THE CARBOHYDRATES OF VARIOUS PIN-MILLED AND AIR-CLASSIFIED FLOUR STREAMS. I. SUGAR ANALYSES[1]

L. A. MacARTHUR[2] and B. L. D'APPOLONIA[2]

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ABSTRACT

Ten flour streams from each of four varieties of hard red spring wheat obtained from a pilot mill were pin-milled and air-classified into high, low, and intermediate protein-containing fractions. Total sugar, reducing sugars, nonreducing sugars, and five individual free sugars were determined. The high protein-containing fraction for all flour streams of the four varieties contained the highest amount of total sugar, likewise reducing and nonreducing sugars. This fraction also contained the highest amounts of separately determined sucrose, raffinose, and often maltose. The amount of total sugars present in the low and intermediate protein-containing fractions, in general, was similar to that present in the original flour. More total sugar was found in the break flour streams than in the middling flour streams. Differences were noted in the various pin-milled and air-classified flour streams as well as between the different varieties in total sugar content, reducing and nonreducing sugars, and individual free sugars.

In early studies, Bailey (1) qualitatively identified the major carbohydrate components in wheat. Since then, several research groups have investigated the sugar composition in wheat flour. Montgomery and Smith (2) positively identified glucose, fructose, sucrose, and maltose by formation of crystalline compounds. Koch *et al.* (3) extracted and identified six different sugars present in a southwestern baker's patent wheat flour. Williams and Bevenue (4) examined wheat-flour carbohydrates of four different flours and found the same sugars to be present in each of them. Cerning and Guilbot (5) investigated the changes in carbohydrate composition of wheat and barley kernels during development and maturation. In both wheat and barley, glucose, fructose, sucrose, glucodifructose or possibly neokestose, and small traces of maltose were revealed by paper chromatography. Likewise, Abou-Guendia and D'Appolonia (6) investigated the changes in free sugars during wheat maturation by ion-exchange chromatography. These workers found that the changes in fructose, glucose, sucrose, and raffinose parallel the changes in total reducing and nonreducing sugars which were found to decrease as the wheat matured.

Studies on the carbohydrates present in pin-milled and air-classified flour fractions are practically nil, although Audidier *et al.* (7) reported that the soluble sugar content was highest in the protein-rich, fine fraction separated by air classification, while the amount in the residual coarse fraction was comparable to the original flour.

Although information is available in the literature on the protein shift that occurs with pin-milling and air classification, little is known concerning what happens to the carbohydrate components. The initial phase of this research study was to investigate total sugar, reducing sugars, nonreducing sugars, and five

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[2]Respectively: Research Chemist and Associate Professor, Department of Cereal Chemistry and Technology.

individual free sugars in the unfractionated flour and the pin-milled and air-classified flour fractions obtained from different millstreams of four different wheat varieties.

The purpose was to ascertain if there was a difference in the sugar present in the different flour fractions obtained as a result of pin-milling and air classification, and if flour millstream or wheat variety had an effect on the sugar analyses.

MATERIALS AND METHODS

Flour Samples

Flour samples used in this investigation were obtained from four hard red spring (HRS) wheat varieties: Waldron, a conventional-height wheat; and Red River 68, Fletcher, and Pitic 62, all semidwarf wheats; however, the last-mentioned is a softer feed-type wheat.

All varieties were grown under experimental conditions at Casselton, N. Dak., during the 1971 crop year. The wheat was milled into flour on a pilot mill with ten streams collected from each variety. These included four middling flour streams (1M, 2M, 3M, 4M), four break flour streams (1B, 2B, 4B, 5B), the tailings (T), and the break dust flour stream (BD). Each stream was pin-milled and air-classified into three fractions designated as: F-1 (first-cut fine fraction), a high-protein fraction; F-2 (second-cut fine fraction), a low-protein fraction; and C-2 (second-cut coarse fraction), the intermediate-protein fraction (8).

