THE VITAMINS OF TRITICALE, WHEAT, AND RYE[1]

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ABSTRACT

One spring wheat, one spring rye, two spring triticales, and two winter triticales were milled into flour, bran, and shorts fractions. These fractions as well as the whole grains were analyzed microbiologically for content of thiamine, riboflavin, niacin, biotin, folacin, pantothenic acid, and the B_6 vitamins. Because of differences in flour extraction rates obtained under optimum milling conditions, a general conclusion was drawn only for the whole-grain vitamin contents. It was concluded that, except for a substantially lower amount of niacin in triticales compared to that of wheat, the vitamin composition of triticales is comparable to that of wheat and better than that of rye.

Triticale is a man-made cereal grain. The parental species are wheat and rye. Since commercial varieties are now readily available, the grain has found increased use as an animal feed (1,2,3), and has also been shown to be suitable for the production of many food products (4,5,6).

Increasing emphasis on food and nutrition in national policies and programs is focusing attention on the importance of expanding and updating information on nutrients in foods (7).

Review of the literature shows that numerous studies have been reported that include data on the vitamin composition of wheats and ryes and their milling fractions. Data on the vitamin content of triticales, however, are virtually nonexistent.

In view of the potential value of triticales as a food for human consumption, a comparison of the vitamin content of this man-made cereal grain with that of its parental species seems essential.

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MATERIALS AND METHODS

Sample Identification

The grain samples analyzed included the spring wheat Chris, the spring rye Prolific, the spring triticales 6-TA-204 and 6-TA-206, and the winter triticales TR 385 and TR 386. All varieties were grown side by side on irrigated plots at the Colorado State University Agronomy Research Center during the 1974 crop year. The grain samples were tempered overnight to moisture levels of 15% for the wheat, 14% for the rye, and 13.5% for the triticales prior to milling on a Quadrumat Senior mill. Preliminary milling experiments showed these moisture levels to be optimum.

The whole grain, flour, bran, and shorts of each variety were analyzed for their vitamin content.

Enzymatic Digestion of Grains and Milling Fractions

Samples were prepared by digestion of the dry samples to release the vitamins into a liquid medium for assay purposes according to a method described by the Association of Vitamin Chemists (8). One gram of each grain sample or milling fraction was extracted with 8 ml of 0.2*N* sodium acetate buffer having a pH of 4.5 and 1 ml of a freshly prepared enzyme suspension containing 20 mg of papain and 20 mg takadiastase per ml for 24 hr at 39°C. The samples were then steamed to inactivate the enzymes and diluted with distilled water to 35 ml. After centrifugation for 10 min at 2000 rpm, the supernatant was poured into dark bottles. One milliliter of toluene was added and the solutions were kept under refrigeration for a maximum of 2 weeks.

It is acknowledged that treatment with H_2SO_4 and autoclaving of the analysis samples for the release of vitamins is now recommended. In our work, however, the Association of Vitamin Chemists' (8) method has proved just as satisfactory in the analysis of thiamine and riboflavin in cereal grains as the autoclaving technique (9, 10). This is the reason the enzyme digestion procedure was used for all vitamins studied.

Vitamin values are not absolute for a given cultivar, but vary with the agronomic and environmental conditions under which the grain is produced. Since it was the purpose of this study to make a comparison of the vitamin contents of these cultivars grown side by side under the same conditions during the 1974 crop year, we felt justified in using the same extraction procedures for all vitamins analyzed.

Microbiological Assays

The microbiological assays were conducted as described in the Difco Manual (11).

The microorganisms were obtained from the Difco Laboratories. Each bacterium was stab-inoculated in 10 ml of micro assay culture agar contained in 18 × 125-mm test tubes. Stock cultures of the mold were made by transferring spores to slants of Neurospora culture agar. After inoculation, the microorganisms were incubated and kept in a refrigerator.

The following organisms were used for analyses of the vitamins: *riboflavin—Lactobacillus casei* 7469 ATCC; thiamine—*Lactobacillus fermenti* ATCC 9338; niacin, biotin, and pantothenic acid—*Lactobacillus plantarum*

ATCC 8014; folacin—*Streptococcus lactic R.* 8043 ATCC; and B_6 vitamins—*Neurospora sitophila* ATCC 9276.

A set of standard tubes containing known amounts of the vitamin was included every time an assay was made. The possible contribution of vitamins from the enzyme solution was determined by including tubes which contained only the enzyme solution in the assay.

At least three separate determinations were made for each vitamin.

