Comparison of Oat and Wheat Carbohydrates. I. Sugars[1]

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ABSTRACT

Sugars in three oat cultivars of different protein levels were investigated and compared with those in a hard red spring wheat cultivar. All samples were milled into flour and bran on a Brabender Quadrumat Jr. flour mill. Percentages of total sugars and individual free sugars were determined in each mill stream. Of the oat flours, the high protein oat cultivar (Dal) contained the greatest amount of total sugars. All three oat cultivars contained less total sugar in the bran than did the wheat bran. Seven individual free sugars, when present, were quantitatively measured. Sucrose was the predominant sugar in all samples, followed by raffinose. Stachyose occurred in the oat flours and brans in relatively high amounts, whereas only a trace was detected in the wheat bran. Small amounts of verbascose were tentatively identified in the oat brans. For all samples, small differences were noted in the amounts of maltose, fructose, and glucose.

Cereal Chem. 56(5):455-457

Although much work has been reported on the free sugars and oligosaccharides in whole wheat and wheat mill fractions (Abou-Guendia and D'Appolonia 1972, Cerning and Guilbot 1973, Koch et al 1951, MacArthur and D'Appolonia 1976, Saunders and Walker 1969, Williams and Bevenue 1951), little information is available on free sugars in oats. Of the investigations on oat sugars, the majority concern changes that occur during maturation of the grain and are not directly concerned with the endosperm, bran, or any particular milled fraction of mature oats. Colin and Belval (1933) investigated five common cereal grains (wheat, barley, rye, oats, and maize) for raffinose and fructosan content. They established a tentative association between raffinose and fructosans in the germ. Both raffinose and fructosans had almost completely disappeared from the embryo by the time the grain reached maturity. Schlubach (1953) reported the presence of fructosans in unripe oat grain but not the duration of fructosans in the developing oat groat or the possible differences among cultivars. Other studies (Peterson and Smith 1976, Singh et al 1973) concerned with changes in chemical composition conclude that the stage of maturity of the oat plant has a profound effect on the nitrogen and carbohydrate fractions. Because of the lack of information on the sugars in oat flour and bran, our objective was to examine the individual free sugars and total sugar content of three cultivars of oats and to compare the results with values obtained for a hard red spring (HRS) wheat flour and bran. Such information would be of benefit for possible new food uses of particular milled fractions of oats.

MATERIALS AND METHODS

Samples

Three cultivars of oats and one HRS wheat cultivar were used for this study. Groats from the oat cultivars Dal, Froker, and Cayuse contained high, intermediate, and low protein levels (21.1, 19.9, and 16.5% at 14% m.b.), respectively, and were grown at Minot, ND, during the 1975–1976 crop year. Waldron, the HRS wheat cultivar, was a field plot sample also grown in North Dakota during the same crop year.

Milling

The dehulled oats (groats) were milled into flour and bran with a Brabender Quadrumat Jr. (Quad) flour mill. The bran was sifted on a 60 mesh sieve for a fixed time interval (6 min) and the throughs were added to the flour.

The HRS wheat sample was also milled on the Quad mill. From the milled-wheat sample, three fractions were obtained, a flour, a bran, and a low grade flour. For additional comparison, a sample of straight grade flour from the same variety (Waldron) was obtained from a pilot Miag mill (Shuey and Gilles 1968).

Analytical Measurements

Moisture, ash, and protein contents were determined by AACC standard methods (1961, 1967).

Sugar Measurements

Total sugar content was measured by the phenol sulfuric acid colorimetric method described by Dubois et al (1956) on an extract obtained using the ternary solvent system described by Ponte et al (1969) with minor modifications. The sample (1 g) was extracted twice instead of once as described, and the combined supernatant was dried on a rotary evaporator. The sample was dissolved in a known volume of distilled water and an aliquot taken for sugar content (Dubois et al 1956).

Seven individual free sugars, when present, were measured in an extract obtained as described for total sugar measurement using a Technicon Sugar Auto Analyzer as described by Abou-Guendia and D'Appolonia (1972). The reagents and elution gradient for Method I as given by Hough et al (1972) was used. The amount of each free sugar was calculated from the peak area, using the triangulation method and a standard curve prepared for each sugar.

