COMPARISON OF STARCH, PENTOSANS AND SUGARS OF SOME CONVENTIONAL HEIGHT AND SEMIDWARF HARD RED SPRING WHEAT FLOURS[1]

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ABSTRACT

Eight samples of hard red spring (HRS) wheat flour which included three conventional-height and five semidwarf wheat varieties were utilized to examine the starch, pentosans, and sugars. Each sample was a composite of a single variety grown at several locations. Small differences were noted in the pasting properties of the starches isolated from the different samples. Peak height for the starch samples ranged from 370 to 520 Brabender Units (BU). Determination of the water-binding capacity values and starch damage values on the isolated starches likewise revealed small differences. Water-soluble and water-insoluble pentosans were isolated from the various flours followed by purification and column-chromatographic fractionation. The amount of amylase-treated water-soluble pentosans obtained from the different flours ranged from 0.58 to 0.72%. The water-insoluble pentosans associated with the "sludge" or "tailings" fraction of flour were separated into four fractions. DEAE-cellulose chromatography of the sludge pentosan fraction treated with α-amylase gave the highest yield for the principally arabinoxylan fraction. Fractionation of the water-soluble pentosans, however, revealed high amounts of glycoproteins. The amount of sucrose, raffinose, maltose, fructose, and glucose present in the various flours was measured using a Technicon Sugar Auto Analyzer. No extreme differences were noted in the amounts of the various sugars in the different flours.

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In recent years semidwarf HRS wheats have been introduced into the HRS wheat growing area of the United States. In many instances these wheats are higher yielding than the conventional standard-height type wheats, thereby making them attractive to the farmer.

One or more quality factors, including protein content, absorption, and mixing properties, of many of the semidwarf wheats, when compared to standard-height HRS wheat varieties, have been of concern to the cereal chemist and others involved in the development of new wheat varieties.

The purpose of this research study was to establish whether any differences in certain carbohydrate properties existed between several semidwarf wheat varieties and the conventional-height types.

MATERIALS AND METHODS

Flour Samples

Flour samples used in this investigation were obtained from three conventional standard-height wheat varieties; Chris, Waldron, and Justin, and five semidwarf wheat varieties; World Seeds 1809, Fletcher, Era, World Seeds 1812, and Red River 68. Each sample of wheat was a composite of an equal portion of that particular variety grown at seven different locations. The wheat was milled into flour on a Buhler laboratory mill.

Isolation of Starch, Water-Soluble and Water-Insoluble Pentosans

A dough ball was made from each flour sample for the isolation of the starch, water-soluble pentosans, and water-insoluble pentosans.

The dough ball was washed thoroughly in several small amounts of distilled water. The gluten protein material remaining was discarded and the washings were centrifuged to recover the prime starch, sludge, and water-soluble material.

The water-soluble supernatant obtained upon centrifugation was heated to 92°C, cooled, treated with celite filter aid, dialyzed, and freeze dried. The procedure used has been described previously (1), with the exception that a temperature of 92°C instead of 95°C was used for heating, and dialysis was performed for 3 days instead of 5 days. The crude pentosans were treated with α-amylase 2× crystallized (Nutritional Biochemical Corp., Cleveland, Ohio) to remove soluble starch according to the procedure of Kundig *et al.* (2).

The sludge fraction obtained as a layer above the prime starch was used for the isolation of the water-insoluble pentosans. Four sludge-pentosan fractions were obtained for each variety as described in a recent communication (3). Due to limited material only the α-amylase-treated sludge-pentosan fraction was investigated further.

The prime starch was recovered as a layer from the bottom of the centrifuge cup, air dried, and then sieved on a No. 70-mesh sieve.

