EFFECT OF WEATHER, VARIETY, AND LOCATION UPON THE VITAMIN B_1 CONTENT OF SOME KANSAS GROWN WHEATS

by

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INTRODUCTION

Wheat today is not only the world's largest food crop but it also contributes one-fourth to one-third of the total food energy in the form of wheat flour to the human race (Swanson, 1941, p. 40). In view of the prominence it plays in human existence, it is only natural that much interest has been created in studying the problems encountered in the production of this crop.

This berry known as wheat, is readily affected by numerous factors during its growth and development. These factors such as variety, soil, humidity, evaporation, wind velocity, temperature, sunlight, and rainfall may directly affect the chemical composition and physical properties of the wheat. Such factors may only be partially controlled by man. One may choose a certain variety that has been tested and proved to be suitably adapted to a certain soil type, or environment, but over climate and seasonal variation man has no direct control. Certain effects of climate may be somewhat compensated for by such suitable farming practices as proper cultivation to insure good absorption and retention of water by the soil.

Chemical compounds such as protein, carbohydrates, ash, fat, crude fiber, and vitamins are undoubtedly influenced greatly by environmental factors in regard to both quantity and quality. It was to study the effect of environment on the vitamin B_1 content of wheat and to study the relationship of both variety and location on the average thiamin content of some Kansas hard red winter wheat varieties, that the present investigation was undertaken.

Since flours were available for each respective wheat sample, the thiamin content of each flour was determined in order to give a rather complete story of the effect of both variety and location on the thiamin content of wheat and flour.

REVIEW OF LITERATURE

During the last half century considerable study has been made upon the effect of environment on the chemical composition of wheat. The major portion of this research however, has been primarily centered on the protein and ash content of wheat in relation to the environment under which the wheat was produced.

Snyder (1908) concluded from his early investigations that the main factors influencing composition of wheat are as follows: seed, soil, climatic conditions, and storage. His experiments showed also that when nitrogen fertilizer was used alone it retarded maturity, and that minerals used alone hastened maturity.

A very extensive study was also made by Snyder (1893) to determine when the wheat plant absorbs the elements from the soil, and the period during growth when most dry matter is produced. By dividing the time from seeding to maturity into four periods: namely, 50 days after seeding, 65 days after seeding, 81 days after seeding, and 105 days after seeding, he concluded after a very extensive chemical analysis that the ash elements are assimilated before organic matter, that wheat takes up over three-fourths of its nutrients from soil before heading out, and finally that the soil must supply the wheat with seven-eighths of its nitrogen requirement by heading time. His work clearly indicates the existence of critical periods during the growth of wheat, periods which greatly influence the composition of the wheat berry.

The famous Tri-local experiments conducted by LeClerc (1910) indicated the influence of environment upon the composition of wheat. LeClerc maintained that,

> Wheat of any one variety, from any one source, and absolutely alike in chemical and physical characteristics, when grown in different localities, possessing different climatic conditions, yield crops of very widely different appearance, and very different in chemical composition.

It was also suggested from the results obtained that one could conclude that soil and seed play only a small part in influencing composition of crops, and that differences are due mainly to climatic variation.

Further studies of environmental influence on chemical composition of wheat were made by LeClerc and Yoder (1914). Their work covered four years of research in which soils from California, Kansas, and Maryland were put down side by side in each of these localities and cropped with the same variety of wheat. Results obtained showed that the soil does not exert the main influence in determining the physical properties or chemical constituents of wheat. They concluded that environment rather than heredity is the major factor influencing the physical and chemical properties of the wheat, and that climate is the principal environmental factor. In summarizing their results they maintained that climate is the principal factor influencing the protein content of wheat, that the soils studied exerted little or no influence, and that soil had very little influence upon the ash content.

Similar investigations involving transfer of Kansas, Maryland, and California soils between each state were made by Shaw and Walters (1911). They found that the soil nitrogen content had little if any effect upon the quantity of nitrogen found in the wheat, and that some climatic factor influenced sufficiently to cover any effect due to the soil.

Thatcher (1910a) likewise has presented corroborative evidence supporting the minor role that the soil plays. He maintained that the chief and perhaps sole factor in determining the composition of a given variety grown in different localities is the climatic conditions during harvest, and that the soil does little more than influence the moisture supply of the plant.

In reviewing some investigations conducted at the Washington Experiment Station concerning the length of the ripening period Thatcher (1910b) wrote,

> Our conclusions from our work thus far are that differences in chemical composition of wheat, either as between different varieties or different samples of the same variety, are due chiefly, if not wholly, to differences in the rapidity of ripening of the grain; or that any climatic condition which results in shortening the time between the blossoming of the plant and the complete maturity of the seed produces grain having a higher percentage of protein and a correspondingly lower relative proportion of starch than will be present in the same or any other grain which ripens more slowly.

Thatcher (1913) further observed from studies involving transfer of different soils to various locations that there was no relationship between the quantity of wheat protein and the composition of the soil in which they were grown and that the nitrogen content of the soil had very little if any influence on the quantity of protein in the wheat for any given season. It was shown also that the average protein content of wheat varied inversely with the total rainfall. It was indicated that when wheat was shaded artificially certain physiological changes were induced that resulted in an increase of mineral and nitrogenous material and a decrease in amount of carbohydrate formed. Data were presented showing also that high temperatures during the ripening period resulted in wheat high in protein, and that the period of kernel formation was the most important part of the whole growing period.

From very extensive and elaborate studies on the relation of the amount of sunlight to the percentage of protein, Shaw (1913) observed that the protein content did not vary inversely with the amount of sunshine which the wheat plants received, and showed that the maximum amount of protein was stored when there existed an optimum amount of sunshine, which was at a point somewhat below the normal amount of sunshine.

In their studies of the effect of moisture and available nitrogen on the protein content, Neidig and Snyder (1924) wrote as follows:

> 1. A high moisture content in a soil containing sufficient available nitrogen for the maximum growth

and development of the wheat plant, results in high yielding wheat containing a high percentage of protein.

2. A low moisture content in the soil containing an excess of available nitrogen results in a lower yield of wheat but a higher protein content. A part of the higher protein content may be due to a shriveling of the wheat kernel.

3. A high or optimum moisture content in a soil, which has considerable nitrogen available for the wheat plant in the early periods of growth, but an insufficient amount during the fruiting and ripening periods for maximum growth, results in a high yield of wheat of low protein content.

4. A low moisture content in a soil which has sufficient nitrogen available to the wheat plant during the early stages of growth, but an insufficient amount for the fruiting and ripening periods, results in a low yield of wheat, the percentage of protein varying according to the degree to which the wheat is shriveled from moisture deficiency.

These findings also emphasized the influence which is exerted by the availability of nutrients during the critical periods of wheat growth.

The Ploti (Russia) Experiment Station (1901) reported that those conditions which favored high yield caused a reduction in the amount of nitrogenous material found in the plant. High humidity favored carbohydrate assimilation, and drought hastened maturity and favored development of grain high in protein and low in carbohydrates.

After studying some seven winter and five summer wheat varieties from 1898 to 1902, Kharchenko (1905) concluded that the greater the annual precipitation, the less the amount of nitrogen found in the winter wheat, and that there was a direct relationship between the temperature and percentage of nitrogen in winter wheat, namely, the hotter the summer, the greater the nitrogen content.

Early studies on the effect of dry years on the protein content were conducted by Melikov (1900) and he stated,

> On the basis of analyses of different varieties of wheat of the crops of the years 1885-1899, the wheat of southern Russia is rich in nitrogenous substances, the proportion of the latter varying with the weather from 14 to 21.2 percent, being highest in dry years, while in years of good crops it falls to 14 percent.

