Enzymatic Analysis of β-Glucan Content in Different Oat Genotypes[1]

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ABSTRACT

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The β-glucan contents of 243 samples of genetically variable oat lines were measured using a modified enzymatic method. Each dehulled sample was ground with a Retsch mill, and the β-glucans were extracted and analyzed. The data among samples showed a normal distribution, with the β-glucan contents for most samples ranging between 4.5 and 5.5%. Results showed significant differences among samples, indicating genetic variability of oat affects the β-glucan content.

The cholesterol-lowering effects of soluble dietary fiber in animals, including that of oat fiber, are well documented (Fisher and Griminger 1967, Chen and Anderson 1979, Chen et al 1981, Anderson and Chen 1986). Similar effects have been observed in humans (Dirby et al 1981, Judd and Truswell 1982, Zavoral et al 1983, Anderson et al 1984, Van Horn et al 1986). The beneficial, cholesterol-lowering effects are attributed primarily to the water-soluble cell-wall polysaccharides in grains, which in oats are the (1→3),(1→4)-linked β-D-glucans (Klopfenstein 1988). The polysaccharide is unbranched and contains about 70% four-linked and 30% three-linked β-D-glucopyranosyl units. Although consumers may be interested in having oat products high in β-glucan, these same components can slow weight gain in poultry (Newman et al 1987, Cave et al 1990).

β-Glucans occur in all cereals, but their concentration is greatest in oat and barley, with values ranging from less than 2% to more than 6% (Anderson et al 1978, Wood 1984, Lim et al 1992). Whether the goal is increased β-glucan for human health or decreased β-glucan for animal feeds, the need for information on the β-glucan contents of currently available oat types is clear.

This article reports a germ plasm survey assessing the range of β-glucan contents in 212 oat varieties, strains, and genotypes used in plant-breeding programs aimed at altering the β-glucan contents.

MATERIALS AND METHODS

Experimental Design and Sample Preparation

Oat samples, representing 212 different oat types consisting of old-time varieties, current varieties, experimental lines from several experiments in the north central region of the U.S., and accessions of *Avena sterilis*, the progenitor of cultivated oats, were grown in a two-replicate experiment at Ames, IA, in 1989. The experiment included two check varieties, Hamilton and Noble, at regular intervals in the list of accessions to give a total of 243 oat samples. The oat lines were chosen to represent a broad range of genotypes available in the U.S. north central region. The *Avena sterilis* accessions were taken from the Oat World Collection, harvested from regions surrounding the Mediterranean Sea.

The 1989 growing season for oats, although drier than normal, produced good yields of plump oat grain. After harvest, the threshed samples were dehulled on a plot basis. Amounts of oat groats (caryopses) available from each plot varied, but generally a minimum of 10 g from each plot was produced. This was the amount required for β-glucan analysis. The groats were stored in a cold room at 4°C and 45% rh until needed for analyses.

All oat samples were milled to pass a 0.5-mm screen (model ZM 1, with a 24-tooth stainless steel rotor, Retsch, GmbH & Co., Haan, Germany). Moisture and β-glucan contents were determined immediately.

The following reagents were used for β-glucan analyses.

Lichenase (endo-(1→3),(1→4)-β-D-glucan-4-glucano-hydrolase) working solution was purchased from Megazyme Australia, Sydney. The enzyme (1.0 ml) was diluted to 20.0 ml with 20 m*M* sodium phosphate buffer (pH 6.5).

β-Glucosidase working solution was purchased from Megazyme Australia. The enzyme (1.0 ml) was diluted to 20.0 ml with 50 m*M* sodium acetate buffer (pH 4.0).

Sodium phosphate buffer (20 m*M*, pH 6.5) from 3.12 g of sodium dihydrogen orthophosphate dihydrate ($NaH_2PO_4 \cdot 2H_2O$) was dissolved in 900 ml of distilled water. The pH was adjusted to 6.5 by the addition of 100 m*M* sodium hydroxide. The volume was then adjusted to 1 L.

Sodium acetate buffer (50 m*M*, pH 4.0) from 1.2 g of sodium acetate trihydrate was dissolved in 950 ml of distilled water, to which was added 1.0 ml of glacial acetic acid.

Concentrated buffer of mono-potassium orthophosphate (136.0 g), sodium hydroxide (33.0 g), para-hydroxy benzoic acid (15.0 g), and sodium azide (2.0 g) was dissolved in 900 ml of distilled water, with the pH adjusted to 7.4. The volume was then adjusted to 1 L.