Analytical Data

Protein, moisture, and ash content of the unfractionated flour and pin-milled and air-classified flour streams were determined according to standard procedures (9).

Average particle size of the pin-milled flour and the three fractions produced by air classification was determined on a Fisher Sub-Sieve Sizer (Fisher Scientific Instruments, Chicago, Ill.) according to the Instrument Manual (10).

Sugar Measurements

A. Free Sugars. Five individual free sugars extracted with the ternary solvent system described by Ponte *et al.* (11) were measured using a Technicon Sugar Auto Analyzer as described by Abou-Guendia and D'Appolonia (6), and the reagents and elution gradient for Method I as given by Hough *et al.* (12).

B. Reducing and Nonreducing Sugars. Reducing and nonreducing sugar analysis on the flour samples was performed according to AACC standard procedures (9).

C. Total Sugars. Total sugar content was measured by the phenol-sulfuric acid colorimetric method described by Dubois *et al.* (13) on an extract obtained using the ternary solvent system described by Ponte *et al.* (11).

RESULTS AND DISCUSSION

Analytical Data

Analytical data for selected unfractionated flour streams and the three fractions obtained from pin-milling and air classification for two varieties, Waldron and Pitic 62, are shown in Table I. Similar information was obtained

TABLE I
Proximate Analysis of Unfractionated, Pin-Milled, and Air-Classified Flour Fractions

Flour Stream	Flour Fraction	Hard Red Spring Wheat Variety Waldron				Hard Red Spring Wheat Variety Pitic 62			
		Moisture %	Ash[a] %	Protein[a] %	Yield %	Moisture %	Ash[a] %	Protein[a] %	Yield %
2M	Unfractionated	14.0	0.33	14.3	...	13.0	0.29	8.6	...
	F-1	10.0	0.56	18.7	11.7	10.5	0.43	20.9	25.2
	C-2	12.3	0.28	15.4	56.2	11.6	0.30	4.6	46.7
	F-2	11.2	0.31	10.9	32.1	11.0	0.26	4.7	28.1
4M	Unfractionated	15.0	0.33	13.9	...	12.8	0.36	8.4	...
	F-1	10.3	0.56	18.8	11.7	10.2	0.50	20.4	24.8
	C-2	12.4	0.27	14.8	52.7	11.4	0.31	5.9	47.1
	F-2	11.3	0.32	10.6	35.6	10.7	0.31	4.8	28.2
2B	Unfractionated	14.8	0.50	16.5	...	13.4	0.31	6.3	...
	F-1	11.0	1.06	20.8	11.7	11.8	0.42	20.7	21.2
	C-2	12.9	0.36	18.1	56.7	12.9	0.27	2.5	62.0
	F-2	11.9	0.49	11.9	31.6	12.4	0.25	4.1	16.8
5B	Unfractionated	13.9	0.88	24.8	...	12.6	0.56	11.3	...
	F-1	11.1	1.81	26.1	12.3	10.4	0.65	22.8	21.8
	C-2	11.8	0.55	26.5	62.7	11.5	0.46	6.1	50.4
	F-2	11.1	0.84	16.6	25.0	11.0	0.38	7.1	27.9

[a]Results expressed on a 14% moisture basis.

for the other flour streams and varieties. Note that the moisture content is lowest in the F-1 fractions. Such a result would be expected because of greater moisture loss from the larger number of particles and surface area involved.