Widtsoe (1902) made additional studies on the relation of protein content to irrigation, and found that the percentage of protein in the wheat kernel increased greatly as the amount of water applied to the soil decreased. Data show that a plat receiving 30 inches of water produced a wheat with 15.25 percent protein, and that wheat from a plat receiving 7.70 inches contained 26.72 percent protein.

Soule and Vanatter (1903) concluded from their work with Tennessee wheat for the years 1900 to 1903 inclusive that the protein content was highest in 1900 and 1902, when the rainfall was less than normal during the ripening period. This condition gave a short, quick ripening period, which retarded the elaboration and translocation of starch from the stems to the grains, and produced higher protein content. Similar results were obtained by Bailey (1913) who maintained that protein content diminishes as rainfall during the growth period increases.

Swanson (1924) attached much importance to the time between heading and ripening of the wheat plant. He pointed out that this critical period influenced the composition of wheat. Two causes were offered for the high and low protein wheat and corresponding fluctuations in yield, namely, concentration and amount of soil solution, which are directly related to the amount of moisture and available nitrogen present in the soil.

Lyon (1910) from his study of climate and soil in relation to the composition of wheat, maintained, that in the same location the hardness and protein content of the same variety of wheat depended upon the temperature and rainfall, and that a dry period preceding heading resulted in wheat which was harder and higher in protein content. It was also indicated that cool, moist weather at the time of ripening resulted in grain which was softer and which contained more starch.

An important study of the effect of rainfall and evaporation on wheat yields was made by Davis and Pallesen (1940), who presented results indicating that there was a high correlation between total seasonal rainfall and yields of spring wheat. The most beneficial effect was from rain which came during the rapid growing period of the plant, and which reached a maximum about three weeks before average heading date. It was also indicated that at that time each additional inch of rainfall increased the yield about four bushels per acre.

In 1901 Wiley studied the effect of environment on the composition of wheat. He grew a Hungarian wheat with 15.07 percent protein in 11 different localities and found that the wheat with greatest protein content (17.86 percent) was grown at Paso Robles, California, and that the wheat containing the lowest protein content (9.68 percent) was grown at College Park, Maryland. In both places the soil, the fertilizer, and the method of culture were similar but not identical. He concluded therefore that such wide variation was not due to the soil, the fertilizer, or the method of culture, but was due almost entirely to differences in climate. He found that the protein content showed the greatest variation and that the variation in the percentage of ash content was next to that of protein. This variation in ash content was not due to differences in climate as was the variation in protein content, but was probably due to the slight differences in the soils and in the fertilizers.

After considerable study of cereals and of other plants Tollens (1901) stated that when plenty of water was present in the soil, the plants were much more efficient in removing the ash constituents from the soil than when there was a deficiency of water, and therefore that other factors beside plant food within the soil influenced the ash content of plants.

Mangels (1925) in studying the rainfall and daily mean temperatures in relation to protein content of North Dakota wheat for the years 1921 to 1924 found that rainfall was not an important factor in determining the amount of protein for these years. He did find, however, that high temperature was an important factor, for during the period from June to July in 1921 and in 1923, when high temperatures prevailed, the amount of protein was higher than during the corresponding period in 1922 and in 1924, when the daily mean temperature was subnormal.

Bayfield (1930) in studying the effect of environment on soft wheat stated that climate produced more effect than soil upon wheat strength and quality. He found also that rainfall of a 10 to 15-day interval during and immediately before the heading stage influenced the amount of protein found in wheat. It was maintained that soil was found to exert almost as much influence as climate upon protein content of wheat, the heavier soil texture being associated with higher protein content. The climate, soil type, and texture were probably the most important factors affecting the soil in that they greatly influenced the supply of available soil nutrients.

Some work indicating the influence of variety and of climatic factors has been shown by Tressler, Mack, and King (1936) in their experiments with vitamin C content of some vegetables, and it was shown that variety, soil, and environmental conditions had a direct influence upon the ascorbic acid content. Working upon apples, Smith and Fellers (1934) found that the quantity of ascorbic acid is greatly influenced by variety.

Nordgren and Andrews (1941) in their studies of thiamin content of some cereals found for spring wheat that the environmental factors were important in deciding the thiamin content of wheat and that varietal factors were much less important. There was no significant relation between thiamin and protein, but there was a high correlation between ash and thiamin. The analysis of variance for winter wheats showed that both variety and environment were highly significant in affecting the thiamin contents. They found no correlation between ash and thiamin content for winter wheat.

In a study involving 265 commercial hard red spring wheats from western Canada, Johannson and Rich (1942) reported that the thiamin values ranged from 2.2 to 8.0 micrograms per gram with an average of 3.93. They found that the means for each province were not significantly different, and that there existed no relation between thiamin and ash, and between thiamin and protein for the flours milled from these wheats. Hoffman, Schweitzer, and Dalby (1940) also have presented data showing no correlation between thiamin and ash content of wheat.

Conner and Straub (1941), on the other hand, reported values which did indicate a direct relationship between the protein content of wheat and its thiamin content. They reported that thiamin content of wheat appeared dependent on variety, protein content, and environmental conditions under which it was grown.

Harris (1934) studied the thiamin content of wheat as influenced by soil treatment and found that soil treatment had very little if any influence. This observation was made also by Leong (1939). Hunt (1927) obtained results indicating that acid phosphate alone or in a complete fertilizer with KCl and $NaNO_3$, produced wheat with highest vitamin B content.

From all the investigations concerning the factors influencing the chemical composition and physical properties of wheat it seems that the most influential one is climate, the one factor over which man has the least control.

MATERIALS AND METHODS

All samples used in the present investigation were grown at various locations in Kansas (Fig. 1). Seven varieties were used as follows: Turkey, Blackhull, Tenmarq, Nebred, Chiefkan, Kawvale, and Clarkan. Samples were available for the years 1941 and 1942 from Tribune, Colby, Garden City, Meade, Dodge City, Hays, Hutchinson, Kingman, Manhattan, Thayer, and Columbus.

The varieties Turkey, Blackhull, and Tenmarq were grown at all 11 stations; Nebred and Chiefkan were grown at all except Thayer and Columbus; and Kawvale and Clarkan, the two soft wheats, were grown at Manhattan, Thayer, and Columbus.

The locations represented some extreme climatic conditions prevailing in Kansas. For example, Tribune in western Kansas receives a low annual precipitation of 16 inches, and Columbus in southeastern Kansas receives nearly 40 inches (Fig. 1).

Figure 2 shows the annual mean temperature range from 52°F. for northwestern Kansas to 58°F. for the southeastern part of the state.

All wheat samples were milled by Mr. Warren F. Keller on the Kansas State College Allis Chalmers experimental mill to a uniform ash content of approximately 0.425 percent. The milling process consisted of four breaks and seven reductions. In blending each sample Mr. Keller used the fourth-break and low-grade flour streams to make the blend approximately 0.425 percent ash. Since the fourth-break and low-grade flours were

EXPLANATION OF FIGURE 1

Precipitation areas in Kansas as given by Cardwell and Flora (1942).

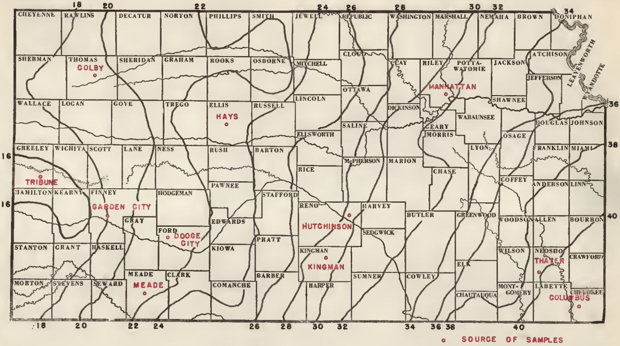


FIG. I. PRECIPITATION AREAS IN KANSAS.
(INCHES)

EXPLANATION OF FIGURE 2

Kansas annual mean temperatures as given by Cardwell and Flora (1942).