Working buffer solution of concentrated buffer solution (100 ml) was diluted to 1 L with distilled water.

Glucose oxidase-peroxidase/4-amino-antipyrine reagent (Megazyme GOPOD) from four vials (12.5 ml per vial) were dissolved in 1 L of working buffer solution. This reagent was stored in the dark at 4°C.

Moisture Determination

Approximately 0.5 g of oat flour was added to oven-dried and preweighed aluminum drying dishes. The samples were dried at

TABLE I
β-Glucan Content, Averages, and Standard Deviations in Webster Groat Samples[a]

	β-Glucan Content (%) Within a Day				
	Measurement			Average	Standard Deviation
Day	1	2	3	(%)	(%)
1	4.43	4.43	4.48	4.45	0.03
2	4.62	4.65	4.67	4.65	0.03
3	4.99	4.93	4.95	4.96	0.03
4	4.24	4.27	4.29	4.27	0.03
5	4.75	4.79	4.71	4.75	0.04
6	4.48	4.49	4.48	4.48	0.01
7	5.01	5.01	5.02	5.01	0.01
8	4.36	4.34	4.34	4.35	0.01
9	4.81	4.83	4.81	4.82	0.01
10	4.57	4.57	4.58	4.57	0.01
11	5.07	5.07	5.10	5.08	0.02
12	4.56	4.57	4.57	4.57	0.01
13	4.82	4.82	4.85	4.83	0.02
14	4.50	4.51	4.57	4.53	0.04

[a]Among days average (%): 4.66; standard deviation (%): 0.24; range: 4.27–5.08, $n = 42$.

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TABLE II
β-Glucan Contents of 243 Different Oat Groat Samples