Starch Analysis

The starch-pasting properties of the starches from the different samples were investigated with the Brabender amylograph. Starch (40 g, db) was suspended in 350 ml distilled water by agitation in a Waring Blendor at low speed for 1 min. The suspension was poured into the amylograph bowl and the blendor rinsed with 100 ml of additional water. The starch suspension was heated uniformly

TABLE I
Recovery of Starch and Sludge from Flour Samples

Sample	Prime Starch[a] %	Sludge[a] %	Prime Starch and Sludge %
Conventional-Height Varieties			
Chris	51.9	17.5	69.4
Justin	51.5	19.9	71.4
Waldron	54.1	16.9	71.0
Semidwarf Varieties			
World Seeds 1809	52.1	21.1	73.2
Fletcher	52.3	20.2	72.5
Era	52.1	21.0	73.1
World Seeds 1812	48.6	23.0	71.6
Red River 68	50.4	22.3	72.7

[a]Expressed on a dry basis.

TABLE II
Starch Pasting Properties of Isolated Starches

Sample	Pasting Temperature °C	Peak Height BU	Peak Temperature °C	15 min Height BU	Set-back BU
Conventional-Height Varieties					
Chris	83.5	510	95 (3 min)	500	560
Justin	82.0	400	95 (.5 min)	420	560
Waldron	83.5	370	95 (2 min)	380	520
Semidwarf Varieties					
World Seeds 1809	80.5	520	95 (2 min)	500	560
Fletcher	80.5	450	95 (1 min)	450	530
Era	80.5	430	95 (1.5 min)	410	550
World Seeds 1812	79.0	430	95 (.5 min)	450	530
Red River 68	80.5	440	95 (1 min)	440	520

TABLE III
Starch Damage Values of Flours

Sample Source	Starch Damage Feu[a]
Conventional-Height Varieties	
Chris	27.3
Justin	31.2
Waldron	32.4
Semidwarf Varieties	
World Seeds 1809	39.0
Fletcher	38.2
Era	29.9
World Seeds 1812	30.1
Red River 68	33.7

[a]Expressed as Farrand equivalent units on a dry basis.

TABLE IV
Starch Damage and Water-Binding Capacity Values of Isolated Starches

Sample Source	Starch Damage Feu[a]	Water-Binding Capacity %
Conventional-Height Varieties		
Chris	4.0	82
Justin	5.0	84
Waldron	9.1	88
Semidwarf Varieties		
World Seeds 1809	5.4	91
Fletcher	6.4	75
Era	8.9	88
World Seeds 1812	8.1	84
Red River 68	6.2	88

[a]Expressed as Farrand equivalent units on a dry basis.

TABLE V
Yield of Crude and Amylase-Treated Water-Soluble Pentosans

Sample	Crude[a] Pentosans %	Amylase-Treated[b] Pentosans %	Amylase-Treated Pentosans[c] %	Protein Content of Amylase-Treated Pentosans %
Conventional-Height Varieties				
Chris	1.4	47.7	0.7	28.0
Justin	1.4	46.0	0.6	32.6
Waldron	1.3	52.3	0.7	29.8
Semidwarf Varieties				
World Seeds 1809	1.5	40.3	0.7	31.4
Fletcher	1.3	54.8	0.7	26.8
Era	1.2	48.7	0.6	24.4
World Seeds 1812	1.1	47.3	0.6	20.6
Red River 68	1.2	50.8	0.6	27.8

[a]Recovery from flour (dry basis).
[b]Recovery from crude pentosans.
[c]Recovery from flour (dry basis).

from 25° to 95°C, held at 95°C for 15 min, and then cooled uniformly to 50°C. Pasting temperature, peak height, peak temperature, 15 min height, and set-back were the measurements obtained from the amylograph curve. Definition of these terms has been given by Medcalf and Gilles (4).

Starch-damage values were obtained according to the method of Williams and Fegol (5) with the exception that a 5.0 g-sample was used for the starch samples and a 1.0 g sample for the flour sample.

Water-binding capacity values were determined by the procedure of Medcalf and Gilles (6).

DEAE-Cellulose Chromatography of Isolated Pentosans

The α-amylase treated water-soluble and water-insoluble pentosans were fractionated into five fractions by stepwise elution from a 2.4 × 30-cm column of DEAE cellulose (borate form). The DEAE cellulose (Whatman DE 23) had an exchange capacity of 1.0 meq/g.

The sample (125 mg) was dissolved in a small amount of distilled water and applied to the top of the column. The procedure used to fractionate the pentosans has been given previously (1).

