]

[a] Mean ± SD; values within a column with no common superscript differ significantly ($P < 0.01$). [b] Neutral detergent fiber. [c] Neutral-detergent-soluble polysaccharides.

Table 5. Composition (Percent Dry Matter)[a] of Dietary Fiber in Defatted Meals Derived from Yellow- and Brown-Seeded Lines/Varieties of Canola

cell wall component	brown-seeded (n = 4)	yellow-seeded (n = 14)
nonstarch polysaccharides	17.8 ± 0.2[b]	21.5 ± 0.6[a]
protein	3.5 ± 0.1[a]	2.2 ± 0.3[b]
ash	1.0 ± 0.1[a]	0.4 ± 0.1[b]
lignin and polyphenols	8.0 ± 1.1[a]	3.2 ± 1.0[b]
total dietary fiber	30.2 ± 0.9	27.3 ± 1.6

[a] Mean ± SD; values within a row with no common superscript differ significantly ($P < 0.01$).

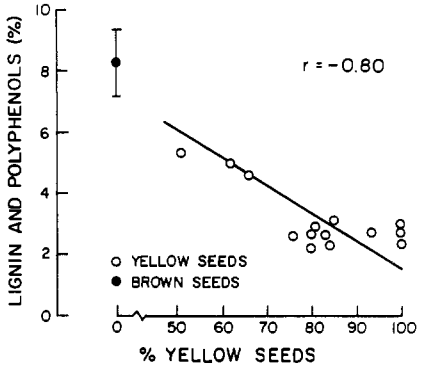

Figure 2. Relationship between the content of lignin and polyphenols in selected lines/varieties of canola and percent yellow seed coat content.

changes in the sugar profile. In this regard, the data presented in the current study do not confirm our earlier suggestion of a higher xylan content in yellow-seeded as compared to brown-seeded canola (Slominski and Campbell, 1990). When characterized according to solubility in water (40 °C, pH 7), both yellow- and brown-seeded canola samples were shown to contain a low content of water-soluble NSP.

Neutral detergent fiber values for yellow-seeded canola were lower than those for brown-seeded canola (Table 4). This is in agreement with reports of a lower fiber value for yellow-seeded rapeseed (Stringam et al., 1975; Bell and Shires, 1982), which was attributed to thin seed coats in yellow-seeded canola (Stringam et al., 1975). However, as pointed out by Theander and Aman (1979), NDF values underestimate cell wall residue due to losses of soluble polysaccharides in the NDF solution. A higher degree of loss of NDSP was evident for yellow-seeded canola as compared with brown-seeded canola in the current study (Table 4). Considering this factor, total dietary fiber for yellow-seeded canola averaged 27.3% (Table 5) and was only slightly lower than that for brown-seeded canola (30.1%). In this regard, total dietary fiber gives a true reflection of the relatively high content of NSP and low content of lignin and associated polyphenols in yellow-seeded canola.

The lignin plus polyphenol content of canola was shown to be directly related to yellow-seed content (Figure 2). This relationship is probably due to changes in polyphenol

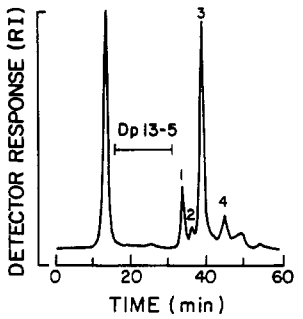

Figure 3. HPLC chromatogram of carbohydrates from yellow-seeded canola cv. Parkland: 1, stachyose; 2, raffinose; 3, sucrose; 4, glucose.

Table 6. Composition (Percent Dry Matter)[a] of Dietary Fiber in Commercial Brown- and Yellow-Seeded Canola Meal Samples Used in the Laying Hen Digestibility Trial

cell wall component	brown-seeded	yellow-seeded
nonstarch polysaccharides	19.6 ± 0.1[b]	23.2 ± 0.2[a]
protein	3.3 ± 0.0	3.5 ± 0.1
ash	0.9 ± 0.1[a]	0.7 ± 0.0[b]
lignin and polyphenols	8.4 ± 0.2[a]	5.5 ± 0.2[b]
total dietary fiber	32.2	32.9

[a] Mean ± SD; values within a row with no common superscript differ significantly ($P < 0.01$).

Table 7. Feed Intake[a] and Percent Dry Matter (DM), Nonstarch Polysaccharide (NSP), and Amino Acid (AA) Digestibilities[a] in Laying Hens Fed Brown- and Yellow-Seeded Canola Meal

type of meal	feed intake (g/day)	digestibility DM	digestibility NSP	digestibility AA
brown-seeded	108.7 ± 6.2	63.5 ± 3.1	3.4 ± 2.5[b]	81.2 ± 0.3
yellow-seeded	109.8 ± 7.5	64.5 ± 2.0	8.6 ± 4.3[a]	82.4 ± 0.6

[a] Mean ± SD; values within a column with different superscripts differ significantly ($P < 0.05$).

content as Theander et al. (1977) reported that the lignin contents of yellow- and brown-seeded rapeseed were similar and that polyphenols rather than lignin were predominant in brown-seeded canola.

Separation of the soluble carbohydrates fraction from yellow-seeded canola on a Rezex HPLC column (Figure 3) indicates that only trace amounts, if any, of the oligosaccharides with a degree of polymerization from 5 to 13 were present in the meal. It can be suggested from these data that galactooligosaccharides or fructosans of intermediate molecular weight make an insignificant contribution to the overall profile of canola carbohydrates.

The composition of the dietary fiber present in samples of commercial canola meal that were used in the laying hen digestibility trial is shown in Table 6. Although the values for both nonstarch polysaccharides and lignin plus polyphenols were higher than those determined for the samples of defatted canola seed, the relative differences between yellow- and brown-seeded samples were similar. The data for the commercial meal samples may reflect the presence of foreign materials since the defatted seed samples were known to be relatively clean seed samples obtained from plant breeders.

The digestibility of NSP was significantly higher in yellow-seeded canola meal in comparison with brown-seeded meal (Table 7). This difference in digestibility may be explained by a lower cell wall lignification in yellow-seeded canola. The digestibility values, however, were low and probably reflect the relatively low water solubility of NSP in canola. Similar low NSP digestibility values

for canola meal have been reported previously (Slominski and Campbell, 1990). Both dry matter and amino acid digestibilities also tended to be higher in yellow-seeded canola meal. Further research is needed to determine the influence that the total dietary fiber in canola meal has on overall nutrient digestibility and on the nutritive worth of the meal.

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