Sample Name	Replicate 1	Replicate 2	Average	Sample Name	Replicate 1	Replicate 2	Average	Sample Name	Replicate 1	Replicate 2	Average
7-131	4.84	4.34	4.59	H713-29	3.93	4.01	3.97	Noble	5.01	5.57	5.29
Andrew (CK)	5.81	5.49	5.65	H719-22	5.35	5.23	5.29	Noble	5.25	5.11	5.18
B605-1085	4.90	4.68	4.79	H722-7	4.99	4.32	4.66	Noble	4.82	4.46	4.64
B605-1085	5.21	5.20	5.21	H722-9	4.37	4.84	4.61	Noble	4.89	4.97	4.93
Bates (CK)	5.78	6.18	5.98	H722-14	5.14	4.46	4.80	Noble	4.78	4.99	4.89
Bates	4.80	4.41	4.61	H722-20	5.09	4.54	4.82	Noble	5.27	5.06	5.17
Blend 226	5.62	5.19	5.41	H722-23	4.82	4.90	4.85	Noble	5.15	5.03	5.09
Blend 227	4.32	4.36	4.34	H729-6	5.28	5.34	5.31	Nodaway 70	4.79	5.35	5.07
Blend 605	5.41	4.90	5.16	H730-12	6.09	6.09	6.09	O'Brien	5.28	5.59	5.44
Bondvic	5.46	4.86	5.16	H731-5	5.44	4.90	5.17	Ogle (CK)	4.93	4.74	4.84
Bonham	5.86	4.34	5.10	Hamilton	5.08	4.93	5.01	Ogle	4.25	4.93	4.59
Bonkee	4.88	4.52	4.70	Hamilton	5.00	4.87	4.94	Ogle	4.68	4.23	4.46
Burnett	4.41	4.41	4.41	Hamilton	4.86	4.70	4.78	OH 1006	6.23	4.71	5.47
Cherokee	4.65	4.78	4.72	Hamilton	4.65	4.24	4.45	OH 1011	5.39	5.86	5.63
Chief	4.69	4.38	4.54	Hamilton	5.01	5.00	5.01	OH 1012	5.36	4.77	5.07
Clintford (CK)	4.43	4.74	4.59	Hamilton	4.78	4.58	4.68	OH 1014	4.75	4.27	4.51
Clintland 64 (CK)	6.73	4.72	5.73	Hamilton	4.89	4.90	4.90	Otee	5.17	5.73	5.45
Clinton	5.26	5.86	5.56	Hamilton	4.41	4.58	4.50	Otter	4.26	4.41	4.34
Craigs Afterlea	5.52	5.18	5.35	Hazel	5.92	5.91	5.92	P7869D1-5-3-2-10-1	6.16	5.74	5.95
D226-30-8	4.98	4.43	4.71	Heritage	5.13	4.71	4.92	P7869D1-5-17-3	5.14	5.17	5.16
D227-32-6	3.91	4.12	4.02	Horican	5.02	5.33	5.18	P76163A1-14-5-3-1-3	5.19	5.51	5.35
D826-356	5.92	5.35	5.64	HYtest	5.33	4.88	5.11	PA 8290-7026	5.04	4.92	4.98
D826-506	4.75	4.97	4.86	IA Y933-11-2	4.41	4.77	4.59	PA 8393-1500	5.00	5.01	5.01
D826-922	5.24	5.24	5.24	IL 81-1882	4.94	4.71	4.83	PA 8393-11138	4.73	4.54	4.64
D826-922	5.42	5.32	5.37	IL 81-1882	4.80	5.52	5.16	PA 8393-15050	5.34	5.23	5.29
D831-1-30	5.87	5.49	5.68	IL 81-1882	4.78	4.39	4.59	PA 8494-4099	6.04	5.34	5.69
D831-1-57	5.79	5.95	5.87	IL 82-2154	6.13	5.49	5.81	PA 8494-11717	4.97	5.17	5.07
D920-51	4.76	5.03	4.90	IL 83-7641-1	5.26	5.02	5.14	PA 8598-4200	5.30	5.15	5.23
D921-643	5.24	5.25	5.25	IL 83-8022	5.20	5.00	5.10	PA 8598-8415	4.62	5.24	4.93
D971-255	6.12	5.81	5.97	IL 83-8037	5.73	5.57	5.65	PA 8598-11662	5.58	5.91	5.75
Dal (CK)	5.53	5.27	5.40	IL 83-8037-1	5.71	5.54	5.63	Pacer	4.44	4.63	4.54
Dal	5.62	5.96	5.79	IL 83-8037-1	4.95	5.15	5.05	Portage	4.25	4.72	4.49
Diana	4.92	5.15	5.04	IL 84-3093	6.00	5.40	5.70	Porter	5.24	4.94	5.09
Don (CK)	5.08	5.44	5.26	IL 85-6183-1	5.67	6.16	5.92	Preston	5.00	4.96	4.98
Don	5.18	5.63	5.41	IL 85-6264-1	5.59	5.16	5.38	Proat	4.72	5.09	4.91
Don	5.78	5.51	5.65	Jaycee	5.85	6.03	5.94	Ransom	4.20	3.72	3.96
Ensiler	5.07	5.41	5.24	Joanette	5.53	5.32	5.43	Richland	4.62	4.61	4.62
Garland	4.62	4.58	4.60	Johnson	5.47	5.27	5.37	Rodney	4.76	4.94	4.85
Goodfield	4.62	4.76	4.69	Kelly	5.24	5.48	5.36	Sandy	5.01	5.67	5.34
Gopher (CK)	6.27	4.04	5.16	Kota	4.02	4.14	4.08	SD 84065	5.30	4.97	5.14
Gopher	5.99	5.14	5.57	Lang	5.34	5.31	5.33	SD 85009	4.83	Missing	4.83
Green Russian	5.34	4.65	4.50	Larry	5.27	4.80	5.04	SD 820045	4.70	Missing	4.70
Grey Algerian	4.36	4.77	4.57	Lodi	4.12	4.82	4.47	SD 830095	5.50	4.77	5.14
Grundy	4.94	4.28	4.61	Marion	4.43	4.30	4.37	SD 840104	5.08	5.15	5.12
H19-1	5.01	4.39	4.70	MN 81229	6.37	6.19	6.28	SD 840104	5.30	5.39	5.35
H19-12	4.50	5.17	4.84	MN 84231	4.02	3.71	3.87	Starter	4.84	5.19	5.02
H19-14	4.48	4.92	4.70	MN 84231	5.24	5.11	5.18	Starter	6.19	6.25	6.22
H23-2	2.80	3.19	3.00	MN 86108	3.84	4.00	3.92	Steele	5.48	4.80	5.14
H27-5	4.35	4.75	4.55	MN 86109	5.33	5.17	5.25	Storemont	4.46	3.79	4.13
H28-5	4.17	4.64	4.41	MN 86226	6.33	5.85	6.09	Stout	4.23	4.45	4.34
H45-8	4.90	4.61	4.76	MN 87180	4.82	4.35	4.59	Trucker	5.14	4.92	5.03
H52-5	5.92	5.56	5.74	MN 87187	5.23	4.62	4.93	Tyler	4.56	5.04	4.80
H61-3-3	4.65	4.51	4.58	MN 87189	4.41	4.25	4.33	Valley	5.02	4.98	5.00
H61-3-3	4.85	4.91	4.88	MN 87194	5.24	4.77	5.01	Victorgrain	4.15	4.21	4.18
H73-9	4.46	4.62	4.54	MN 87230	4.84	5.01	4.93	W 82056 (Robert)	5.51	5.03	5.27
H75-117	4.72	4.71	4.72	MO 07929	6.59	6.27	6.43	Webster	5.04	5.33	5.19
H79-2	4.65	4.83	4.74	MO 07929	6.18	5.94	6.06	Webster	5.28	5.00	5.14
H87-4	5.14	4.81	4.98	MO 07941	5.26	5.87	5.57	White Oale	5.37	4.93	5.15
H87-7-4	5.86	5.94	5.90	MO 08054	5.53	4.87	5.20	WI X4872-1	5.02	4.84	4.93
H553	4.22	4.17	4.20	MO 08139	4.95	4.53	4.74	WI X4872-1-3	5.39	4.97	5.18
H688-4	4.59	4.98	4.79	MO 08236	4.74	4.87	4.81	WI X5209-1	5.06	4.69	4.88
H688-4	4.97	4.51	4.74	MO 08291	5.62	5.49	5.56	WI X5229-1	5.43	5.35	5.39
H688-11	5.83	5.69	5.76	Montezuma	3.09	3.93	3.51	WI X5445-4	5.88	5.31	5.60
H689-8	4.57	4.14	4.36	Moore	4.93	4.84	4.89	Y 22-15-9	5.09	5.61	5.35
H689-13	4.99	4.42	4.71	Multiline 77	5.13	5.79	5.46	Y 933-11-2	4.60	4.58	4.59
H689-13	4.82	4.42	4.62	ND 830646	5.51	4.32	4.92	Y 933-11-2	5.15	5.27	5.21
H695-1	4.24	4.74	4.49	ND 830775	5.39	4.48	4.94	Y 949-9-2	4.33	4.29	4.31
H696-8	4.19	4.24	4.22	ND 830341	3.63	3.90	3.77	Y 949-9-2	5.20	5.38	5.29
H702-4	5.91	5.24	5.58	ND 840769	6.25	5.71	5.98	Z 965-105	5.09	4.68	4.89
H710-10	4.47	4.43	4.45	ND 810104	3.97	3.99	3.98	Z 965-202	4.91	5.35	5.13
H713-9	5.26	4.76	5.01	Noble	5.02	4.80	4.91				