Ratio of Component Sugars in DEAE-Cellulose Pentosan Fractions

The ratio of component sugars in the various pentosan fractions was determined by gas chromatography using the procedure of D'Appolonia (7).

Sugar Analysis

Reducing and nonreducing sugar analysis on the flour samples was performed according to AACC standard procedures (8) while individual free sugars were

TABLE VI
Yield and Protein Content of Amylase-Treated Pentosan Fraction from Sludge

Sample	Yield[a] %	Protein Content %
Conventional-Height Varieties		
Chris	24.5	4.3
Justin	24.3	6.9
Waldron	28.0	6.6
Semidwarf Varieties		
World Seeds 1809	34.8	8.0
Fletcher	32.5	7.9
Era	30.3	6.7
World Seeds 1812	21.7	8.4
Red River 68	19.5	6.7

[a]Yield based on sludge fraction recovered on top of 400-mesh sieve.

TABLE VII
Yield of DEAE-Cellulose Fractions of α-Amylase-Treated Water-Soluble Pentosans

	Conventional-Height Varieties			Semidwarf Varieties				
Fraction	Chris %	Justin %	Waldron %	World Seeds 1809 %	Fletcher %	Era %	World Seeds 1812 %	Red River 68 %
F_1	31.1	25.6	30.0	27.2	15.4	26.1	39.2	21.5
F_2	15.9	12.3	11.1	8.0	21.4	15.7	16.5	11.5
F_3	17.4	33.6	24.5	27.9	8.3	13.6	4.1	17.2
F_4	24.4	16.1	24.9	22.4	37.5	33.5	23.7	34.4
F_5	11.1	12.3	9.4	14.4	17.1	11.0	16.5	15.3

measured using a Technicon Sugar Auto Analyzer as described by Abou-Guendia and D'Appolonia (9), however, using the reagents and elution gradient for Method I as given by Hough *et al.* (10).

RESULTS AND DISCUSSION

Starch

Table I shows the amount of prime starch and sludge obtained from the different flour samples. Also shown are the values for the recovery of the starch and sludge combined, since this value may be more meaningful than the individual values as it is somewhat difficult to obtain a complete separation of the starch and sludge.

The conventional-height varieties contained less amounts of starch and sludge combined than the semidwarf wheat varieties as is evident from the table. All of

TABLE VIII
Yield of DEAE-Cellulose Fractions of α-Amylase-Treated "Sludge" Pentosans

Fraction	Conventional-Height Varieties			Semidwarf Varieties				
	Chris %	Justin %	Waldron %	World Seeds 1809 %	Fletcher %	Era %	World Seeds 1812 %	Red River 68 %
F_1	48.9	51.0	49.3	33.7	47.8	46.9	27.8	39.8
F_2	25.0	21.4	26.5	28.1	19.2	23.0	32.3	28.8
F_3	6.3	6.5	7.4	10.3	11.0	9.3	13.4	3.1
F_4	6.3	7.1	6.0	9.3	7.5	5.8	8.0	4.5
F_5	13.5	14.0	10.8	18.5	14.4	15.0	19.2	23.8

TABLE IX
Ratio of Component Sugars in DEAE-Cellulose Fractions

Sample Source	Fraction	α-Amylase-Treated Water-Soluble Pentosans Ratio ARAB:XYL:GAL	α-Amylase-Treated Sludge Pentosans Ratio ARAB:XYL
	UNF	1:0.84:0.70	1:1.50
	F_1	1:1.44:--	1:1.64
	F_2	1:1.12:--	1:1.25
Justin	F_3	1:0.51:1.58	1:1.15
	F_4	1:0.24:1.87	1:1.16
	F_5	1:1.35:--	1:1.35
	UNF	1:0.83:0.95	1:1.50
	F_1	1:1.50:--	1:1.82
	F_2	1:1.14:--	1:1.38
World Seeds 1809	F_3	1:0.20:1.54	Material unavailable for analysis
	F_4	1:0.30:2.04	1:1.24
	F_5	1:1.28:--	1:1.49

TABLE X
Intrinsic Viscosity Values of DEAE-Cellulose Pentosan Fractions F_1 and F_2