Highest ash and protein contents were localized in the F-1 fraction. However, the pattern for these two constituents of the three fractions was somewhat different. In most cases, ash content increased from C-2 to F-2 to F-1 for the different flour streams, whereas protein content increased from F-2 to C-2 to F-1 except in the variety Pitic 62. With this variety, the separation of flour into high- and low-protein fractions was achieved more readily and therefore gave a wider

TABLE II
Particle-Size Analysis of Pin-Milled and Air-Classified Flour Fractions

Flour Stream	Flour Fraction	Waldron	Red River 68	Pitic 62	Fletcher
		μ	μ	μ	μ
1M	F-1	4.0	3.7	3.1	3.5
	C-2	31.0	28.2	11.2	26.2
	F-2	12.0	12.6	6.8	11.2
2M	F-1	4.2	3.8	3.1	4.1
	C-2	32.2	31.0	11.2	29.0
	F-2	12.6	11.6	7.4	11.3
3M	F-1	3.5	4.2	3.0	3.5
	C-2	30.0	28.8	9.7	27.8
	F-2	11.2	11.8	4.3	10.6
4M	F-1	4.0	3.6	2.9	3.7
	C-2	30.0	26.4	9.8	24.2
	F-2	11.2	11.1	4.1	10.4
1B	F-1	4.4	4.0	2.9	3.2
	C-2	32.8	26.0	10.2	25.8
	F-2	11.1	10.3	6.0	9.4
2B	F-1	3.7	3.6	2.6	3.6
	C-2	28.4	24.4	10.2	23.2
	F-2	11.7	11.6	6.1	9.8
4B	F-1	4.6	3.4	3.1	3.5
	C-2	30.2	25.8	10.2	27.8
	F-2	12.4	11.0	6.3	10.1
5B	F-1	3.9	3.5	3.2	3.1
	C-2	26.0	23.0	9.4	24.6
	F-2	9.5	9.2	6.0	8.9
T	F-1	3.5	3.3	3.7	3.6
	C-2	25.0	22.8	8.5	20.6
	F-2	10.5	9.1	5.6	8.8
BD	F-1	3.5	3.9	3.3	3.9
	C-2	34.2	31.0	9.8	31.4
	F-2	12.2	11.5	6.7	10.4

range in protein content than the hard wheat flours. Fraction C-2 was obtained in the highest yield for all four varieties, and F-2 was the next highest yielding fraction. The F-1 fraction of the hard wheat varieties was produced in lowest yield whereas, for the softer wheat, Pitic 62, it was considerably higher. The yields for the C-2 and F-2 fractions of Pitic 62, in general, were lower than those of the other three varieties because of more efficient grinding when pin-milled. This results in better separation during the air-classification process.

Particle-size analysis of the three pin-milled and air-classified fractions obtained from the four varieties is shown in Table II. The average particle size ranged from 3 to 5 μ for the first fines (F-1), from 9 to 13 μ for the second fines (F-2), and from 21 to 34 μ for the coarse fraction (C-2), with the exception of Pitic 62. This variety showed lower particle-size values for all fractions, particularly fraction C-2.

Sugar Measurements

A. Free Sugars Analysis. The individual free sugar analyses of the unfractionated flour and the three pin-milled and air-classified fractions for four of the ten flour streams obtained from Waldron, Red River 68, and Pitic 62 are shown in Table III. The variety Fletcher, although used for certain determinations, was not included in the free sugar analysis.

Five individual free sugars were quantitatively measured. The glucofructans, including glucodifructose, were not investigated. Sucrose was the predominant sugar in all flour streams and fractions, followed by raffinose, maltose, glucose, and fructose. For Waldron and Red River 68, sucrose and raffinose contents were highest in the F-1 fraction, which showed the highest protein and ash contents and the lowest average particle size (Tables I and II). This distribution of sugars was poorly defined in the variety Pitic 62.

The unfractionated flour generally had a higher sucrose value than either the C-2 or the F-2 fraction. Sucrose is concentrated in the F-1 fraction, leaving the C-2 and F-2 fractions with lesser amounts than the original, unfractionated flour. The raffinose data for the varieties Waldron and Red River 68 also indicate higher concentrations in the F-1 fraction.