TABLE II (*continued*)
β-Glucan Contents of 243 Different Oat Groat Samples

Sample Name	Replicate 1	Replicate 2	Average	Sample Name	Replicate 1	Replicate 2	Average	Sample Name	Replicate 1	Replicate 2	Average
Avena sterilis accessions				PI 324771	5.21	5.23	5.22	PI 412242	5.58	5.86	5.72
PI 295903	5.80	5.89	5.85	PI 324790	4.99	4.18	4.59	PI 412268	4.68	4.63	4.66
PI 296250	5.42	5.32	5.37	PI 411521	5.43	5.56	5.50	PI 412309	5.07	4.77	4.92
PI 309075	4.86	6.24	5.55	PI 411537	3.95	3.96	3.96	PI 412321	5.14	4.90	5.02
PI 309322	5.00	4.22	4.61	PI 411560	5.74	5.74	5.74	PI 412330	4.86	4.49	4.68
PI 324722	4.44	4.77	4.61	PI 411569	4.97	5.09	5.03	PI 412368	5.09	4.91	5.00
PI 324738	5.26	5.48	5.37	PI 411677	4.81	3.39	4.10	PI 412377	3.74	3.96	3.85
PI 324740	5.19	5.15	5.17	PI 411779	4.89	3.37	4.13	PI 412555	5.32	Missing	5.32
PI 324745	4.14	3.88	4.01	PI 412003	4.59	4.64	4.62	PI 412689	6.16	5.68	5.92
PI 324749	4.00	4.35	4.18	PI 412031	4.91	5.25	5.08				
PI 324757	6.18	5.33	5.76	PI 412207	5.66	5.92	5.79				

130°C for 2 hr in triplicate. After cooling in a desiccator, the containers and contents were weighed accurately, and the oven-dried sample weights were calculated and averaged. The moisture values were used to report the β-glucan content on a dry-weight basis.