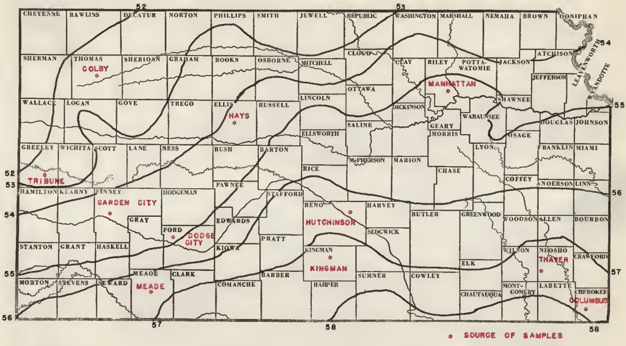


FIG. 2. KANSAS ANNUAL MEAN TEMPERATURES.
(DEGREES FAHRENHEIT)

generally not used because they served only to bring the ash content up to the desired level, the flours used in this investigation were patent flours. Flour yield values were taken from the records of the Department of Milling Industry.

Protein, ash, and moisture analyses for all the wheat and flour samples were determined by approved A. O. A. C. methods and were taken from the official records of the Department of Milling Industry.

The wheat and flour samples were stored in air tight jars in a refrigerated room at approximately 40°F. until thiamin determinations were made.

Before the wheat was placed under refrigeration, it was passed through a Eureka cleaner to remove foreign material. The samples were finely ground in a Hobart grinder, model 275, to pass a 32 W screen.

Thiamin content was determined by a modification of Hennessy's (1942) thiochrome method. Each sample taken for the determination furnished approximately 20 micrograms of thiamin. The method consisted of one hour digestion of the sample in 75 ml of 0.1 N H_2SO_4. The ratio of the volume of solvent and the weight of the sample was kept at 15:1. This ratio was based on the principle that the most efficient extraction is obtained from the use of the largest ratio possible between the volume of the solvent and weight of sample.

After digestion and cooling, the pH was adjusted to 4.0 - 4.5 with 2.5 M sodium acetate, and the extraction mixture was made 0.5 percent with takadiastase. The sample was then digested for two hours at 45 - 50°C., to free any thiamin from its pyrophosphoric ester form. After the enzymatic hydrolysis, the sample was cooled, brought up to 100 ml, and filtered, and an aliquot taken for the oxidation of thiamin to thiochrome.

It should be mentioned at this point that the base exchange step was omitted from the procedure involving the analysis of both wheat and flour. This purification process was omitted after it was found that wheat and flour did not contain sufficient foreign material or other interfering pigments to merit their elimination. Also in the analysis of flour the enzymatic digestion with takadiastase was omitted, as this digestion is required only when some of the thiamin is present as cocarboxylase.

The elimination of these steps whenever possible is a valuable asset to the routine chemist, especially when a large number of samples are to be analyzed. Shetlar and Lyman (1941) in their studies of soft wheat streams have also mentioned the possibility of eliminating these steps when working with certain cereal products.

The aliquot taken for production of thiochrome contained from 0.7 to 2.5 micrograms of thiamin. Two aliquots were taken and placed in separatory funnels, one for the production of thiochrome and the other to serve as a blank. To the first aliquot was added 3 ml of sodium hydroxide-potassium ferricyanide (2.9 ml and 15 percent NaOH and 0.1 ml of 1 percent $K_3Fe(CN)_6$) and 28 ml (depending upon size of cuvette) of isobutyl alcohol, and the contents were shaken for one and one-half minutes. To the aliquot which serves as the blank, was added 28 ml of isobutyl alcohol and 3 ml of 15 percent NaOH, and the contents were likewise shaken for one and one-half minutes. After the alcoholic layer separated distinctly from the lower portion, the lower phase was drawn off and discarded, and the top layer (isobutanol layer containing the extracted thiochrome) was filtered through one-half inch of anhydrous Na_2SO_4, to remove any traces of water.

Readings were made on a Klett fluorophotometer, which was standardized with a standard thiamin solution. This instrument measures the fluorescent light intensity as a potentiometer setting. The fluorescence of the solutions was excited by the ultraviolet light emitted by the type H-4 mercury lamp. The ratio of the fluorescence of the unknown to that of a standard was measured by a two-photocell balanced circuit in which a highly sensitive galvanometer was used only as null instrument. The potentiometer reading was proportional to the intensity of the flurorescent light emitted by the solution tested.

The standard of fluorescence used for this work was not the standard commonly used, quinine sulfate, for it was found that the quinine sulfate was unstable when exposed to the ultraviolet light and, consequently, erroneous readings would result. The method used was a standardization, designed by Dr. E. B. Working, which eliminated the use of quinine sulfate. In the cuvette holder on the right side of the fluorophotometer a mirror was placed which reflected the beam of light coming through an adjustable slot to the photocell. In the left cuvette holder, a Corning fluorescent filter, No. 375 was inserted. Before readings were made, the potentiometer scale was set to read 300 by adjusting the light slot controlling the amount of light reflected from the mirror to the photocell. After the instrument was adjusted to give a potentiometer reading of 300, a reading for a known amount of thiamin was determined, and thus the potentiometer scale was readily calibrated in micrograms per one scale division.

Suitable filters were selected for this determination. The primary filter was a Corning filter No. 586, which gave a maximum transmission at 3700 Angstroms. The secondary filter was a combination of Corning filters Nos. 038 and 430, a combination which gave a maximum transmission of 4600 Angstroms.

Duplicate determinations were made on all samples, and if the duplicates failed to check within 10 percent, a third determination was made and an average of the three determinations taken as the true value.

The thiamin values are listed in the tables as micrograms per gram and milligrams per pound. The thiamin values expressed as milligrams per pound were obtained by multiplying the microgram per gram values by the factor 0.4536.

To verify the reliability of the procedure and technique used, values are listed in Table 1, which are the thiamin contents of the monthly collaborative thiamin check sample issued by the American Association of Cereal Chemists.[1] Listed are the values for the monthly samples obtained by the present investigator together with the average values obtained by some 30 collaborators using the thiochrome method. Table 1 is self explanatory and indicates the reliability of the method and technique involved in these studies.

Table 1. Data illustrating reliability of method and technique used in this study.

Month (1942-43)	Value obtained by present investigator ug/g	Average value[1] ug/g
March	4.78	4.71
April	3.39	3.42
July	3.19	2.67
September	2.58	2.59
October	3.94	3.52
November	3.81	3.89
December	3.73	3.38
January	29.20	26.50
February	3.46	3.81
March	4.03	4.03

[1] Average of some 30 collaborators.

EXPERIMENTAL RESULTS

The thiamin content and chemical analysis of all wheats and flours used in this investigation are shown in Tables 2 and 3.

[1] Records filed in the Department of Milling Industry.

As indicated in Tables 4 and 5 the grand average of 2.03 milligrams per pound of thiamin for the 1942 wheat crop is approximately 15 percent higher than 1.77 milligrams per pound for the 1941 crop. The grand average for the 1941 and 1942 flours are very nearly the same as shown in Tables 6 and 7.

Daily rainfall and daily maximum and minimum temperatures were obtained from April 15 to the date the wheat was ripe. April 15 was considered to be a date sufficiently early in the life of the plant to start collecting weather data to supply adequate information for an investigation of this type.