Differences in individual sugars were noted among the three varieties and also among the ten flour streams within each variety. Waldron, in general, showed higher amounts of sucrose for a particular flour stream and fraction than the corresponding stream and fraction of the other two varieties, except for the tailings stream for Pitic 62, which had a very high sucrose content. Red River 68, in general, showed lower amounts of sucrose for the middling flour streams and fractions, but higher values for the break flour streams when compared to the corresponding flour streams and fractions obtained from Pitic 62.

In most cases, there did not appear to be any major difference in the amounts of maltose, fructose, and glucose between the different flour streams and fractions of the different varieties. Maltose content showed somewhat higher values for the majority of the F-1 fractions of the various streams obtained from Red River 68 and Pitic 62. However, this was not as evident with the variety Waldron. Consistently low fructose values were obtained for all streams and fractions of the varieties investigated. The low values obtained for fructose are in agreement with previously reported values (6) for this sugar in wheat flour. The results would indicate that, with fructose, no shift took place during pin-milling and air

TABLE III
Analysis of Five Individual Free Sugars in Unfractionated, Pin-Milled, and Air-Classified Flour Fractions[a]

Flour Stream	Flour Fraction	Sucrose			Raffinose			Maltose			Fructose			Glucose		
		A[b] %	B[c] %	C[d] %	A[b] %	B[c] %	C[d] %	A[b] %	B[c] %	C[d] %	A[b] %	B[c] %	C[d] %	A[b] %	B[c] %	C[d] %
2M	Unfractionated	0.19	0.14	0.16	0.06	0.03	0.06	0.06	0.03	0.03	0.02	0.02	0.01	0.05	0.07	0.05
	F-1	0.25	0.22	0.18	0.10	0.10	0.08	0.05	0.08	0.05	0.02	0.02	0.02	0.04	0.06	0.04
	C-2	0.13	0.09	0.14	0.03	0.02	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.04	0.05	0.04
	F-2	0.16	0.12	0.13	0.05	0.03	0.04	0.06	0.04	0.03	0.04	0.02	0.01	0.05	0.04	0.03
4M	Unfractionated	0.19	0.12	0.18	0.06	0.03	0.09	0.06	0.05	0.06	0.03	0.02	0.02	0.10	0.06	0.04
	F-1	0.27	0.17	0.20	0.16	0.08	0.07	0.05	0.09	0.04	0.03	0.02	0.02	0.05	0.05	0.04
	C-2	0.14	0.10	0.16	0.03	0.02	0.07	0.05	0.05	0.04	0.03	0.02	0.02	0.04	0.04	0.04
	F-2	0.15	0.13	0.15	0.04	0.03	0.08	0.06	0.04	0.04	0.03	0.02	0.01	0.03	0.04	0.03
2B	Unfractionated	0.17	0.12	0.10	0.06	0.04	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.04	0.03	0.03
	F-1	0.28	0.26	0.15	0.13	0.12	0.04	0.06	0.08	0.05	0.02	0.02	0.02	0.05	0.05	0.04
	C-2	0.14	0.12	0.11	0.05	0.04	0.02	0.05	0.04	0.03	0.02	0.02	0.02	0.04	0.05	0.05
	F-2	0.17	0.14	0.12	0.05	0.05	0.03	0.06	0.03	0.03	0.03	0.02	0.02	0.05	0.05	0.05
5B	Unfractionated	0.34	0.28	0.30	0.17	0.14	0.14	0.02	0.01	0.03	0.03	0.01	0.02	0.08	0.04	0.04
	F-1	0.45	0.56	0.31	0.27	0.26	0.16	0.06	0.06	0.04	0.02	0.02	0.01	0.05	0.05	0.04
	C-2	0.27	0.23	0.28	0.11	0.12	0.13	0.03	0.05	0.03	0.02	0.01	0.01	0.04	0.05	0.03
	F-2	0.34	0.35	0.19	0.18	0.18	0.08	0.04	0.03	0.03	0.02	0.01	trace	0.04	0.04	0.02

[a]Results expressed on a dry basis.
[b,c,d]Data obtained for the varieties Waldron, Red River 68, and Pitic 62, respectively.

classification. Glucose likewise exhibited no apparent shift.