β-Glucan Assay Procedure

The β-glucan was measured using the method of McCleary and Glennie-Holmes (1985), modified by the use of Megazyme GOPOD and a multipoint calibration. For clarity, the exact procedure followed is reported. Samples of oat flours (0.5 g) of known moisture content were accurately weighed into 30-ml polypropylene centrifuge tubes. To each tube was added an aliquot (1.0 ml) of aqueous ethanol (50%, v/v) to aid dispersion of the samples and 5 ml of sodium phosphate buffer. The tubes were incubated in a boiling water bath (Blue M Inc., Blue Island, IL) for 2 min, removed, vigorously stirred on a vortex mixer, and then heated for an additional 3 min. The tubes were cooled to 40°C, and 0.2 ml of lichenase working solution was added to each tube. The tubes were then capped and incubated at 40°C for 1 hr. To check temperature, a blank tube with reagents was used. After incubation, the volume in each tube was adjusted to 30.0 ml with distilled water. The contents of the tubes were mixed thoroughly, and an aliquot from each tube was centrifuged at 2,000 × *g* for 10 min. From each supernatant, 0.1-ml aliquots were carefully and accurately transferred to the bottom of three test tubes. To one of these (the blank) was added 0.1 ml of acetate buffer (50 m*M*, pH 4.0), and to the other two was added 0.1 ml of β-glucosidase (in 50 m*M* acetate buffer, pH 4.0). The tubes were incubated at 40°C for at least 15 min. Standard glucose solutions of different concentrations (blank, 12.5, 25, 50, 75, and 100 μg/0.1 ml) were included in every running batch. The GOPOD reagent (3.0 ml) was added at timed intervals (such as 15 sec) so that the absorbances at 510 nm of the tubes could be measured at exact times after incubating at 40°C.

Statistical Analyses

Analyses, including linear regression, standard deviations, and frequency distributions, were run according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Time of Maximum Color Development

The time of maximum color development of the GOPOD reagent and a glucose standard was 25 min and was measured using AACC method 32-22 (AACC 1983).

Standard Calibration Curve

The calibration curve was prepared using standard glucose solutions of different concentrations (blank, 12.5, 25, 50, 75, and 100 μg/0.1 ml) and plotting their absorbances. A linear regression equation was obtained. For the calibration curve shown, $y = -7.59 \times 10^{-3} + 8.52 \times 10^{-3}\ x$ (where $r = 0.996$). Therefore, $x = y + 7.59 \times 10/8.52 \times 10$ μg glucose. The β-glucan content of the oats on a dry-weight basis was calculated using the equation:

$$\beta\text{-glucan (\%)} = \mu\text{g glucose} \times 300 \times 1/1{,}000 \times 100/w \times 162/180 = \mu\text{g glucose}/w \times 27$$

where:
300 is the volume correction (0.1 ml taken from 30.0 ml); 1/1,000 is the conversion from μg to mg; 100/*w* is the factor to express β-glucan content as a percentage of dry flour; *w* is the calculated dry weight of the sample analyzed in mg; 162/180 is the factor to convert from free glucose, as determined, to anhydroglucose in β-glucan; and μg glucose is the *x* value from the linear regression equation of the standard glucose curve.

A glucose standard curve was run with every batch of samples. The original procedure by McCleary and Glennie-Holmes suggests running only one absorbance point to calculate β-glucan contents. The addition of the standard curve of glucose in every running batch allows more accurate and consistent calculations of the data.

Evidence of Reproducibility of the β-Glucan Assay

Table I shows individual data, averages, and standard deviations of β-glucan measurements in Webster groats. Within a day, the standard deviation was less than 0.04, whereas among days, the standard deviation was 0.24, suggesting good reproducibility among days as well as within a day. Larger differences among days than within a day probably reflected the greater variation in values obtained from different grindings. Analyses within a day were all performed on the same ground-oat sample.