The data were analyzed through analyses of variance using the tables of D values at 5% level of significance by Kurz *et al.* (12).

RESULTS AND DISCUSSION

Milling Data

In agreement with results obtained by several workers (13,14), the triticales had flour extraction rates below those of wheat, as seen in Table I. This has been attributed to the shriveled condition of the triticale kernels which does not permit an efficient separation into milling fractions (14). Relatively large amounts of endosperm, which ideally should have been part of the flour fraction, adhered to the bran and thus lowered the flour yield while raising the yield of bran. Total flour yield of the rye was slightly lower than that of the triticales. All triticales had bran yields lower than rye but higher than wheat.

Since flour yields for triticale significantly higher than those in this study have not been reported, the triticale flours obtained can be considered representative of such flours. The bran and shorts milling fractions are used as feeds. Their vitamin contents should be of interest to the feed industry.

Most of the triticale is presently marketed in the form of a whole-grain meal. The vitamin results of the whole grains, therefore, would be representative of these products.

Vitamin Data

The vitamin contents of the cereal grains and their milling fractions are given in Table II.

Thiamine. The whole-grain thiamine values for wheat are slightly higher than values reported in the literature (15,16). The analysis was repeated a total of seven times, each time indicating the slightly higher than expected values.

One of the difficulties in using *L. fermenti* as the assay organism is the fact that

TABLE I
Milling Data (%)

Milling Fraction	Wheat Chris	Winter Triticales TR385	Winter Triticales TR386	Spring Triticales 6TA204	Spring Triticales 6TA206	Rye Prolific
Break flour	28.0	19.6	16.7	29.7	25.9	27.3
Reduction flour	41.0	40.7	37.8	35.1	35.2	24.7
Total flour	69.0	60.3	54.5	64.8	61.1	52.0
Shorts	6.4	10.9	12.2	6.0	6.9	10.5
Bran	20.8	26.4	30.9	27.7	30.5	33.6

the organism is unstable. Occasionally, it will develop the ability to synthesize thiamine when the culture maintenance procedure is followed (17). This would make the organism useless for assay purposes. The organism used for this study was received immediately before the grain samples were analyzed and before the recommended culture maintenance procedure needed to be followed.

The results, therefore, have to be explained as being due to the environmental and agronomic conditions under which the grains were grown rather than to positive drift. All triticale grains showed thiamine content essentially identical to that of the wheat sample. The value for rye was significantly below those found for the wheat and the triticales. The difference was statistically significant.

Since the thiamine values for the grain samples were slightly higher than expected, based on literature values, the thiamine results for the bran fractions

TABLE II
Vitamin Contents of Wheat, Rye, and Triticale and Their Milling Fractions (μg/g, Dry Basis)

	Wheat	Winter Triticales		Spring Triticales		Rye
	Chris	TR385	TR386	6TA204	6TA206	Prolific
Grain						
Thiamine	9.9	9.8	8.7	9.0	9.5	7.7
Riboflavin	3.1	2.5	4.1	2.5	3.3	2.9
Niacin	48.3	17.9	16.3	16.0	15.6	15.3
Biotin	0.056	0.067	0.062	0.066	0.063	0.054
Folacin	0.56	0.59	0.61	0.77	0.70	0.49
Pantothenic acid	9.1	6.5	6.8	8.3	8.8	6.3
Vitamin B_6	4.7	4.2	5.0	4.9	4.8	3.4
Flour						
Thiamine	0.7	0.2	0.4	0.3	0.3	0.8
Riboflavin	1.5	1.4	1.4	1.4	1.3	1.3
Niacin	9.5	6.5	6.5	7.6	7.0	8.8
Biotin	0.013	0.012	0.010	0.011	0.008	0.011
Folacin	0.09	0.09	0.10	0.09	0.07	0.13
Pantothenic acid	2.5	2.4	2.4	3.3	2.7	2.7
Vitamin B_6	0.48	0.43	0.44	0.35	0.36	0.46
Shorts						
Thiamine	10.1	5.2	4.7	9.0	8.5	4.0
Riboflavin	1.8	1.8	1.6	2.3	2.4	2.8
Niacin	23.5	14.4	13.7	17.1	16.9	18.0
Biotin	0.055	0.046	0.045	0.047	0.051	0.078
Folacin	0.59	0.33	0.25	0.56	0.55	0.72
Pantothenic acid	7.0	5.0	4.6	6.9	6.9	9.1
Vitamin B_6	5.3	3.4	2.5	4.7	3.8	3.7
Bran						
Thiamine	13.2	12.5	11.8	12.0	12.8	9.3
Riboflavin	5.5	5.1	5.5	4.5	4.4	4.1
Niacin	171.4	58.2	58.0	57.3	58.4	27.4
Biotin	0.162	0.123	0.120	0.122	0.129	0.119
Folacin	1.59	1.32	1.20	1.68	1.50	0.83
Pantothenic acid	31.7	19.9	18.5	19.2	18.3	10.9
Vitamin B_6	13.0	8.5	9.0	12.0	9.5	6.6