In order to study the climatological data in relation to their influence upon the thiamin content of wheat, it was necessary to condense the daily weather data into five-day periods. The date the wheat was ripe (fifteenth period) was taken as a starting point for condensing the weather data. The total rainfall and temperatures (maximum and minimum) were compiled in five-day periods from the date of ripening back to April 15, or to a date which insured that each period would contain five days. The weather data for the five day periods are given in Tables 8 to 13 inclusive.

Since the weather conditions for 1941 and 1942 were quite different, it appears from the results that the growing conditions of 1942 were more favorable for thiamin production than were those of the preceding season. The 1941 season had sufficient precipitation throughout the time preceding the heading of the wheat, and during the heading stages rains were so

Table 2. Chemical analysis of 1941 crop samples.[1/]

Serial no.	Variety	Test weight lb.	Protein %	Wheat: ash %	Thiamin ug/g	Thiamin mg/lb	Flour yield % Pat.	Protein %	Flour: ash %	Thiamin ug/g	Thiamin mg/lb
					Hays Experiment Station						
1759	Turkey	59.5	13.9	1.68	3.96	1.80	90.2	12.8	.44	.91	.41
1760	Blackhull	60.6	14.2	1.72	4.14	1.88	91.0	13.4	.41	.93	.42
1761	Tenmarq	59.8	13.1	1.46	3.79	1.72	92.4	12.6	.42	.93	.42
1762	Nebred	59.9	15.2	1.59	3.45	1.56	92.4	14.4	.42	1.07	.49
1763	Chiefkan	63.2	13.4	1.41	3.49	1.58	90.5	12.8	.42	1.13	.51
					Garden City Experiment Station						
1764	Turkey	61.9	14.2	1.72	5.18	2.35	92.1	13.6	.42	1.14	.52
1765	Blackhull	60.3	14.6	1.80	4.41	2.00	92.9	14.4	.42	1.09	.49
1766	Tenmarq	61.0	15.2	1.62	4.38	1.99	92.1	14.2	.44	1.03	.47
1767	Nebred	61.6	15.0	1.77	4.46	2.02	93.7	14.3	.40	1.21	.55
1768	Chiefkan	62.2	14.0	1.77	3.51	1.59	90.7	13.2	.43	.63	.26
					Meade Experiment Field						
1769	Turkey	51.8	14.8	2.12	4.45	2.02	92.7	13.8	.47	1.05	.48
1770	Blackhull	53.2	15.0	1.96	3.92	1.78	89.6	13.9	.46	1.02	.46
1771	Tenmarq	52.9	14.6	1.98	4.47	2.03	92.8	14.0	.46	1.02	.46
1772	Nebred	54.3	14.6	2.07	5.18	2.35	92.1	13.8	.46	1.00	.45
1773	Chiefkan	58.5	14.0	1.74	3.75	1.70	91.7	13.2	.44	.95	.43

Table 2. (Cont.)

				Dodge City Experiment Field							
1774	Turkey	56.8	13.3	1.84	4.78	2.17	90.2	12.4	.44	.88	.40
1775	Blackhull	58.6	13.6	1.82	3.93	1.78	87.0	12.8	.42	.84	.38
1776	Tenmarq	59.0	13.4	1.71	3.74	1.70	90.8	12.4	.42	1.07	.49
1777	Nebred	59.2	13.4	1.66	3.92	1.78	91.3	12.2	.46	1.12	.51
1778	Chiefkan	62.5	13.5	1.56	3.07	1.39	91.8	12.7	.40	1.12	.51
				Hutchinson Experiment Field							
1779	Turkey	55.6	12.1	1.62	3.87	1.76	93.6	11.0	.43	.69	.31
1780	Blackhull	57.5	13.2	1.77	2.93	1.33	91.5	11.9	.42	1.08	.49
1781	Tenmarq	56.9	12.4	1.48	3.99	1.81	90.6	11.4	.41	.78	.35
1782	Nebred	57.0	12.4	1.62	4.07	1.85	92.0	11.1	.44	.96	.44
1783	Chiefkan	60.3	12.8	1.40	3.19	1.45	93.5	12.2	.42	1.18	.54
				Kingman Experiment Field							
1784	Turkey	54.9	13.6	1.87	3.98	1.81	92.0	12.0	.46	1.05	.48
1785	Blackhull	57.0	13.5	1.88	3.57	1.62	91.3	12.4	.44	.84	.38
1786	Tenmarq	57.9	13.0	1.70	4.79	2.17	92.5	12.2	.44	1.33	.60
1787	Nebred	55.5	13.8	1.95	3.08	1.40	92.3	12.8	.47	1.12	.51
1788	Chiefkan	61.2	13.8	1.55	3.30	1.50	91.9	13.4	.41	1.15	.52
				Colby Experiment Station							
1789	Turkey	56.9	13.0	1.54	4.24	1.92	92.4	11.9	.42	.82	.37
1790	Blackhull	57.1	13.6	1.66	3.81	1.73	93.2	12.6	.42	.92	.42
1791	Tenmarq	58.7	12.8	1.55	3.84	1.74	93.4	11.7	.42	.64	.29
1792	Nebred	58.7	13.5	1.51	4.33	1.96	93.7	12.4	.42	.99	.45
1793	Chiefkan	59.9	12.7	1.44	4.61	2.09	91.9	11.8	.42	.81	.37

Table 2. (Concl.)

				Tribune Experiment Station							
1794	Turkey	57.6	12.8	1.62	5.19	2.35	94.6	11.4	.40	.79	.36
1795	Blackhull	57.6	13.1	1.58	5.16	2.34	93.5	12.4	.43	1.27	.58
1796	Tenmarq	57.9	13.0	1.53	4.49	2.04	91.5	12.1	.41	.82	.37
1797	Nebred	59.2	13.4	1.36	3.66	1.66	94.0	12.2	.44	.76	.34
1798	Chiefkan	60.6	12.8	1.48	3.23	1.47	89.8	12.1	.42	.87	.39
				Thayer Experiment Field							
1799	Turkey	58.0	11.2	1.74	4.02	1.82	91.4	10.2	.41	.81	.37
1800	Blackhull	59.2	11.6	1.70	3.66	1.66	86.9	11.0	.40	.93	.42
1801	Tenmarq	58.0	11.6	1.58	3.15	1.43	92.4	10.8	.41	.88	.40
1802	Kawvale	57.8	12.2	1.64	2.36	1.07	96.5	10.6	.43	1.00	.45
1803	Clarkan	60.3	12.3	1.54	2.30	1.32	94.8	11.3	.42	1.93	.88
				Columbus Experiment Field							
1804	Turkey	56.1	10.0	1.54	3.83	1.74	--	No sample			
1805	Blackhull	56.2	10.3	1.52	4.45	2.02	--	No sample			
1806	Tenmarq	58.7	11.1	1.48	4.44	2.01	98.1	10.2	.40	1.33	.60
1807	Kawvale	57.7	10.7	1.50	3.79	1.72	94.7	9.6	.42	1.16	.53
1808	Clarkan	59.4	11.4	1.84	3.75	1.70	100.0	10.4	.40	1.65	.75
				Agronomy Farm - Manhattan							
1681	Kawvale	--	14.9	1.66	3.01	1.37	90.5	12.8	.42	.61	.28
1682	Clarkan	--	12.0	1.74	3.33	1.51	100.0	10.8	.36	.82	.37
1683	Turkey	54.2	13.4	1.69	4.17	1.89	90.5	11.4	.44	.53	.24
1684	Tenmarq	55.8	13.2	1.75	4.01	1.82	92.3	12.4	.42	.80	.36
1685	Blackhull	58.4	13.4	1.65	3.58	1.61	98.6	12.4	.45	1.20	.54
1686	Nebred	57.6	13.6	1.50	3.35	1.52	92.0	12.0	.42	.61	.28
1687	Chiefkan	60.5	13.1	1.50	3.40	1.54	98.4	12.7	.41	.94	.43

1/ % protein, ash and thiamin expressed on 15% moisture basis.