β-Glucan Analyses of 243 Groat Samples

Using the procedures and calculations described, two replicates of 243 groat samples were analyzed for β-glucan contents. The individual values are presented in Table II. A frequency distribution based on the average of the two replicates is presented in Figure 1. Several oat lines are listed more than once, representing several plantings of the same line for a total of 243 plantings in replicate. Because the moisture contents ranged from 4.2 to 9.2% among different oat lines, β-glucan values were calculated on a dry-weight basis. The β-glucan contents of the different samples showed a normal distribution, with most genotypes having values ranging between 4.5 and 5.5%. As shown in Figure 1, 14.8% of the oat lines had β-glucan values of less than 4.50%, whereas 18.1% had β-glucan values greater than 5.49%. Oat lines with high β-glucan values, as listed in Table II, were MO 07929 (both plantings), MN 81229, Starter (one planting), and Bates (CK). The second planting of Starter oats averaged much less β-glucan (5.02%). The beginning Starter oat material was the same, so these differences likely were environmentally caused. Most other oat lines grown more than once, such as D826-922, Don, and IL81-1882 (Table II), had much closer agreement of β-glucan values. The oat types, H 23-2, Montezuma, ND 840341, PI 412377, Ransom, and ND 810104 had low average β-glucan contents of 3.00, 3.51, 3.77, 3.85, 3.96, and 3.98%, respectively.

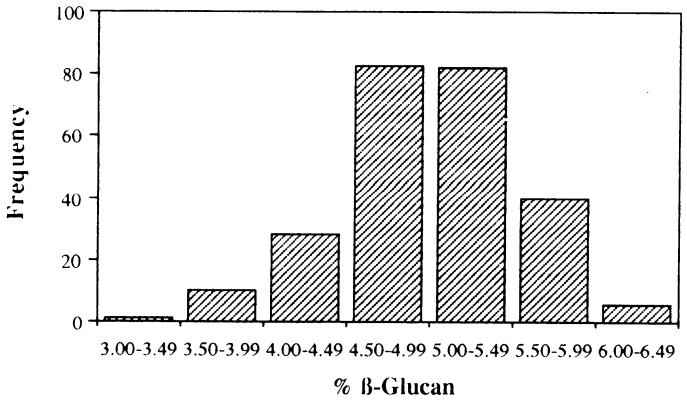

Fig. 1. Frequency distribution data for β-glucan in 243 oat groat types.

In other work, Henry (1987) reported β-glucan contents of 3.78 and 3.98% for groats from two oat types, Stout and Camelia, respectively. Wood et al (1977) reported 3.32% β-glucan in Hinoat oat flour. Prentice et al (1980) found β-glucan contents in Lodi and Goodland Oats of 6.6% and 4.8%, respectively. The Lodi groats measured in our experiment had only 4.47% β-glucan. The least β-glucan reported was 2.5% in Avon oats grown in Australia (Anderson et al 1978). Stuart et al (1987) found β-glucan contents of Bulban oats ranging from 2.5 to 6.6%. The β-glucan contents from our data showed a range in values similar to those reported in the literature for other oat types.

Table II also shows β-glucan data for *Avena sterilis* oat lines. The range of β-glucan contents for 50% of all *Avena sterilis* samples was between 4.5 and 5.5%, and the mean was 5.0%. Twenty percent of the *Avena sterilis* lines had β-glucan values of less than 4.5%, whereas 30% had β-glucan values greater than 5.5%. Miller et al (1993) reported a value of 5.2% β-glucan for an *Avena sterilis* line germinated in the dark, grown in a growth chamber, and transplanted in the field at four weeks.

The variability of β-glucan contents within the same groat type and among its replicates was evaluated by growing two replicates each of eight check samples of Hamilton and Noble oats (Table II). The average β-glucan contents of Hamilton and Noble oats were 4.79 and 5.01%, respectively, with standard deviations of 0.24 and 0.25, respectively. Prentice et al (1980) reported a standard deviation of 0.4 in β-glucan contents of Lodi oats and a standard deviation of 0.2 in Goodland oats. Overall, the use of the modified β-glucan assay in our results showed relatively low and consistent standard deviations.

The difference in β-glucan contents between replicates one and two of the same oat type was greater than 0.5% β-glucan for 61 of the oat lines examined. This difference in β-glucan content may be due to environmental differences between different plots. Peterson (1991) and Lim et al (1992) found a significant environmental interaction on the β-glucan contents of oats. However, the interaction would not be of much practical importance in a variety development program. Sampling errors are also possible, either during grinding or because of cross-contamination during harvesting.

In conclusion, the variability of β-glucan contents among different oat genotypes showed genetic differences in the oat, with β-glucan values exhibiting a normal distribution curve. Data differences of β-glucan within the same genotype might be due to environmental effects. However, a more rigorous examination of environmental effects is needed and is currently underway in our laboratory. The data described in this study provides a broad base of information needed to identify cultivars for use in breeding programs to alter β-glucan content in oats.

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