TABLE I
Ash and Protein Content of Oat and Wheat Fractions[a]

Sample Source	Ash (%)	Protein[b] (%)
Oat Flour		
Dal	0.91	16.6
Froker	0.68	14.6
Cayuse	0.64	12.6
Wheat Flour		
Waldron[c]	0.64	13.6
Waldron lowgrade[c]	0.83	12.5
Waldron[d]	0.38	13.8
Oat Bran		
Dal	2.42	22.5
Froker	3.20	24.0
Cayuse	2.62	18.6
Wheat Bran		
Waldron[c]	4.44	14.1

[a]Results expressed on a 14.0% m.b.
[b]6.25 × N and 5.7 × N were used as factors for conversion from nitrogen to protein for oats and wheat, respectively.
[c]Sample obtained from Brabender Quadrumat Jr. mill.
[d]Sample obtained from Miag Pilot mill.

[1]Presented in part at the Sixth International Cereal and Bread Congress, Winnipeg, Canada, September 1978. Published with the approval of the director of the Agricultural Experiment Station, North Dakota State University, Fargo, as Journal Series 985.
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0009-0352/79/000073$3.00/0
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RESULTS AND DISCUSSION

Milling

The oat bran milled on the Quad mill was sieved because a large amount of endosperm remained in it. The combined flour yield for the three oat cultivars Dal, Froker, and Cayuse was 36.3, 50.9, and 45.2%, respectively. The yield of the wheat flour fraction was 62.0%. Low yields for oat flour milled on an experimental mill were reported previously (Youngs 1973). Amounts of bran are higher in oat groats than in wheat, and the percent of bran in the groat generally increases as the groat protein increases; conversely, the percent of endosperm decreases (Youngs 1973).

Analytical Measurements

The data in Table I show the ash and protein contents of the flour and bran samples. Ash content of the oat flours and brans ranged from 0.64 to 0.91% and from 2.43 to 3.20%, respectively. The ash values obtained for the HRS wheat samples could be directly associated with the type of milling process used. The wheat sample milled on the Quad mill showed a flour ash value similar to that of the oat flours. The wheat flour sample obtained from the Miag mill had an ash content of 0.38%, which agrees with reported values for wheat flour (0.36–0.39%) (Pomeranz 1971). Ash content was lower in the oat brans than in the HRS wheat sample. The lower ash values may be due in part to a greater amount of endosperm material adhering to the oat bran, whereas the wheat bran was relatively free of endosperm. In addition, the nature of the oat bran itself may have accounted for the lower values.

Protein concentration of all flour samples ranged from 12.5 to 17.2%. The intermediate and high protein oat flours contained higher amounts of protein than the HRS wheat flour. All three oat brans were appreciably higher in protein concentration than the wheat bran. Youngs and Gilchrist (1976) showed that the bran and endosperm protein concentrations in oats increase as the total groat protein increases, but the increase in bran protein is greater than the increase in endosperm protein.

TABLE II
Percent Total Sugar in Oat and Wheat Flours and Brans

Sample Source	Total Sugar[a] (%)
Oat Flour	
Dal	1.3
Froker	0.9
Cayuse	0.9
Wheat Bran	
Waldron[b]	2.2
Waldron lowgrade[b]	2.8
Waldron[c]	1.3
Oat Bran	
Dal	2.6
Froker	3.4
Cayuse	2.6
Wheat Bran	
Waldron[b]	4.9

[a]Results are an average of two or more determinations expressed on a dry basis.
[b]Sample obtained from a Brabender Quadrumat Jr. mill.
[c]Sample obtained from Miag Pilot mill.

Total Sugars

Sugar contents of the oat and wheat flours and brans are shown in Table II. Of the three oat flours, Dal had the highest value (1.3%). This cultivar also had the highest protein content and the lowest flour yield. Froker and Cayuse flour had slightly lower values (0.9%). These values are similar to total sugar values previously reported for oat flour (Matz 1969). The Quad-milled HRS wheat flour sample and the low grade flour sample had higher sugar values than the Miag-milled wheat flour sample, which was probably a result of greater contamination with bran particles. Wheat bran has been reported to contain considerably higher sugar amounts than the endosperm (Saunders and Walker 1969).