Table 3. Chemical analysis of 1942 crop samples. 1/

Serial no.	Variety	Test weight lb	Protein %	Wheat: ash %	Thiamin ug/g	Thiamin mg/lb	Flour yield % Pat.	Protein %	Flour: ash %	Thiamin ug/g	Thiamin mg/lb
				Hays Experiment Station							
2900	Turkey	57.7	16.6	1.37	5.27	2.39	86.4	15.6	.42	1.16	.53
2901	Blackhull	57.5	16.6	1.89	5.55	2.52	90.0	16.1	.42	1.32	.60
2902	Tenmarq	56.2	16.3	1.97	6.43	2.92	86.9	15.8	.42	1.05	.48
2903	Nebred	56.0	17.2	1.92	5.84	2.65	87.1	16.2	.42	.95	.43
2904	Chiefkan	60.6	16.5	1.30	4.03	1.83	90.0	16.0	.42	1.28	.58
				Garden City Experiment Station							
2907	Turkey	59.2	19.0	2.07	4.78	2.17	88.2	17.5	.44	.97	.44
2908	Blackhull	59.5	18.7	2.14	5.18	2.35	86.8	17.9	.44	1.13	.51
2909	Tenmarq	55.7	18.5	2.24	5.54	2.51	88.2	17.6	.45	1.12	.51
2910	Nebred	59.1	18.6	2.10	5.38	2.44	89.3	17.9	.42	1.27	.58
2911	Chiefkan	59.8	18.8	2.18	5.11	2.32	85.5	18.2	.51	.76	.34
				Meade Experiment Field							
2914	Turkey	58.4	15.8	2.07	4.64	2.10	88.5	14.5	.43	.86	.39
2915	Blackhull	59.2	15.1	2.00	5.10	2.31	97.2	14.7	.43	1.28	.58
2916	Tenmarq	56.9	15.3	1.98	5.36	2.43	88.3	14.5	.43	.89	.40
2917	Nebred	58.4	16.7	1.95	5.58	2.53	93.8	15.8	.48	1.88	.85
2918	Chiefkan	59.5	17.2	1.98	4.51	2.05	86.6	15.7	.44	1.16	.53

Table 3. (Cont.)

					Dodge City Experiment Field						
2921	Turkey	58.9	16.0	1.99	5.66	2.57	88.7	14.7	.46	.65	.29
2922	Blackhull	57.4	15.6	2.00	5.80	2.63	89.1	15.0	.43	.99	.45
2923	Tenmarq	52.5	16.7	2.03	6.67	3.03	84.7	15.5	.46	.87	.39
2924	Nebred	58.7	16.2	1.99	5.94	2.69	89.7	15.2	.43	1.04	.47
2925	Chiefkan	60.3	16.0	2.01	5.31	2.41	87.6	15.1	.47	.57	.26
					Hutchinson Experiment Field						
2928	Turkey	59.3	13.5	1.56	4.55	2.06	93.0	12.2	.43	1.22	.55
2929	Blackhull	59.6	13.8	1.65	4.52	2.05	91.9	12.7	.39	1.38	.63
2930	Tenmarq	58.4	13.8	1.43	5.36	2.43	87.5	12.3	.41	1.29	.59
2931	Nebred	59.7	13.9	1.58	5.25	2.38	100.0	12.4	.40	1.13	.51
2932	Chiefkan	60.5	13.6	1.60	3.56	1.61	89.7	12.6	.41	.83	.38
					Kingman Experiment Field						
2942	Turkey	56.5	13.4	1.65	3.78	1.71	86.3	12.0	.45	.48	.22
2943	Blackhull	57.9	14.8	1.70	3.73	1.69	87.0	12.9	.42	.59	.27
2944	Tenmarq	55.8	15.2	1.71	2.96	1.34	87.0	13.0	.42	.64	.29
2945	Nebred	56.4	15.4	1.72	3.47	1.57	90.6	12.9	.42	.86	.39
2946	Chiefkan	58.5	14.6	1.70	2.76	1.25	87.5	12.6	.42	.64	.29
					Colby Experiment Station						
2949	Turkey	57.6	13.8	1.86	3.74	1.70	87.3	13.4	.42	.56	.25
2950	Blackhull	58.3	15.0	1.94	4.19	1.90	85.6	14.0	.42	1.11	.50
2951	Tenmarq	57.9	13.6	1.75	4.58	2.08	86.2	13.2	.42	.87	.39
2952	Nebred	56.9	15.5	1.86	4.27	1.94	86.4	13.6	.41	.78	.35
2953	Chiefkan	61.6	14.2	1.69	3.81	1.73	85.3	13.0	.40	.59	.27

Table 3. (Concl.)

				Tribune Experiment Station							
2956	Turkey	59.1	16.8	1.92	5.15	2.34	88.9	15.1	.42	1.12	.51
2957	Blackhull	No sample									
2958	Tenmarq	58.9	15.8	1.75	4.74	2.15	86.3	14.6	.42	1.06	.48
2959	Nebred	60.2	16.7	1.80	4.59	2.08	94.0	15.4	.42	1.42	.64
2960	Chiefkan	61.0	15.4	1.86	2.75	1.25	89.7	14.6	.42	1.35	.61
				Thayer Experiment Field							
2963	Turkey	57.1	12.5	1.62	3.90	1.77	88.8	11.0	.41	.83	.38
2964	Blackhull	56.5	13.6	1.74	2.91	1.32	94.4	12.8	.42	1.24	.56
2965	Tenmarq	57.9	12.2	1.48	4.15	1.88	100.0	11.2	.42	1.23	.56
2966	Kawvale	58.0	12.4	1.56	3.35	1.52	92.0	10.8	.44	1.14	.52
2967	Clarkan	60.0	12.4	1.62	4.43	2.01	100.0	11.7	.42	2.40	1.09
				Columbus Experiment Field							
2968	Turkey	61.0	10.2	1.71	3.94	1.79	95.1	9.3	.42	1.18	.54
2969	Blackhull	54.5	11.3	1.82	4.24	1.92	97.6	10.4	.41	1.72	.78
2970	Tenmarq	55.2	10.8	1.62	4.59	2.08	95.8	9.6	.42	1.53	.69
2971	Kawvale	53.3	11.0	1.77	3.25	1.47	94.6	9.8	.43	1.17	.53
2972	Clarkan	55.4	10.7	1.94	2.80	1.27	100.0	9.6	.40	1.33	.60
				Agronomy Farm - Manhattan							
2857	Turkey	54.3	13.4	1.86	4.33	1.96	100.0	11.8	.42	1.25	.57
2858	Tenmarq	54.2	14.4	1.75	5.22	2.37	99.4	12.8	.43	1.25	.57
2859	Blackhull	55.2	13.6	1.86	4.45	2.02	100.0	12.3	.38	1.36	.62
2860	Nebred	56.3	13.2	1.86	3.96	1.80	100.0	12.2	.41	1.55	.70
2861	Chiefkan	57.0	14.6	1.93	4.21	1.91	93.5	13.4	.44	.94	.43
2862	Kawvale	54.5	13.6	1.86	2.94	1.33	99.2	12.4	.42	1.17	.53
2863	Clarkan	58.4	13.6	1.92	2.88	1.31	100.0	12.6	.39	1.63	.74

1/ % protein, ash and thiamin expressed on 15% moisture basis.