Sample	Water-Soluble Pentosans		Sludge Pentosans	
	F_1 [η]	F_2 [η]	F_1 [η]	F_2 [η]
Conventional-Height Varieties				
Chris	1.7	1.9	2.2	3.0
Justin	3.1	3.0	3.1	3.7
Waldron	2.0	2.0	1.9	2.1
Semidwarf Varieties				
World Seeds 1809	1.9	1.8	...	3.0
Fletcher	1.9	...	...	2.3
Era	0.8	1.1	2.7	3.2
World Seeds 1812	1.9	2.2	1.9	3.2
Red River 68	1.6	1.7	3.6	3.1

TABLE XI
Reducing and Nonreducing Sugars[a]

Sample	mg Maltose/10 g flour	mg Sucrose/10 g flour
Standard-Height Varieties		
Chris	...	...
Justin	20	91
Waldron	22	100
Semidwarf Varieties		
World Seeds 1809	18	86
Fletcher	23	86
Era	22	94
World Seeds 1812	20	112
Red River 68	17	93

[a]Expressed on an "as-is" basis.

the starch samples isolated contained .04% nitrogen while the range in nitrogen content for the sludge samples was between 0.19 - 0.30%.

Table II shows the pasting properties of the starch isolated from the different flours. The pasting temperature of the starches isolated from the semidwarf wheats was, in all cases, slightly lower than the pasting temperature of the conventional-height wheat starches. The peak height for all starches ranged from 370 to 520 BU with Waldron and World Seeds 1809 having the low and high values, respectively. It was not possible to detect definite differences in peak height, peak temperature, 15-min height, and set-back between the conventional-height and semidwarf wheat flour starches.

Starch damage values on the different flours (Table III) revealed that Chris had the lowest amount of starch damage [27.3 (Farrand equivalent units) (feu)], while the range in values was between 27.3 – 39.0 feu. The starch-damage values for the conventional-height flour samples were similar to the semidwarf flour samples with the exception of World Seed 1809 and Fletcher, which had somewhat higher values.

TABLE XII
Individual Free Sugar Analysis[a]

Sample	Sucrose %	Raffinose %	Maltose %	Fructose %	Glucose %
Standard-Height Varieties					
Chris	.10	.04	.03	.02	.03
Justin	.10	.04	.04	.02	.03
Waldron	.12	.05	.04	.02	.03
Semidwarf Varieties					
World Seeds 1809	.12	.06	.04	.02	.03
Fletcher	.10	.04	.04	.01	.03
Era	.11	.05	.05	.02	.03
World Seeds 1812	.12	.05	.04	.02	.03
Red River 68	.12	.06	.05	.02	.04

[a]Expressed on a dry basis.

Starch-damage and water-binding capacity values on the isolated starches are shown in Table IV. As would be expected, the starch-damage values on the starches were lower than on the respective flours. Some damaged starch and soluble starch would be lost during the isolation of the prime starch. Chris starch had the lowest level of starch damage, as was the case with the flour, however, Waldron starch showed the highest level of damage which was not noted with the Waldron flour. The high-starch damage value for Waldron might explain the low-amylogram peak height obtained for this variety as seen in Table II. In general, differences in water-binding capacity values between all samples were minimal.

Water-Soluble and Water-Insoluble Pentosans

Table V shows the recovery values for the crude and amylase-treated water-soluble pentosans from the different flour samples. The amount of crude pentosans obtained ranged from 1.1 to 1.5%, whereas the amount of amylase-treated pentosans ranged from 0.6 to 0.7%. There was an approximate 50% loss in material as a result of the amylase treatment. The protein content of the amylase-treated pentosans ranged from 20.6 to 32.6%. Calculated on a protein-free basis the amount of amylase-treated pentosans recovered from the various flours ranged from 0.4 to 0.5%. The amount of amylase-treated pentosans obtained from the different samples indicated that it was impossible to establish any difference in yield between the conventional-height samples and the semidwarf samples. The yield of α-amylase-treated pentosans was used to ascertain whether differences existed in pentosan content between the various samples, since in these preparations any soluble starch would have been removed by the α-amylase and the protein content in the preparation could also be taken into consideration.