Of the three oat brans, Froker contained the highest amount of total sugar, while Dal and Cayuse showed similar values (2.2 and 2.3%, respectively). The lower sugar values for the oat brans than for the wheat bran could be due partially, but not entirely, to the presence of greater amounts of adhering endosperm material. Also, oats contain very small amounts of glucofructans compared with the significant amounts in wheat, particularly in its bran (MacLeod and Preece 1954).

Free Sugars

Data on individual free sugar in the oat and wheat flours and brans are shown in Table III. Seven individual free sugars, when present, were quantitatively measured. The glucofructans were not investigated because no appreciable amount was detected in the oat flours or brans. This is evident if the sum of the individual sugars (Table III) and the total sugar content (Table II) are compared. For the wheat flour and bran, the sum of the individual sugars does not equal the the total sugar content, due to the large amounts of

TABLE III
Analysis of Seven Individual Free Sugars in Oat and Wheat Flours and Brans[a]

Sample Source	Sucrose (%)	Raffinose (%)	Maltose (%)	Stachyose (%)	Verbascose (%)	Fructose (%)	Glucose (%)
Oat Flour							
Dal	0.63	0.26	0.03	0.07	...	0.03	0.07
Froker	0.45	0.16	0.01	0.08	...	0.05	0.06
Cayuse	0.40	0.20	0.02	0.08	...	0.02	0.06
Wheat Flour							
Waldron[b]	0.47	0.31	0.08	...	...	0.03	0.04
Waldron lowgrade[b]	0.60	0.43	0.09	...	...	0.03	0.06
Waldron[c]	0.16	0.05	0.07	...	...	0.02	0.05
Oat Bran							
Dal	2.28	0.48	0.05	0.20	0.03	0.04	0.10
Froker	2.66	0.30	0.01	0.24	0.03	0.07	0.08
Cayuse	1.70	0.29	0.02	0.20	0.05	0.03	0.07
Wheat Bran							
Waldron[b]	1.75	1.30	0.03	0.04	...	0.05	0.09

[a]Results are an average of two determinations expressed on a dry basis.
[b]Sample obtained from Brabender Quadrumat Jr. mill.
[c]Sample obtained from Miag Pilot mill.

glucofructans.

Sucrose was the predominant sugar in all samples. Amounts of sucrose were higher in the oat flours than in the HRS wheat flour, with the exception of the low grade flour. Of the oat flours, Dal contained the highest amount (0.63%) followed by Froker and Cayuse with 0.45 and 0.40%, respectively. The Miag-milled wheat flour contained the least sucrose, which agrees with reported studies (MacArthur and D'Appolonia 1976), whereas the Quad-milled wheat flour samples contained higher amounts, possibly due to greater bran contamination. Of the three oat brans, Froker contained the highest amount of sucrose, followed by Dal and Cayuse. The wheat bran contained less sucrose than Froker and Dal but slightly more than Cayuse. Raffinose was the second predominant sugar, with the wheat bran exhibiting the highest value (1.30%). The low concentrations of raffinose in the oat brans compared with wheat bran are noteworthy. The least raffinose was found in the Miag-milled wheat flour.

Of the remaining sugars in oats, stachyose was of particular interest. Stachyose has been found in most grass seeds that contain raffinose. Its detection is, in most cases, facilitated by the absence of fructosans (French 1954). The fructosan content of mature oats is very low. The amount of fructosan is a function of the degree of ripeness; none would be found in a fully ripe sample. Only trace amounts of stachyose were found in the low grade flour and bran of the HRS wheat sample. Stachyose has been reported previously in wheat bran (Saunders and Walker 1969).

Verbascose, a pentasaccharide, has been reported in wild oats (*Avena fatua*) along with raffinose and stachyose (French 1954). Its presence has also been reported in legumes. Naivikul and D'Appolonia (1978) tentatively identified this sugar by collecting the unknown peak as it was eluted from an ion-exchange column, hydrolyzing it, and measuring the ratio of component sugars. The 1:1:3 ratio of fructose, glucose, and galactose suggested that the sugar was verbascose. A similar ratio was also reported by Kawamura (1963). The work of Naivikul and D'Appolonia (1978) suggests that trace amounts of verbascose occur in the oat brans. Since no standard for verbascose was available, the amount was determined by using stachyose as a standard curve.

