Protein Distribution in the Oat Kernel[1]

V. L. YOUNGS[2], Department of Agronomy, University of Wisconsin, Madison 53706

ABSTRACT

Five cultivars and two experimental lines of *Avena sativa* (common oats) with a wide range of protein were studied. Percent groats, groat and hull protein, and 1,000 kernel weight and bran thickness of the groats were measured. Groats from each variety were hand-dissected into the embryonic axis, scutellum, bran (aleurone layer included), and starchy endosperm. The embryonic axis accounted for 1.1 to 1.4% of the total groat weight; scutellum, 1.6 to 2.6%; bran, 28.7 to 41.4%; and endosperm, 55.8 to 68.3%. The endosperm weights varied inversely, and the bran weights directly, with the groat protein concentrations. Analysis of each groat fraction for protein showed the greatest concentration in the embryonic axis, with a range of 26.3 to 44.3%; scutellum next, 24.2 to 32.4%; followed by the bran, 18.5 to 32.5%; and endosperm, 9.6 to 17.0%. Both the bran and endosperm protein concentrations increased as the total groat protein increased. Since most of the groat weight is in the bran and endosperm, these fractions contained the greatest part of the total groat protein. However, groats with higher protein generally contained a greater amount of bran protein rather than endosperm protein. Bran thickness was measured on 12 different varieties (range 0.058 to 0.101 mm.), and varied directly with groat protein.

Of the small grains used for cereals, wheat probably has received the greatest attention relative to protein distribution in the kernel. An excellent review of this literature has been written by MacMasters et al. (1). *Avena sativa* L., common oats, and in particular the oat groat (the oat kernel with its hull removed), have received little consideration. The oat groat is of special current interest because it has high protein with a good amino acid balance (2). This investigation was undertaken to study the distribution of protein within the kernels of different oat genotypes which had a wide range of total-grain protein contents.

MATERIALS AND METHODS

Five cultivars and two experimental lines of oats, all grown at Madison, Wis., in 1970, were selected for this study; the groats ranged in protein from 13.8 to 22.5% (dry basis). The oats were hand dehulled, and both the hulls and groats weighed. Percent groats in the oats and 1,000 kernel weight (groats) were determined.

Groats from each variety were hand dissected into the embryonic axis, scutellum, bran (with the aleurone layer), and starchy endosperm, under a dissecting microscope (30X). Previous to the hand dissection, it was necessary to place the groats for an hour or more in a covered petri dish which contained a dampened tissue. If the groat had not absorbed considerable water, it was impossible to separate the scutellum from the endosperm. A dentist's instrument,

[1]Cooperative investigations, Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Agricultural Experiment Station, University of Wisconsin, Madison.

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[2]Research Chemist, Oat Quality Laboratory, U.S. Department of Agriculture.

with a blade width of 1 mm.; tweezers; and a scalpel were the tools used. The embryonic axis was removed first, then the scutellum. Removal of the latter required special care to produce a clean separation between the scutellum and endosperm. The degermed groat then was split along the crease with a scalpel, each half-kernel opened, and the endosperm scraped out with the dentist's instrument. At least ten or more groats of each variety were dissected to obtain enough of the germ fractions (embryonic axis and scutellum) for accurate weighing and protein analysis. Three or more degermed groats were separated into bran and endosperm for each analysis. Duplicate dissections for analysis were performed on each variety. A variety that was hand dissected also was milled on a Brabender Quadrumat, Jr. experimental mill. A comparison of endosperm and bran yields was made.

Percent nitrogen in the groats, hulls, and groat fractions was determined by the micro-Kjeldahl method as described in AACC Method 46-13 (3). Protein was calculated by multiplying percent nitrogen by 6.25, and expressed on a moisture-free basis. These analyses were made on representative samples which included different sized groats. In this study, however, large groats were dissected; thus, the protein determinations of the groat fractions were on large groats. As a check, the protein concentration of the groat was also calculated by determining the amount of protein contributed by each fraction. In all cases, the protein concentration of the whole groat determined from the groat fractions was within two percentage points of the Kjeldahl value reported as percent protein in the groat. This is within the variation we have noted by single seed determinations with a given variety.