Table VI shows the yield and protein content of the amylase-treated pentosan fraction obtained from the sludge. Two of the semidwarf varieties, World Seeds 1812 and Red River 68 showed the lowest recoverable yield. As evident from this table the sludge pentosans were considerably lower in protein content than the water-soluble pentosans.

Table VII shows the yield of the five DEAE-cellulose pentosan fractions obtained for each of the water-soluble pentosans extracted from the different flours. Certain differences were noted in the amounts obtained for the different fractions of the different flours; however, there was no consistent pattern difference between the conventional-height samples and the semidwarf samples.

Table VIII shows the yield of the five DEAE-cellulose pentosan fractions obtained for each of the α-amylase-treated sludge pentosans. With the sludge pentosans, the greatest yield was obtained in fractions 1 and 2. The yield for these two fractions was considerably higher than the yield obtained from the same two fractions of water-soluble pentosans. Also, fractions 3, 4, and 5 of the water-soluble pentosans were quite high in protein content, whereas the same fractions for the sludge pentosans were considerably lower in protein.

Table IX shows the ratio of component sugars obtained by gas-liquid chromatography for the five DEAE-cellulose fractions obtained from the water-soluble pentosans and from the amylase-treated sludge pentosans for two samples, Justin and World Seeds 1809. As noted in this table the ratio of component sugars, arabinose:xylose for fractions 1 and 2, which are essentially arabinoxylan fractions, is higher for the amylase-treated sludge pentosan fractions than for the amylase-treated water-soluble pentosans. This result was found to be true for six of the eight varieties investigated. Only Fletcher and Era had lower arabinose:xylose ratios for F_1 of the amylase-treated sludge pentosans than F_1 of the amylase-treated water-soluble pentosans.

The water-soluble pentosans contained appreciable amounts of galactose in fractions 3 and 4, whereas the sludge pentosans did not. Small differences were noted in the sugar ratios of the different fractions between the different varieties for the amylase-treated water-soluble pentosans. Fractions 1 and 2, however, for Era and World Seeds 1812, not shown in this table, had the highest arabinose:xylose ratios which would indicate that these pentosans would have a lower degree of branching when compared to the pentosans of the other varieties.

Not shown in Table IX, a higher arabinose:xylose ratio was obtained for fractions 1 and 2 of the amylase-treated sludge pentosans for World Seeds 1812 than was obtained for the same fractions from the other varieties. This again, would indicate less branching in the pentosans for this variety.

Table X shows the intrinsic-viscosity values of the DEAE-cellulose pentosan fractions F_1 and F_2 obtained from the amylase-treated water-soluble and sludge pentosans of the different varieties. The variety Justin had the highest intrinsic-viscosity values for both fractions for the water-soluble pentosans, while the variety Era showed the lowest values. Fraction 1 of Era also had the highest arabinose:xylose ratio which would indicate the lowest degree of branching. Era also had one of the lowest yields of amylase-treated pentosans. Although it is impossible to detect a definite difference in intrinsic-viscosity values between the pentosans of the conventional-height samples and the semidwarf samples, differences were noted in the samples as a whole. For the majority of the varieties, the intrinsic-viscosity values for the sludge pentosan fractions were higher than for the corresponding water-soluble pentosan fractions. As for the water-soluble pentosans, however, differences were noted between the different varieties but it was not possible to separate the semidwarf samples from the conventional-height samples based on this measurement.

Reducing and nonreducing sugar values for the different flour samples are shown in Table XI. Results expressed as maltose values for all flour samples were essentially the same while sucrose values showed small variation between samples. Analysis of the individual free sugars in the different flour samples (Table XII), likewise revealed no extreme differences.

The results of this investigation have indicated that of the particular carbohydrate properties investigated it would not be possible to separate the conventional-height wheat varieties from the semidwarf samples, by any one particular character measured. Certain differences in carbohydrates were noted between varieties. However, the differences were not always between the conventional-height samples and the semidwarf samples but existed also among the conventional-height varieties and among the semidwarf wheat varieties.

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