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## THE MINERAL CONTENT OF GRAIN

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**D**URING the past ten years numerous fairly complete analyses of the mineral content of whole grains have been made at the Utah Experiment Station. A summary of these results is of considerable interest for a number of reasons: (1) In the case of wheat, oats, and barley they represent the averages of many determinations: Wheat 1755 samples, oats 1205 samples, barley 110 samples, and corn 75 samples. (2) These grains were grown under both irrigated and dry-farm conditions. (3) They were grown on soils having a wide variation in composition. The soils varied from the so-called "alkali-free" to "alkali soils" and from the highly calcareous to those in which calcium was present only in moderate quantities. (4) The sulfur of the soil varied greatly. Some of the soils were highly impregnated with gypsum while others contained only small quantities of sulfur. (5) The wheat represents various varieties grown under similar conditions; consequently, we have a crude measure of the effect of irrigation, soil, and variety on the mineral content. (6) The determinations of ash, calcium, magnesium, potassium, phosphorus, sulfur, and iron were all made by modern methods of analysis, usually those approved by the Association of Official Agricultural Chemists (6). In each table is given the maximum, the average, and the minimum percentage; consequently, we have the extremes in variation.

TABLE I  
PERCENTAGE ASH IN OATS, BARLEY, WHEAT, AND CORN GROWN UNDER VARYING CONDITIONS

	Oats	Barley	Wheat	Corn
Maximum .....	4.87	3.71	2.94	1.79
Average .....	4.05	3.00	1.85	1.73
Minimum .....	1.68	2.08	1.35	1.65

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There is a variation of 290, 178, and 218 per cent between the maximum and minimum ash content of oats, barley, and wheat, respectively. The small variation in the case of corn is due to the fact that all the samples analyzed were grown on the same soil and represent only one variety. It is evident from these results that animals kept on the same rations, but with grains coming from different sources, may be receiving a great variation in ash. The probable extreme variation shown by our work which may be attributed, in the case of wheat, to irrigation water is 46 per cent, to variety 31 per cent, and to soil 118 per cent.

These average results for oats are considerably higher than those reported by Armsby (1), Hopkins (3), König (4), or Sherman (7). The Utah-grown barley carries an ash content almost the same as those reported by Hopkins. There is a remarkable agreement in the average ash content of the Utah-grown wheat and that reported by König and the 20-year averages for the Rothamsted work (5).

TABLE II  
PERCENTAGE CALCIUM IN OATS, WHEAT, BARLEY, AND CORN GROWN  
UNDER VARYING CONDITIONS

	Oats	Wheat	Barley	Corn
Maximum.....	0.190	0.296	0.150	0.180
Average.....	0.117	0.090	0.086	0.150
Minimum.....	0.019	0.028	0.029	0.130

So far as calcium is concerned, there is a much wider spread in variation in the case of wheat than any of the other grains. Considered from the standpoint of average, oats are richer in calcium than any of the other grains; however, a few wheats contained more calcium than any of the oats.

The average calcium content of these grains is about double that reported as the 20-year average for the Rothamsted work, and they are considerably higher than those reported by Sherman. It is most probable that this would have a profound influence in the nutrition of farm animals which may be kept on a ration consisting primarily of grains. The part it plays in human nutrition where the extensive use of highly-milled grains enters will be known only after determinations have been made on the milled and natural grain.

Wheat grown in some localities was found to carry six times the calcium of wheat grown in other localities. Wheat raised with 67.5 inches of irrigation water contained 2.6 times as much calcium as did similar wheat

grown on similar soil without irrigation water. Some varieties of wheat even though grown under similar conditions contained twice the calcium contained in other varieties. Similar variations were found to exist in the case of the oats and barley. Many of these grains were grown on highly calcareous soil and often with irrigation water, which are the reasons for the high calcium content of these grains.

TABLE III  
PERCENTAGE MAGNESIUM IN WHEAT, OATS, BARLEY, AND CORN  
GROWN UNDER VARYING CONDITIONS

	Wheat	Oats	Barley	Corn
Maximum.....	0.276	0.278	0.273	0.220
Average.....	0.184	0.181	0.181	0.203
Minimum.....	0.131	0.141	0.147	0.190

The ash and total calcium varied with the different grains, but no such variation is found in the case of barley; in fact, the maximum and average are within experimental error. However, the variation within each specific grain is large.

The variation in magnesium content among different varieties amounted to 25 per cent and that due to irrigation 32 per cent. The average magnesium content of the various varieties of wheat grown at Nephi were 0.184 per cent, whereas the average of the Greenville-grown wheat was 0.188 per cent. The calcium content of the Nephi-grown wheat was 0.079 per cent and that of the Greenville-grown wheats 0.167 per cent; consequently, while the magnesium content of the grains from the two districts is not far different, the calcium content is twice as high in the Greenville-grown grain as it is in the Nephi-grown. This is due to two factors: (1) The greater calcium content of the Greenville soils and (2) the application of irrigation waters to some of the Greenville-grown grains.