Bran-thickness measurements were performed on three different sized groats from each of the seven varieties of common oats. A scalpel was used to remove a thin cross-section of groat at its widest part. This section was dipped into an ethanol:water:iodine solution for a few seconds to stain the endosperm, making the bran layer more distinguishable. The groat section then was placed on a microscope equipped with an optical micrometer, and the bran thickness was measured at three locations, as shown in Fig. 1.

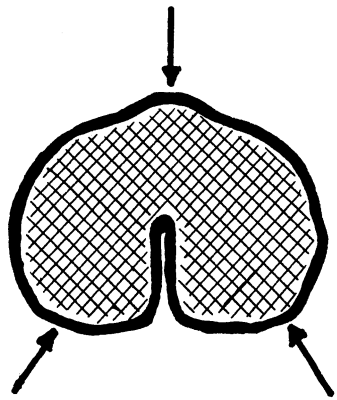

Fig. 1. Drawing of cross-section of an oat groat. The arrows show the approximate positions where bran-thickness measurements were taken.

RESULTS AND DISCUSSION

Table I describes the percent by weight of groats in the oats of each variety, percent protein in the groats and hulls, 1,000 kernel weight, and the bran thickness of the groats. With the exception of Lodi, the varieties used were quite high in percent groats. While the varieties were chosen to give a wide range in groat protein, the range in hull protein was small (1.4 to 1.9%).

Bran-thickness values for each variety in Table I represent an average of three readings at different positions on each of three different sized groats, or a total of nine readings. Average bran thickness ranged from 0.063 to 0.101 mm. These values showed a high correlation with groat protein ($R=0.93$). When the average bran-thickness values for five additional varieties were included, the range was 0.058 to 0.101 mm., and a correlation of 0.90 resulted when compared to groat protein ($P<0.01$). A high correlation between bran thickness and kernel protein was not consistently observed in wheat (1).

Results of the weight distribution in dissected groats are shown in Table II. The embryonic axis and scutellum, the two fractions forming the germ, comprise only about 3% of the total weight. The percent bran in the groat generally shows an increase as the groat protein increases; conversely, the percent endosperm decreases, or $R=0.74$ and -0.70, respectively ($P<0.10$). One would expect, then, that as the amount of bran increases in groats, the amount of endosperm would decrease ($R=-0.86$, $P<0.05$).

Data on the weight distribution of hand-dissected wheat fractions, performed by

TABLE I. PHYSICAL CHARACTERISTICS AND PROTEIN CONTENT OF OATS (A. sativa)

Variety	Groats %	Groats Protein %	Hulls Protein %	Groats 1,000 Kwt. g.	Groats Bran Thickness mm.
Orbit	71.9	13.8	1.7	21.5	0.063
Lodi	68.2	14.6	1.6	20.7	0.058
Garland	72.0	14.8	1.4	14.4	0.065
Froker	74.9	15.5	1.4	22.7	0.079
Portal	73.4	16.5	1.9	16.7	0.075
X-1289	76.4	20.8	1.5	19.5	0.087
X-1656	73.4	22.5	1.9	20.3	0.101

TABLE II. WEIGHT DISTRIBUTION OF GROATS (A. sativa)

Variety	Embryonic Axis %	Scutellum %	Bran %	Starchy Endosperm %
Orbit	1.2	1.8	28.7	68.3
Lodi	1.1	2.0	33.6	63.3
Garland	1.4	2.1	33.9	62.7
Froker	1.0	1.8	30.2	67.0
Portal	1.2	1.6	39.8	57.4
X-1289	1.1	2.6	34.4	61.8
X-1656	1.1	1.7	41.4	55.8

TABLE III. PROTEIN CONTENT OF GROAT FRACTIONS (A. sativa)

Variety	Embryonic Axis %	Scutellum %	Bran %	Starchy Endosperm %
Orbit	44.3	32.4	18.8	9.6
Lodi	36.5	26.2	19.6	10.7
Garland	40.5	28.9	18.5	10.9
Froker	26.3	28.0	20.7	9.7
Portal	35.3	29.1	23.0	10.3
X-1289	40.9	24.2	26.5	13.5
X-1656	40.7	32.4	32.5	17.0