Of the various streams analyzed, Waldron and Red River 68 showed higher sucrose and raffinose levels in the break flour streams than in the middling flour streams. This result was not noted for Pitic 62, which showed similar values for these two sugars in both the middling and break flour streams except for the higher values of 5B. The tailings of Pitic 62 (data not shown) contained considerably higher sucrose and raffinose amounts than were found in the tailings of Waldron or Red River 68. The higher amounts of sugar present in the break streams of the hard wheats indicates the presence of more bran particles. Also, the high sugar level present in the tailings flour stream of Pitic 62 is an indication of the different response of the softer wheat to fractionation. The bran is separated more easily during the milling of the softer wheat (Pitic 62).

B. Reducing and Nonreducing Sugars. Reducing and nonreducing sugar values for the unfractionated flour and the three pin-milled and air-classified fractions obtained from four of the ten flour streams for the four varieties are shown in Table IV. Similar data were obtained for the other six flour streams.

Waldron showed the highest values for both the reducing and nonreducing sugars for all streams except the tailings flour stream.

Pitic 62 had the lowest content of reducing sugars in the different fractions for the various streams when compared to the other varieties, but had nonreducing sugar values which were similar to the values obtained for Waldron. The low reducing sugar values obtained for Pitic 62 may be attributed, in part, to less damage imparted during the milling process because of its softer nature.

The variety Fletcher showed the lowest nonreducing sugar values for all fractions of the different streams, with the exception of the tailings flour stream. In most cases, slightly lower nonreducing sugar values were obtained for Red River 68 than were obtained for Pitic 62, whereas the reverse was true for these two varieties for reducing sugar values. Similar reducing sugar values were obtained for Fletcher and Red River 68.

As was true for the individual free sugars, highest reducing and nonreducing sugar values were observed in F-1, the high protein-containing fraction. Several research groups (14,15,16) have indicated that maltose values in the fine fractions are usually from 1.5 to 2 times that of the flour being fractionated. Our results agree with those studies (15).

The F-2 and C-2 fractions for all streams and all varieties had reducing sugar values similar to the unfractionated flour for the particular flour stream. In general, the same differences noted among the varieties and streams within a particular variety for the free sugar analysis also were apparent in the reducing and nonreducing sugar analysis.

C. Total Sugars. Total sugar content of the unfractionated flour and the pin-milled and air-classified fractions of the different streams for all varieties investigated is shown in Table V. In general, F-1 contained the highest amount of total sugar in all ten streams for the four varieties analyzed. Of these, Fletcher showed the lowest level of total sugar, particularly in the unfractionated flour and F-1. Higher total sugar levels were associated with the break flour streams than with the middling-flour streams. The fifth break and tailings streams contained the highest amount of sugar when compared to the remaining streams. This would indicate that these two streams contain appreciable amounts of material found in the outer layers of the wheat kernel, which is higher in sugar

TABLE IV
Total Reducing and Nonreducing Sugars in Unfractionated, Pin-Milled, and Air-Classified Flour Fractions of Different Wheat Varieties