Table 4. Thiamin content[1] of 1941 wheats.

Location	Turkey (A)	Tenmarq (A)	Blackhull (A)	Av. 3 varieties (A)	Nebred (B)	Chiefkan (B)	Av. 5 varieties (A & B)	Kawvale (C)	Clarkan (C)	Av. 5 varieties (A & C)
Manhattan	1.89	1.82	1.61	1.77	1.52	1.54	1.68	1.37	1.51	1.64
Hays	1.80	1.72	1.86	1.80	1.56	1.58	1.71			
Colby	1.92	1.74	1.73	1.80	1.96	2.09	1.89			
Tribune	2.35	2.04	2.34	2.24	1.66	1.47	1.97			
Garden City	2.35	1.99	2.00	2.11	2.02	1.59	1.99			
Meade	2.02	2.03	1.78	1.94	2.35	1.70	1.98			
Dodge City	2.17	1.70	1.73	1.88	1.78	1.39	1.76			
Kingman	1.81	2.17	1.62	1.87	1.40	1.50	1.70			
Hutchinson	1.76	1.81	1.33	1.63	1.85	1.45	1.64			
Av. above locations	2.01	1.89	1.79	1.90	1.79	1.59	1.81			
Thayer	1.82	1.43	1.66	1.64				1.07	1.32	1.46
Columbus	1.74	2.01	2.02	1.92				1.72	1.70	1.84
Av. all locations	1.97	1.86	1.80	1.88						
Av. 3 locations[2]	1.82	1.75	1.76	1.78				1.39	1.51	1.77*

1 Expressed in milligrams per lb on 15% moisture basis.

2 Average for Manhattan, Thayer and Columbus only.

* Grand average for all varieties and locations.

Table 5. Thiamin content[1] of 1942 wheats.

Location	Turkey (A)	Tenmarq (A)	Blackhull (A)	Av. 3 varieties (A)	Nebred (B)	Chiefkan (B)	Av. 5 varieties (A & B)	Kawvale (C)	Clarkan (C)	Av. 5 varieties (A & C)
Manhattan	1.96	2.37	2.02	2.12	1.80	1.91	2.01	1.33	1.31	1.80
Hays	2.39	2.92	2.52	2.61	2.65	1.83	2.46			
Colby	1.70	2.08	1.90	1.89	1.94	1.73	1.87			
Tribune	2.34	2.15	--	2.25	2.08	1.25	1.96			
Garden City	2.17	2.51	2.35	2.34	2.44	2.32	2.36			
Meade	2.10	2.43	2.31	2.28	2.53	2.05	2.28			
Dodge City	2.57	3.03	2.63	2.74	2.69	2.41	2.67			
Kingman	1.71	1.34	1.69	1.58	1.57	1.25	1.51			
Hutchinson	2.06	2.43	2.05	2.18	2.38	1.61	2.11			
Av. above locations	2.11	2.36	2.18[3]	2.22	2.23	1.82	2.14			
Thayer	1.77	1.86	1.32	1.66				1.52	2.01	1.70
Columbus	1.79	2.08	1.92	1.93				1.47	1.27	1.71
Av. all locations	2.05	2.29	2.07	2.14						
Av. 3 locations[2]	1.84	2.11	1.75	1.90				1.44	1.53	2.03*

1 Expressed in milligrams per lb on 15% moisture basis.
2 Average for Manhattan, Thayer and Columbus only.
* Grand average for all varieties and locations.
3 Average for eight locations only.

Table 6. Thiamin content[1] of 1941 flours.

Location	Turkey (A)	Tenmarq (A)	Blackbull (A)	Av. 3 varieties (A)	Nebred (B)	Chiefkan (B)	Av. 5 varieties (A & B)	Kawvale (C)	Clarkan (C)	Av. 5 varieties (A & C)
Manhattan	0.24	0.36	0.54	0.38	0.28	0.43	0.37	0.28	0.37	0.36
Hays	0.41	0.42	0.42	0.42	0.49	0.51	0.45			
Colby	0.37	0.29	0.42	0.36	0.45	0.37	0.38			
Tribune	0.36	0.37	0.58	0.44	0.34	0.39	0.41			
Garden City	0.52	0.47	0.49	0.49	0.35	0.26	0.46			
Meade	0.48	0.46	0.46	0.47	0.45	0.43	0.46			
Dodge City	0.40	0.49	0.38	0.42	0.51	0.51	0.46			
Kingman	0.48	0.60	0.38	0.49	0.31	0.52	0.50			
Hutchinson	0.31	0.35	0.49	0.38	0.44	0.54	0.43			
Av. above locations	0.40	0.42	0.43	0.42	0.45	0.44	0.43			
Thayer	0.37	0.40	0.42	0.40				0.45	0.88	0.50
Columbus	--	0.60	--	0.60				0.53	0.75	0.63
Av. all locations	0.39	0.44	0.46	0.43						
Av. 3 locations[2]	0.31	0.48	0.48	0.42				0.42	0.67	0.45*

[1]Expressed in milligrams per lb on 15% moisture basis.
[2]Average for Manhattan, Thayer and Columbus only.
*Grand average for all varieties and locations.

Table 7. Thiamin content[1] of 1942 flours.

Location	Turkey (A)	Tenmarq (A)	Blackhull (A)	Av. 3 varieties (A)	Nebred (B)	Chiefkan (B)	Av. 5 varieties (A & B)	Kawvale (C)	Clarkan (C)	Av. 5 varieties (A & C)
Manhattan	0.57	0.57	0.62	0.59	0.70	0.43	0.58	0.53	0.74	0.61
Hays	0.53	0.48	0.60	0.54	0.43	0.58	0.52			
Colby	0.25	0.39	0.50	0.38	0.35	0.27	0.35			
Tribune	0.51	0.48	--	0.50	0.64	0.61	0.56			
Garden City	0.44	0.51	0.51	0.49	0.58	0.34	0.48			
Meade	0.39	0.40	0.58	0.46	0.85	0.53	0.55			
Dodge City	0.29	0.39	0.45	0.38	0.47	0.26	0.37			
Kingman	0.22	0.29	0.27	0.26	0.39	0.29	0.29			
Hutchinson	0.55	0.59	0.63	0.59	0.51	0.38	0.53			
Av. above locations	0.42	0.46	0.52[3]	0.46	0.55	0.41	0.47			
Thayer	0.38	0.56	0.56	0.50				0.52	1.09	0.62
Columbus	0.54	0.69	0.78	0.67				0.53	0.60	0.63
Av. all locations	0.42	0.49	0.55	0.48						
Av. 3 locations[2]	0.50	0.61	0.65	0.58				0.55	0.81	0.50*

1 Expressed in milligrams per lb on 15% moisture basis.

2 Average for Manhattan, Thayer and Columbus only.

3 Average for 8 locations only.

* Grand average for all varieties and locations.

Table 8. Precipitation in inches for 1941 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location										
	Garden City	Meade	Tribune	Columbus	Colby	Dodge City	Hays	Kingman	Manhattan	Hutchinson	Thayer
1	.45		.62		1.11		.70				
2	.06	.80	.16		--	.16	--			.51	
3	1.30	.28	.34	.64	.59	.68	.97	.34	.37	.24	1.00
4	1.30	2.07	1.31	.07	.27	1.02	.71	--	--	.34	--
5	.55	.32	.34	.48	--	.31	--	1.34	.64	.99	.89
6	--	.99	--	.34	.32	.44	--	1.09	.63	.52	.45
7	.81	--	.90	.03	.51	--	.05	--	--	--	.21
8	.40*	1.20*	.67	.56*	.97*	.85*	.70	--	.65*	.35*	.23*
9	.75	.28	.04*	.17	.86	1.07	1.40*	1.08*	1.41	1.30	.00
10	1.22	1.51	2.71	.20	1.99	.84	.11	--	--	.12	--
11	2.23	.49	1.80	--	2.72	.22	4.93	.20	.13	.97	--
12	--	1.23	.01	2.69	--	2.00	--	.95	.97	3.40	3.83
13	.05	.05	.26	3.59	--	.45	--	3.75	3.01	1.50	2.59
14	2.45	.86	.57	--	.19	.19	.68	.32	.09	--	--
15	2.23	--	.28	--	.14	1.88	.68	--	--	--	--

*Wheat headed during this period.