are not surprising. Values for the triticale bran fractions were slightly lower than those of the wheat bran because the difference in flour extraction resulted in higher triticale bran fractions compared to wheat. The differences in thiamine content between the wheat and triticale brans, as well as the differences between wheat and rye bran, and between triticale and rye bran were significant statistically.

The rye sample had the lowest flour extraction but the highest amount of thiamine in the flour, which indicates a different vitamin distribution pattern in kernels of rye compared to wheat. The difference in thiamine content between wheat and rye flour, however, was insignificant. Thiamine contents of the triticale flours were significantly lower than those of either the wheat or the rye flour.

The shorts fraction of wheat contained significantly more thiamine than the shorts fractions of the other grains. The spring triticales had thiamine contents intermediate between those of the wheat shorts and those found for the winter triticale and rye shorts.

The data suggest that the thiamine content is an inverse function of shorts yield.

Riboflavin. Among the whole-grain samples, the only statistically significant differences in riboflavin content were between triticale TR 386 and the triticales TR 385 and 6-TA-204.

The flour fractions were essentially identical in riboflavin content. The differences were insignificant.

The bran fractions of the triticales showed riboflavin contents intermediate between those of wheat and rye, which was expected based on the milling data. While the differences in riboflavin values between the wheat and the winter triticale (TR 385 and TR 386) bran fractions were not significant, those between values of these grains and those determined for the rye and the spring triticales (6-TA-204 and 6-TA-206) were significant.

The shorts fraction of the spring triticales was significantly higher in riboflavin than the shorts of the wheat or the winter triticales, yet significantly below the amount found in rye. The amount of rye shorts collected during milling was considerably higher than that of wheat, but the amount of riboflavin in the rye shorts was significantly higher than that in the wheat shorts, pointing again to a different vitamin distribution in kernels of rye compared to wheat.

Niacin. Cheldelin and Williams (18) reported that the enzyme digestion method used in this study extracted only 70% of the niacin from whole-wheat flour compared to autoclaving with 1*N* H_2SO_4. Theoretically, this should result in relatively low values. Comparison of the data found in this study with accepted values in the literature, however, shows an excellent agreement (15,16).

The niacin value of the whole-grain wheat sample was approximately three times as high as that in rye. This difference, which was highly significant, has been reported in the literature (19). The niacin values in the whole-grain samples of both the spring and winter triticales were higher than those found in the rye sample, but not significantly so.

In the flour fractions, significant differences were found only between the wheat flour and flours milled from the winter triticales. The difference in niacin content between wheat and rye flours was considerably smaller than it was in the whole-grain samples, which is surprising. It cannot be explained based on flour extraction rates and has to be due to a different vitamin distribution pattern in rye compared to wheat, which also seems to have been inherited by the triticales.

The bran fractions showed essentially the same significant differences in niacin content as observed for the whole grains, the wheat samples containing approximately three times the level as determined for the triticale brans.

The niacin content of wheat shorts was significantly higher than that in all other shorts. The differences in vitamin value among the triticales and between the triticales and the rye short were insignificant.

Biotin. Whole-grain biotin values determined in this study for wheat and rye agree with values in the literature (20). There were no significant differences between grain samples.

Although there were differences in biotin values among samples within the bran, shorts, and flour fractions of the grains, these were not significant statistically.

Folacin. Folacin values of the whole-grain wheat and rye samples were within the range of values reported in the literature (19,20) using assay procedures comparable to those reported here. Total folacin determinations after conversion of polyglutamate forms and analysis by *L. casei* which uses all forms available to man have been reported to result in higher values (21).

With the enzyme digestion procedure, this was the only vitamin found in higher amounts in whole-grain triticale than in wheat or rye. Rye contained significantly lower value than all other grains. The spring triticales (6-TA-204 and 6-TA-206) were found to have the highest amounts of folacin. The values were significantly different from those found in the whole-grain samples of wheat and the winter triticales.