Flour Stream	Flour Fraction	Reducing Sugar Values[a]				Nonreducing Sugar Values[b]			
		Waldron	Red River 68	Pitic 62	Fletcher	Waldron	Red River 68	Pitic 62	Fletcher
2M	Unfractionated	22.5	16.2	15.5	16.1	112.3	82.5	106.8	74.1
	F-1	51.0	42.8	31.0	37.0	145.3	143.2	141.5	93.5
	C-2	21.9	16.5	12.8	16.3	85.0	80.5	95.3	66.3
	F-2	22.5	15.3	12.0	16.8	93.0	79.0	98.0	61.5
4M	Unfractionated	18.0	16.5	15.6	17.7	101.0	84.3	117.5	75.6
	F-1	42.7	41.5	27.8	39.3	154.8	139.3	157.3	117.0
	C-2	23.2	17.1	14.3	14.8	91.2	83.7	111.0	69.5
	F-2	22.7	17.0	12.8	16.8	96.3	83.5	111.0	70.7
2B	Unfractionated	20.8	18.2	14.0	20.5	99.6	99.0	99.3	79.0
	F-1	62.2	48.9	26.7	51.3	161.7	150.5	151.8	137.0
	C-2	23.2	18.7	15.4	16.3	127.8	92.0	81.0	72.0
	F-2	23.5	18.3	12.3	19.0	105.5	94.0	107.4	73.5
5B	Unfractionated	25.5	22.5	16.5	24.5	136.3	140.5	147.0	121.1
	F-1	65.2	58.2	42.7	58.3	216.2	231.8	183.5	175.2
	C-2	22.3	22.3	14.2	17.7	127.9	131.5	145.3	99.1
	F-2	27.8	23.8	14.8	21.5	148.0	150.0	134.0	115.3

[a]Values reported are an average of two or more determinations expressed as mg maltose/10 g flour.
[b]Values reported are an average of two or more determinations expressed as mg sucrose/10 g flour.

TABLE V
Total Sugar Content in Unfractionated, Pin-Milled, and Air-Classified Flour Fractions of Different Wheat Varieties[a]

Flour Stream	Flour Fraction	Waldron %	Red River 68 %	Pitic 62 %	Fletcher %
1M	Unfractionated	1.3	1.3	1.1	1.0
	F-1	2.0	1.2	1.9	1.2
	C-2	1.0	1.2	1.3	1.3
	F-2	1.0	1.4	1.4	1.2
2M	Unfractionated	1.2	1.3	1.2	1.0
	F-1	2.3	2.8	2.2	1.7
	C-2	1.0	1.2	1.4	1.3
	F-2	1.3	1.5	1.2	1.2
3M	Unfractionated	1.2	1.3	1.4	1.1
	F-1	2.3	2.5	2.3	1.3
	C-2	1.0	1.3	1.5	1.2
	F-2	1.3	1.4	1.5	1.3
4M	Unfractionated	1.3	1.4	1.4	1.1
	F-1	2.2	1.5	2.2	1.2
	C-2	1.1	1.5	1.5	1.2
	F-2	1.6	1.5	1.6	1.4
1B	Unfractionated	1.1	1.5	1.1	1.1
	F-1	2.5	2.2	2.0	1.8
	C-2	1.1	1.5	1.1	1.2
	F-2	1.4	1.7	1.3	1.3
2B	Unfractionated	1.0	1.3	1.1	1.0
	F-1	2.4	3.1	2.2	2.0
	C-2	1.0	1.4	0.9	1.2
	F-2	1.2	1.5	1.3	1.3
4B	Unfractionated	1.1	1.4	1.3	1.0
	F-1	2.3	3.7	1.6	1.4
	C-2	1.3	1.5	1.2	1.1
	F-2	1.8	1.8	1.3	1.3
5B	Unfractionated	1.4	1.9	1.5	1.4
	F-1	3.1	4.2	2.3	2.0
	C-2	1.3	1.7	1.6	1.3
	F-2	1.8	2.3	1.6	1.7
T	Unfractionated	1.5	1.6	3.5	1.5
	F-1	2.4	4.0	3.8	3.0
	C-2	1.3	1.6	3.6	1.4
	F-2	1.3	2.2	3.1	1.8
BD	Unfractionated	1.1	1.3	1.4	1.0
	F-1	3.3	3.0	2.0	2.2
	C-2	1.5	1.5	1.5	1.3
	F-2	1.8	1.5	1.3	1.4

[a]Values reported are an average of two determinations expressed on a dry basis in terms of sucrose.

content than the endosperm portion. The C-2 and F-2 fractions, in the majority of the streams, were comparable to the unfractionated flour in total sugar content, with F-2 slightly higher in most cases.