Maltose was found in very small amounts in the oat flours and brans, with Dal containing the highest amount. Maltose amounts were slightly higher in the HRS wheat flour samples, which is in agreement with previous studies (MacArthur and D'Appolonia 1976).

Fructose and glucose values were similar in all flour and bran samples examined, with the values for glucose being slightly higher than fructose.

LITERATURE CITED

ABOU-GUENDIA, M., and D'APPOLONIA, B. L. 1972. Changes in carbohydrate components during wheat maturation. I. Changes in free sugars. Cereal Chem. 49:664.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved Methods of the AACC (7th ed.). Method 44-15A, approved April 1967; Methods 08-01 and 46-10, approved April 1961. The Association: St. Paul, MN.

CERNING, J., and GUILBOT, A. 1973. Changes in the carbohydrate composition during development and maturation of the wheat and barley kernel. Cereal Chem. 50:220.

COLIN, H., and BELVAL, H. 1933. La raffinose dans les cereales. Compt. Rend. 196:1825.

DUBOIS, M., GILLES, K. A., HAMILTON, J. D., REBERS, P.A., and SMITH, F. 1956. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28:350.

FRENCH, D. 1954. The raffinose family of oligosaccharides. Adv. Carbohydr. Chem. 9:149.

HOUGH, L., JONES, J. V. S., and WUSTEMAN, P. 1972. On the automated analysis of neutral monosaccharides in glycoproteins and polysaccharides. Carbohydr. Res. 21:9.

KAWAMURA, S. 1963. The oligosaccharides of some Japanese legumes. II. Higher oligosaccharides in mung beans. Kagawa Daigaku Nogakubu Gakuzyutu Hokoku 15:29.

KOCH, R. B., GEDDES, W. F., and SMITH, F. 1951. The carbohydrates of the gramineae. I. The sugars of the flour of wheat (Triticum vulgare). Cereal Chem. 28:424.

MacARTHUR, L. A., and D'APPOLONIA, B. L. 1976. The carbohydrates of various pin-milled and airclassified flour streams. I. Sugar analyses. Cereal Chem. 53:916.

MacLEOD, A. M., and PREECE, I. A. 1954. Studies on the free sugars of the barley grain. V. Comparison of sugars and fructosans with those of other cereals. J. Inst. Brew. 60:46.

MATZ, S. A. 1969. Cereal Science. Avi Publishing Company, Inc.: Westport, CT.

NAIVIKUL, O., and D'APPOLONIA, B. L. 1978. Carbohydrates of legume and wheat flour carbohydrates. I. Sugar Analysis. Cereal Chem. 55:913.

PETERSON, D. M., and SMITH, D. 1976. Changes in nitrogen and carbohydrate fractions in developing oat groats. Crop Sci. 16:67.

POMERANZ, Y. (ed.) 1971. Wheat Chemistry and Technology (2nd ed.) Am. Assoc. Cereal Chem.: St. Paul, MN.

PONTE, J. G., DeSTEFANIS, V. A., and TITCOMB, S. T. 1969. Application of thin-layer chromatography to sugar analysis in cereal based products. Abstr. 54th Meeting AACC, Chicago, IL.

SAUNDERS, R. M., and WALKER, H. G., Jr. 1969. The sugars of wheat bran. Cereal Chem. 47:85.

SCHLUBACH, H. H. 1953. Über den kohlenhydratstaffwechsel der getreidearten. Experientia 9:230.

SHUEY, W. C., and GILLES, K. A. 1968. Evaluating wheat quality on a laboratory scale commercial mill. Northwestern Miller. 275:8.

SINGH, R., AHUJA, A. K., and PRADHAM, K. 1973. Effect of stage of maturity on the chemical composition of oats. Hau J. Res. Hissar 3:35.

WILLIAMS, K. T., and BEVENUE, A. 1951. The chromatographic examination of sugars in wheat flour. Cereal Chem. 28:416.

YOUNGS, V. L. 1973. Protein distribution in the oat kernel. Cereal Chem. 49:407.

YOUNGS, V. L., and GILCHRIST, K. D. 1976. Note on protein distribution within oat kernels of single cultivars that differ in protein concentration. Cereal Chem. 53:947.

[Received April 17, 1978. Accepted January 24, 1979]