TABLE IV. DISTRIBUTION OF TOTAL PROTEIN IN GROAT (A. sativa)

Variety	Embryonic Axis % Protein	Scutellum % Protein	Bran % Protein	Starchy Endosperm % Protein
Orbit	4.0	4.5	41.3	50.2
Lodi	2.8	3.6	46.2	47.4
Garland	4.0	4.2	43.9	47.8
Froker	1.9	3.7	46.3	48.1
Portal	2.7	2.9	57.3	37.2
X-1289	2.4	3.4	49.2	45.0
X-1656	1.9	2.3	56.2	39.7

several workers, have been reviewed by MacMasters et al. (1). The following ranges are reported: embryonic axis, 1.0 to 1.6%; scutellum, 1.09 to 2.0%; bran, 10.4 to 21.4%; and starchy endosperm, 74.9 to 86.5%. The values obtained in our study on oats show a similarity between groat and wheat-germ fractions, but the bran fraction from groats is greater, and the endosperm less than from wheat.

Oat groats from the variety Froker were milled in an experimental mill. The flour yield was 34.6%, much lower than the hand-dissected yield of 67.0%. The bran was also lower: 23.3%, as compared with 30.2% in Table II. The third fraction from the experimental mill, the shorts, was largest: 42.1%.

Micro-Kjeldahl protein analyses were performed on each groat fraction. Results are shown in Table III. The embryonic axis contains the largest concentration of protein, followed by the scutellum. Similar results were reported for wheat (1). There appears to be no relationship between germ protein and total groat protein. The bran, which includes the protein-rich aleurone layer in this study, contains a larger concentration of protein than the endosperm, but both show a regular increase as the groat protein increases: $R=0.97$ and 0.93 for percent groat protein vs. percent bran protein and endosperm protein, respectively ($P<0.01$).

Protein values for the experimentally milled fractions of Froker were: bran, 19.5%; flour, 11.1%; and shorts, 16.0%.

The pigment strand located within the crease of the groat was dissected from several Orbit groats. It contained 15.3% protein.

Data in Table IV were obtained by considering the weight of each fraction, and its protein concentration. Although the germ is rich in protein, its contribution to the total groat protein is only about 6%. Most of the protein is found in the bran

and endosperm. If average values for all the varieties are considered, 48.6% of the total groat protein is found in the bran, and 45.1% in the endosperm. There is a considerable range, however. Because high-protein oats contain more bran and less endosperm (Table II), the contribution of each fraction to the total groat protein varies accordingly.

CONCLUSIONS

Of the four fractions, the bran and endosperm contribute the largest amount of protein to the groat. This amount can be affected by: a) variation in fraction weight, and b) variation in protein concentration. In the seven varieties tested, certain trends were observed. As the total protein of the groat increases, the bran weight increases. This is confirmed by an increase in bran thickness. Conversely, the weight of the endosperm decreases. However, the protein concentration of both the bran and endosperm increases. The actual change in bran:endosperm weight ratio probably is largely responsible for the change noted in the protein contribution of these fractions to the groat (Table IV). It should be noted that hand dissection, while the most precise method to determine composition of grain fractions, can be performed on small samples only. Consequently, the data must be interpreted with caution.

The implications of a thicker bran-higher protein oat probably would not be serious where the entire groat is used commercially, such as in some breakfast cereals. It is doubtful that there would be any adverse effect on flavor or texture. However, where oat flour is the prime consideration, the flour yield likely would be lower with a high-protein variety, based on the results obtained in this study. Yet it is encouraging that an increase in endosperm protein accompanies an increase in total groat protein.

Literature Cited

1. MacMASTERS, MAJEL M., HINTON, J. J. C., and BRADBURY, DOROTHY. Microscopic structure and composition of the wheat kernel. In: Wheat: Chemistry and Technology, ed. by Y. Pomeranz, Chapt. 3. American Association of Cereal Chemists: St. Paul, Minn. (1971).
2. ROBBINS, G. S., POMERANZ, Y., and BRIGGLE, L. W. Amino acid composition of oat groats. Agr. Food Chem. 19: 536 (1971).
3. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. AACC Approved methods (7th ed.). The Association: St. Paul, Minn. (1962).

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