In the flour fraction of these samples, rye had the highest amount of folacin even though it had the lowest flour extraction rate, which points again to a difference in vitamin distribution within kernels of wheat and rye. The folacin value for the rye flour was significantly higher than all other flour folacin values.

The bran fraction of rye had the lowest folacin content, the value being significantly lower than those determined for all other bran fractions. A comparison of the wheat and the triticale bran fractions indicated only significantly lower values for the winter triticales. The deviation from the folacin pattern observed in the whole grains is due to differences in flour extraction rates.

In the shorts fraction, the rye was found to contain significantly higher amounts than the shorts fractions of the other grains. The differences in vitamin value between the wheat shorts and those from the spring triticales were insignificant. The folacin values for the shorts of the winter triticales were significantly lower than all the other values obtained for the shorts fraction of the grains, as one might expect from the milling data.

Pantothenic Acid. Pantothenic acid values for whole-grain rye and wheat fell within the range reported in the literature (15,19,22). Higher pantothenic acid values have been obtained with biological materials by treatment with alkaline phosphatase and liver enzyme (23). The official procedures of the AACC and AOAC, however, have not adopted as yet all the desirable modifications in procedure.

Whole-grain rye showed the lowest pantothenic acid value, which was significantly different from values determined for wheat and the spring triticales.

Differences in whole-grain values for this vitamin between wheat and the spring triticales were insignificant.

The statistical analysis of pantothenic acid values in the different flours indicated no differences.

The bran fraction of wheat had the highest while that of rye had the lowest pantothenic acid values. The statistical analysis indicated a significant difference between wheat and all other bran fractions and between the bran fractions of the triticales and the rye. Differences among the four triticale bran fractions were insignificant.

The shorts fraction of rye contained the most pantothenic acid. The value was significantly different from those determined for all other shorts fractions and suggests again a difference in vitamin distribution between kernels of wheat and rye. Pantothenic acid values in the spring triticale shorts were the same as those found in wheat shorts. The values for the winter triticales were significantly lower compared with pantothenic acid values of all other shorts fractions.

Vitamin B_6 (Pyridoxine, Pyridoxal, and Pyridoxamine). The B_6 vitamins were found in whole-grain wheat and rye in amounts expected based on literature values (16,19). The differences in vitamin values in the whole grains and in the

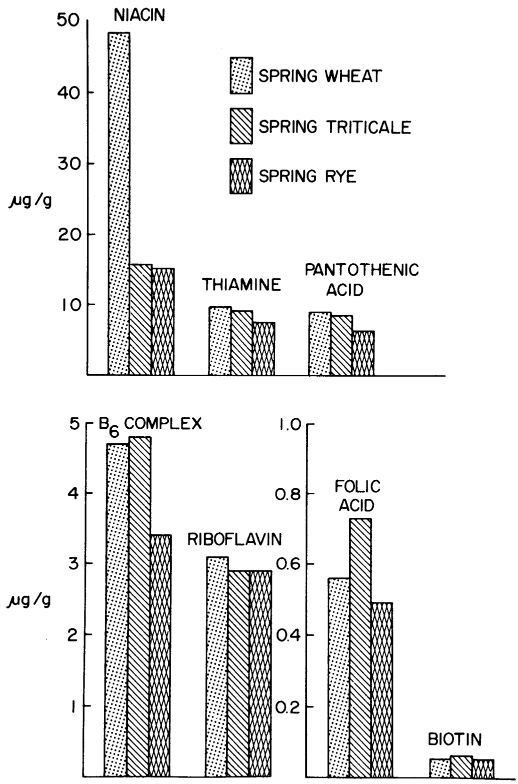

Fig. 1. The vitamin contents of whole grains of spring cultivars of wheat, rye, and triticale.

flour fractions of the different cereal grains analyzed were not large enough to be of any statistical significance.

In the bran fraction, significant differences in B_6 vitamin content were found between wheat and rye and between wheat and the winter triticales.

Although wheat displayed the highest B_6 value for shorts, it was not significantly higher than values for the spring triticales and the rye. The winter triticales, however, were significantly lower in B_6 vitamins than the wheat shorts.

SUMMARY AND DISCUSSION

Comparing the vitamin contents of the whole grains of the spring cultivars of wheat, rye, and triticale grown side by side under the same agronomic and environmental conditions during the 1974 crop year, shown in Fig. 1, it is concluded that, except for the substantially lower amounts of niacin in triticales, the vitamin composition of triticales is comparable to that of wheat and better than that of rye. While some of the vitamins (biotin, folacin, and the B_6 vitamins) were present in slightly higher amounts in triticales compared to wheat, others were found in slightly lower quantities (thiamine, riboflavin, and pantothenic acid).