Table 9. Average maximum temperatures in degrees Fahrenheit for 1941 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location: Garden City	Meade	Tribune	Columbus	Colby	Dodge City	Hays	Kingman	Manhattan	Hutchinson	Thayer
1	58		55		56		62				
2	62	36	62		66	54	64			72	
3	71	63	61	69	66	62	66	74	65	65	70
4	66	67	66	67	69	68	72	68	70	70	68
5	73	74	70	74	72	76	72	72	74	73	74
6	84	89	85	79	86	72	84	75	76	78	79
7	80	87	76	66	78	85	80	78	74	81	76
8	70*	74*	70	80*	74*	72*	75	87	84*	84*	82*
9	83	73	84*	82	85	81	85*	83*	82	78	83
10	76	81	74	82	76	80	80	81	81	86	81
11	76	78	72	86	71	75	77	90	87	86	87
12	73	79	71	81	70	76	74	85	78	78	80
13	84	79	88	80	89	76	84	82	76	74	78
14	88	93	85	75	86	88	92	78	76	81	75
15	92	90	92	85	94	87	92	89	89	91	85

* Wheat headed during this period.

Table 10. Average minimum temperatures in degrees Fahrenheit for 1941 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location										
	Garden City	Meade	Tribune	Columbus	Colby	Dodge City	Hays	Kingman	Manhattan	Hutchinson	Thayer
1	34		32		32		40				
2	40	35	38		38	36	36			49	
3	50	44	48	49	46	46	50	44	40	41	48
4	51	50	48	46	50	54	53	45	40	50	44
5	49	48	46	54	45	52	48	54	56	58	54
6	53	50	51	58	50	52	54	56	50	52	58
7	55	51	53	51	54	57	56	51	48	56	50
8	53*	50*	51	58*	50*	57*	55	61	62*	60*	60*
9	60	57	55*	56	56	59	62*	58*	62	58	58
10	56	56	54	53	53	61	60	58	62	66	59
11	53	51	50	66	50	56	57	64	65	64	68
12	50	48	47	62	47	54	49	60	58	58	62
13	61	54	59	64	60	55	59	60	59	57	64
14	63	58	59	55	60	64	64	52	53	57	55
15	63	64	59	58	60	63	66	62	68	68	61

* Wheat headed during this period.

Table 11. Precipitation in inches for 1942 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location										
	Dodge City	Hays	Garden City	Meade	Hutchinson	Manhattan	Tribune	Columbus	Colby	Thayer	Kingman
1		2.38	2.73	2.06	1.36		1.43		.52	3.01	1.27
2		1.29	.63	1.71	1.73	.50	.10		.04	--	3.50
3	2.02	.07	.35	--	1.05	.51	--	.29	.50	--	.78
4	--	.10	--	--	--	2.19	--	1.37	--	.55	--
5	--	.11	.03	.33	--	--	--	1.11	--	--	.33
6	--	--	--	.06	.36	1.02	.19	1.19	.31	.99	--
7	.26	.22	.24	.10	--	.04	--	.37	.22	--	--
8	.01	--	--	--	.06*	1.49*	--*	.86	--	--	--*
9	.21	4.49*	.16*	--*	--	.68	--	--	--*	--	.48
10	--*	.29	.02	.93	.50	2.70	3.18	.21	1.95	.35*	--
11	.06	1.06	1.47	2.93	3.25	.33	.87	--*	1.07	5.06	.95
12	.91	.78	.33	.17	.88	.90	.19	--	.68	1.51	.49
13	.61	3.67	.41	1.88	3.87	.64	1.27	4.24	.47	4.72	2.02
14	.84	.41	.94	--	1.81	5.99	.74	2.02	.02	2.03	1.03
15	.56	.83	.17	--	.61	1.80	.02	1.58	--	--	2.01

* Wheat headed during this period.

Table 12. Average maximum temperatures in degrees Fahrenheit for 1942 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location										
	Dodge City	Hays	Garden City	Meade	Hutchinson	Manhattan	Tribune	Columbus	Colby	Thayer	Kingman
1		64	57	65	76		64		87	70	70
2		68	64	62	64	66	74		76	75	70
3	68	76	72	76	76	74	66	71	68	76	78
4	72	66	66	72	70	76	80	76	66	69	77
5	71	75	73	78	71	66	70	76	74	73	75
6	70	77	76	80	78	78	70	70	70	74	80
7	60	72	69	78	74	66	84	72	67	72	75
8	68	80	80	76	71*	68*	91*	74	90	76	80*
9	70	95*	95*	94*	90	80	89	69	87*	88	92
10	90*	88	90	90	92	87	78	76	82	92*	94
11	91	81	78	82	84	89	69	87*	78	83	84
12	84	77	74	80	81	82	82	92	76	74	81
13	80	86	87	88	78	67	80	85	73	82	88
14	72	78	80	87	83	82	83	74	84	80	85
15	87	92	91	94	90	80	90	82	85	88	92

* Wheat headed during this period.

Table 13. Average minimum temperatures in degrees Fahrenheit for 1942 by five-day periods (Fifteenth five-day period ends at date ripe).

Period	Location										
	Dodge City	Hays	Garden City	Meade	Hutchinson	Manhattan	Tribune	Columbus	Colby	Thayer	Kingman
1		49	45	48	56		42		45	53	50
2		46	45	42	46	48	42		42	54	50
3	45	50	48	45	53	53	38	53	40	59	54
4	46	44	40	42	48	54	48	52	38	46	46
5	46	48	50	43	46	42	36	58	46	53	51
6	40	47	41	40	53	57	38	46	36	52	49
7	53	41	42	42	45	44	50	51	40	52	54
8	42	52	54	46	49*	46*	53*	54	55	54	54*
9	46	64*	61*	57*	66	57	58	52	56*	70	68
10	60*	62	61	59	66	66	54	53	56	67*	64
11	66	62	58	59	66	68	50	69*	54	68	64
12	63	52	50	54	60	65	58	65	51	57	55
13	61	61	62	56	55	50	57	68	56	61	62
14	53	61	59	61	62	63	58	58	58	62	62
15	62	63	63	64	68	65	54	61	53	72	68

* Wheat headed during this period.

plentiful that almost twice as much fell during this time as during the same period of growth in 1942. After the heading, rains were frequent and plentiful throughout the ripening stages, and the weather became increasingly warmer as the ripening progressed. The 1942 season preceding the heading stage was characterized by a scarcity of moisture which lasted until after heading. There was approximately twice as much precipitation during the 1941 heading period as during the heading period for 1942. Rains during 1942 were more frequent and plentiful after heading than during the preceding year. In 1942 warm weather followed the heading stage, but it gradually became cooler during the late stages of ripening.

After a brief summary of the weather conditions that existed during 1941 and 1942, data are presented to show the relationship of thiamin to the other constituents in the wheat kernel.

Table 14 gives the correlation coefficients as obtained from the pure wheat varieties studied. Statistically, it shows no relation between thiamin and wheat ash contents or thiamin and wheat protein contents for either the 1941 or 1942 crops. These results are in agreement with those of Hoffman, Schweitzer, and Dalby (1940) and Nordgren and Andrews (1941), who found no relation between thiamin and ash contents for winter wheats.