The average magnesium content of all these grains is considerably higher than reported by other workers. However, the increase in magnesium is not so great as the increase in calcium. This is seen from an examination of the calcium-magnesium ratios. These ratios for the grains reported by König are: Wheat, 1:3.1; oats, 1:1.7; barley, 1:1.7. The calcium-magnesium ratios of the Utah-grown grains are: Wheat, 1:2; oats, 1:1.5; and barley, 1:2.1. These results establish three important factors: (1) There is a great variation in the magnesium content of grains,

wheat, oats, and barley, depending upon the composition of the soil on which they are grown; (2) the magnesium content of grains, wheat, oats, and barley, varies with the quantity of irrigation water used in their production; and (3) the average magnesium content of Utah-grown grains is higher than that usually reported from other districts.

The calcium and magnesium contents of the corn here reported is much higher than that reported by other workers. This, however, may not represent the general calcium and magnesium contents of Utah-grown corn, as the samples all came from one district.

TABLE IV  
PERCENTAGE POTASSIUM IN WHEAT, OATS, BARLEY, AND CORN  
GROWN UNDER VARYING CONDITIONS

	Wheat	Oats	Barley	Corn
Maximum.....	0.960	1.000	0.923	0.410
Average.....	0.476	0.570	0.561	0.390
Minimum.....	0.307	0.418	0.389	0.370

The variation in potassium content of wheat of different varieties grown under the same conditions amounted to 51 per cent, the variation due to irrigation water 35 per cent, and the variation due to locality, primarily soil, to 28 per cent. The average potassium content of wheat, oats, and barley, as here reported, is not greatly different, but the variation between grains grown under different conditions is very great. We have an extreme variation between the maximum and minimum in wheat of 312 per cent, in oats of 239 per cent, and in barley of 237 per cent. The average potassium content of Utah-grown grains is higher than those reported for some districts and lower than those reported for others, but the difference is in no case so great as was found for calcium and magnesium.

TABLE V  
PERCENTAGE OF PHOSPHORUS IN WHEAT, OATS, BARLEY, AND CORN  
GROWN UNDER VARYING CONDITIONS

	Wheat	Oats	Barley	Corn
Maximum.....	0.458	0.451	0.440	0.350
Average.....	0.331	0.364	0.351	0.334
Minimum.....	0.150	0.267	0.238	0.320

All the grains listed, except corn, show a wide spread in their phosphorus content, the extreme difference in the case of wheat amounting to over

300 per cent. All evidence points to the conclusion that there are at least three factors causing the variation—irrigation, soil, and variety of grain grown.

The average phosphorus contents of these grains are lower than the phosphorus reported by others. Consequently, there is a difference in the calcium-phosphorus ratio. The calcium-phosphorus ratios calculated from the great number of determinations reported by König are: Wheat, 1:8.9; oats, 1:4.4; barley, 1:4.4; corn, 1:12.8; whereas those for the Utah-grown grains are: wheat, 1:3.7; oats, 1:3.1; barley, 1:3.1; corn, 1:2.2. This greater proportion of calcium to phosphorus in the Utah-grown grains should make of them a more nearly balanced food than is the case with the grains proportionately higher in phosphorus. Whether this narrower ratio will be maintained in the highly-milled products can be answered only by further work.

TABLE VI  
PERCENTAGE SULFUR IN WHEAT, OATS, AND BARLEY GROWN UNDER VARYING CONDITIONS

	Wheat	Oats	Barley
Maximum.....	0.287	0.294	0.241
Average.....	0.204	0.190	0.155
Minimum.....	0.120	0.115	0.082

The variation in sulfur content of wheat, which our work indicates can be attributed to irrigation water, is 48 per cent; to variety, 40 per cent; and to soil 30 per cent. The wheat showed a maximum variation of 139 per cent. The average sulfur content of wheat is 8 per cent greater than it is in oats and 32 per cent greater than it is in barley. The sulfur contents here reported are higher than those given in work referred to in this article, but this cannot be taken as an indication of a high sulfur content of Utah-grown grains as these determinations were made by the moist-fusion method, whereas most others were obtained by the ashing of the grains. This would result in a considerable loss of sulfur.

TABLE VII  
PERCENTAGE IRON IN WHEAT, OATS, AND BARLEY GROWN UNDER VARYING CONDITIONS

	Wheat	Oats	Barley
Maximum.....	0.032	0.022	0.021
Average.....	0.005	0.007	0.006
Minimum.....	0.001	0.004	0.004

While the iron content of wheat, oats, and barley is not widely different, the difference which was found to exist between different samples grown under varying conditions was very great. We found that irrigation water, soil, and variety all contributed to a variation in the iron content of the various grains. These results are not far different in many cases from those reported by others, and what difference there is may be due to methods. We used the colormetric method of Berman (2) after the ash had been prepared by the Official Methods (6).

#### SUMMARY

The ash, calcium, magnesium, potassium, phosphorus, sulfur, and iron contents of wheat, oats, barley, and corn are reported. The maximum, average, and minimum contents of each mineral for the various grains grown under varying conditions are given. Variation in the mineral content of different samples of each grain is great, the variation being due to the use of irrigation water, the nature of the soil on which the grain was grown, and the variety of grain. In the case of wheat, a crude measure of the effect of each of these factors is given.

The calcium, magnesium, and sulfur contents of these grains are higher than those usually reported for grains grown elsewhere. The phosphorus content is lower; consequently, the proportion of calcium to phosphorus is higher than usually reported. The question is raised whether these factors would not materially modify the nutritive value of grains grown on these highly fertile calcareous soils.

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