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Literature Cited

1. SELL, J. L., HODGSON, G. C., and SHEBESKI, L. H. Triticale as a potential component of chick rations. Can. J. Anim. Sci. 42: 158 (1962).
2. BUSCH, R. H., and WILKINS, H. D. Agronomic performance of triticale in North Dakota. N. Dak. Farm Res. 29(3): 29 (1972).
3. ZILLINSKY, F. J., and BORLAUG, N. E. Triticale research in Mexico. Agr. Sci. Rev. 9(4): 28 (1971).
4. LORENZ, K. Food uses of triticale. Food Technol. 26(11): 66 (1972).
5. LORENZ, K., WELSH, J., NORMANN, R., and MAGA, J. Comparative mixing and baking properties of wheat and triticale flours. Cereal Chem. 49: 187 (1972).
6. LORENZ, K., DILSAVER, W., and LOUGH, J. Evaluation of triticale in the manufacture of noodles. J. Food Sci. 37(5): 765 (1972).
7. MATTHEWS, R. H., WEIHRAUCH, J. L., and WATT, B. K. Nutrient content of wheat and rice: Present knowledge, problems, and needed research. Cereal Foods World 20: 348 (1975).
8. ASSOCIATION OF VITAMIN CHEMISTS, INC. Methods of vitamin assay, p. 154. Interscience: New York (1966).
9. BEETNER, G., TSAO, T., FREY, A., and HARPER, J. Degradation of thiamine and riboflavin during extrusion processing. J. Food Sci. 39: 207 (1974).
10. BEETNER, G., TSAO, T., FREY, A., and LORENZ, K. Stability of thiamine and riboflavin during extrusion processing of triticale. J. Milk Food Technol. 39: 244 (1976).
11. DIFCO LABORATORIES. Difco manual of dehydrated culture media and reagents for microbiological and clinical laboratory procedures (9th ed.). Difco Labs.: Detroit, Mich. (1953).
12. KURZ, T. E., LINK, B. F., TUKEY, J. W., and WALLACE, D. L. Short-cut multiple comparisons for balanced single and double classifications. Technometrics 7: 95 (1965).
13. ANDERSON, R. A., STRINGFELLOW, A. C., and GRIFFIN, E. L., Jr. Preliminary processing studies reveal triticale properties. Northwest. Miller 279(2): 10 (1972).
14. LORENZ, K. The history, development and utilization of triticale. Crit. Rev. Food Tech. 5: 175 (1974).

15. WAGGLE, D. H., LAMBERT, M. A., MILLER, G. D., FARRELL, E. P., and DEYOE, C. W. Extensive analyses of flours and millfeeds made from nine different wheat mixes. II. Amino acids, minerals, vitamins, and gross energy. Cereal Chem. 44: 48 (1967).
16. TOEPFER, E. W., POLANSKY, M. M., EHEART, J. F., SLOVER, H. T., MORRIS, E. R., HEPBURN, F. N., and QUACKENBUSH, F. W. Nutrient composition of selected wheats and wheat products. XI. Summary. Cereal Chem. 49: 173 (1972).
17. PEARSON, W. N. Thiamine, p. 80. In: The vitamins, ed. by P. György and W. N. Pearson. Academic Press: New York (1967).
18. CHELDELIN, V. H., and WILLIAMS, R. R. Extraction and assay of nicotinic acid from animal and plant products. Ind. Eng. Chem. Anal. Ed. 14: 671 (1942).
19. JANICKI, J., and KOWALCZYK, J. Der ernährungsphysiologische Wert des Roggens und Weizens mit spezieller Berücksichtigung des Eiweisses und der Vitamine. Getreide Mehl 17: 73 (1967).
20. POMERANZ, Y. Composition and functionality of wheat-flour components, p. 585. In: Wheat: Chemistry and technology (2nd ed.), ed. by Y. Pomeranz. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1971).
21. BUTTERFIELD, S., and CALLOWAY, D. H. Folacin in wheat and selected foods. J. Amer. Diet. Ass. 60: 310 (1972).
22. IHDE, A. J., and SCHUETTE, H. A. Thiamine, nicotinic acid, riboflavin and pantothenic acid in rye and its milled products. J. Nutr. 22: 527 (1941).
23. BIRD, O. D., and THOMPSON, R. Q. Pantothenic acid, p. 222. In: The vitamins, ed. by P. György and W. N. Pearson. Academic Press: New York (1967).

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