Statistical Evaluation

Table VI shows the statistical relation between protein content, ash content, and particle size and various sugar measurements. In agreement with the analytical data, protein content is significantly correlated with ash content at the 1% level. There was no correlation between protein content and particle size. However, highly significant correlations were shown between protein content and total sugars and reducing sugars. Correlations significant at the 5% level were obtained between protein content and nonreducing sugars, maltose, and glucose.

The correlation of ash content with total sugars was highly significant. A flour containing more bran material is reflected in higher ash content. It is known that the bran contains greater amounts of sugar than the endosperm portion of the kernel (17). Other highly significant correlations were obtained between ash content and reducing sugars, nonreducing sugars, sucrose, and raffinose.

Particle size showed highly significant negative correlations with total sugars, reducing sugars, nonreducing sugars, and ash content.

Correlation coefficients between total sugars, reducing sugars, and nonreducing sugars and other variables investigated are shown in Table VII. Total sugars were highly significantly correlated with reducing sugars, nonreducing sugars, sucrose, and raffinose. These correlation coefficients confirm the individual free sugar analyses which showed that sucrose and raffinose were present in larger amounts. In addition, significantly high correlations were obtained between total sugars and protein content and ash content. A highly significant negative correlation was shown between total sugars and particle size, indicating that the small-particle-size fraction had a high sugar content and vice versa.

Significantly high correlations were obtained between reducing sugars and

TABLE VI
Relation between Protein Content, Ash Content, and Particle Size and Various Sugar Measurements

	Correlation Coefficients		
	Protein content *vs.*	**Ash content** *vs.*	**Particle size** *vs.*
Total sugars	0.40**	0.81**	−0.56**
Reducing sugars	0.66**	0.84**	−0.45**
Nonreducing sugars	0.34*	0.77**	−0.49**
Sucrose	0.19	0.67**	−0.33*
Raffinose	0.19	0.68**	−0.34*
Maltose	0.33*	0.23	−0.17
Fructose	0.01	−0.15	0.25
Glucose	0.28*	0.10	0.24
Protein content	1.00	0.59**	0.08
Ash content	0.59**	1.00	−0.38**
Particle size	0.08	−0.38**	1.00

TABLE VII
Relation between Total Sugars, Reducing Sugars, and Nonreducing Sugars and Other Variables

	Correlation Coefficients		
	Total sugars *vs.*	**Reducing sugars** *vs.*	**Nonreducing sugars** *vs.*
Total sugars	1.00	0.77**	0.89**
Reducing sugars	0.77**	1.00	0.71**
Nonreducing sugars	0.89**	0.71**	1.00
Sucrose	0.81**	0.57**	0.94**
Raffinose	0.80**	0.56**	0.95**
Maltose	0.24	0.51**	0.10
Fructose	−0.17	0.05	−0.16
Glucose	−0.03	0.14	−0.07
Protein content	0.40**	0.66**	0.34*
Ash content	0.81**	0.84**	0.77**
Particle size	−0.56**	−0.45**	−0.49**

total sugars, nonreducing sugars, sucrose, and raffinose. A highly significant correlation was obtained between reducing sugars and maltose content. As with total sugars, highly significant correlations between reducing sugars and protein content, ash content, and particle size were realized.

Nonreducing sugars were highly significantly correlated with sucrose and raffinose. However, lower correlations with protein and ash content were obtained than with the reducing sugars. These results suggest a difference in the distribution of the reducing and nonreducing sugars.

This study has shown that certain differences exist among flour streams and varieties in reducing and nonreducing sugars, total sugars, and five individual free sugars. Also, the high protein-containing fraction contained the highest sugar content. Such information may be of use in selecting a particular flour stream or pin-milled and air-classified flour fraction for a particular end product, be it bread, cakes, or cookies.

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