Table 14. Correlation coefficients between thiamin and wheat ash content and thiamin and wheat protein content for the 1941 and 1942 crops.

Variety	Ash corr. coef. 1941	Ash corr. coef. 1942	Protein corr. coef. 1941	Protein corr. coef. 1942
Turkey	.15	.57	.45	.69*
Blackhull	-.42	.65*	.48	.58
Tenmarq	.31	.55	.36	.47
Nebred	.40	.45	.18	.55
Chiefkan	-.02	.86**	-.20	.64

* Significant.

** Highly significant.

As shown in Table 14, only two varieties gave a significant correlation coefficient for thiamin and ash content. They were Blackhull (probability of five percent) and Chiefkan (probability of one percent) both from the 1942 crop. The only variety showing a significant relation between the thiamin and protein content was Turkey of the 1942 crop. It is interesting to observe that the correlation between thiamin and wheat ash contents and thiamin and wheat protein contents ranged all the way from a negative to a positive correlation. Very definite trends were noted when both of these constituents were plotted against thiamin content. In nearly every case, however, there appeared one or two locations which were very much out-of-line and which resulted in nonsignificant correlation coefficients. No explanation can be offered for these locations which failed to fit the trend. Probably these fluctuations were caused by one or perhaps several factors which were not considered because their presence was not known. Possibly, if these interfering factors were accounted for, a definite relation might be established between the thiamin and wheat ash contents or thiamin and wheat protein contents or perhaps both. These disturbing factors might be attributed to some soil influence which was not accounted for when these relationships were studied.

It is to be regretted that sufficient data were not available for a study of the soil as an influence upon the thiamin content of wheat, since that influence might have been great. If the soil, however, were the dominant factor influencing thiamin content of wheat, it might be expected that a certain region or location would tend to produce wheat high in thiamin content from one season to another, but, as Tables 4 and 5 show, this does not appear to be the case. In 1941 Garden City, Meade, and Tribune, all located in the western portion of Kansas (Figs. 1 or 2) were the high thiamin producing areas, as shown in Tables 4 and 5.

In 1942 the only high thiamin producing area in western Kansas was Garden City. The highest producing areas were Dodge City and Hays, located near central Kansas, as shown in Figs. 1 or 2. From these observations it may appear that the western area of Kansas may tend to produce wheat high in thiamin content, but when studying the values listed in Tables 4 and 5, it is apparent that there is another factor or factors which exert a greater influence than the soil in view of the fact that the same locations failed to produce wheat high in thiamin for 1941 and 1942.

Since the heading and blossoming stages in the life of the wheat plant are known to be very critical periods, it is probable that weather conditions during this time greatly influence the composition of the wheat plant, Swanson (1941).

Table 15. Total precipitation and average minimum temperatures for the seven day interval following heading (excluding two days for blossoming) for 1941.

Location	Thiamin (mg/lb)	Precipitation (inches)	Av. minimum temperature (F.°)
Garden City	1.99	1.89	57.4
Meade	1.98	1.71	58.6
Tribune	1.97	2.71	55.1
Colby	1.89	2.20	55.6
Dodge City	1.76	1.91	61.7
Hays	1.71	0.14	60.0
Kingman	1.70	0.40	58.7
Manhattan	1.68	1.41	58.4
Hutchinson	1.64	0.80	61.9

In Table 15 are given the total rainfall and average minimum temperatures for each location during the seven-day interval for 1941 omitting a period of two days after heading which allows for the wheat to be in blossom, and assuming that the wheat was in blossom two days after heading. Plates I and II indicate the relationship of thiamin content to total precipitation and average minimum temperature for the seven-day interval following heading, excluding two days for blossoming. As the rainfall increased during this interval, it resulted in wheat higher in thiamin content, and the correlation coefficient was 0.73, with a probability of three percent. For the same period the average minimum temperature and thiamin content were negatively related, and a negative correlation coefficient of -0.67, with a probability of five percent was obtained. This relationship indicates that during the period following blossoming, cool weather with increasing rainfall resulted in greater amounts of thiamin in the wheat berry.

For the same interval during the 1942 growing season no significant relationship was found between the precipitation and the thiamin content, although a positive trend was evident as shown in Plate I. Plate II shows the relationship between the average minimum temperature and thiamin content, a relationship which lacked significance but which showed a slightly negative trend as was found in 1941.

The scarcity of rain preceding and immediately following the heading period may be a possible explanation for the failure to find as significant a relationship for the 1942 season as was found for the preceding year.

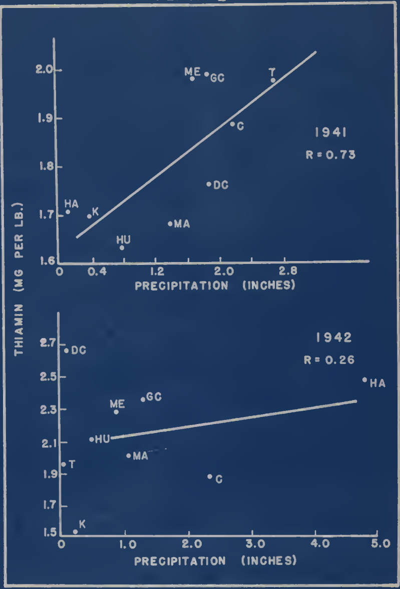
Plate III illustrates the relationship of thiamin content and test weight. There was a slightly positive relationship for thiamin content and test weight for 1941, but the relationship was negative for 1942. Correlation coefficients of 0.39, which was nonsignificant, and -0.866, which was highly significant, were obtained for the 1941 and 1942 data, respectively. The

EXPLANATION OF PLATE I

Thiamin content of 1941 and 1942 wheat crops and amount of precipitation for the seven day interval following heading (excluding two days for blossoming).

C	Colby	K	Kingman
DC	Dodge City	Ma	Manhattan
GC	Garden City	Me	Meade
Ha	Hays	T	Tribune
Hu	Hutchinson		

PLATE I

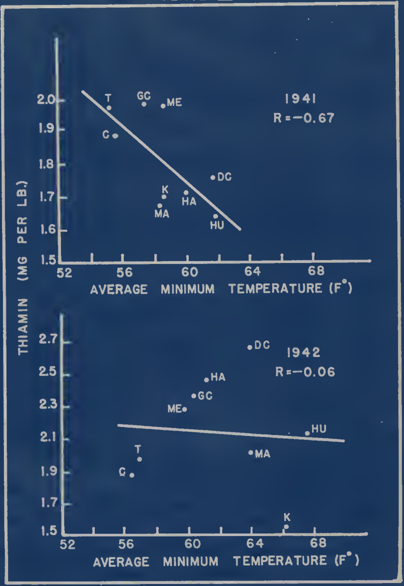

THIAMIN (MG PER LB.)
2.0
1.9
1.8
1.7
1.6
ME
GC
T
C
DC
HA
K
MA
HU
1941
R = 0.73
0
0.4
1.2
2.0
2.8
PRECIPITATION (INCHES)
2.7
2.5
2.3
2.1
1.9
1.7
1.5
DC
ME
GC
HU
MA
T
C
K
HA
1942
R = 0.26
0
1.0
2.0
3.0
4.0
5.0
PRECIPITATION (INCHES)

EXPLANATION OF PLATE II

Thiamin content of 1941 and 1942 wheat crops and average minimum temperature for the seven day interval following heading (excluding two days for blossoming).

C - Colby	K - Kingman
DC - Dodge City	Ma - Manhattan
GC - Garden City	Me - Meade
Ha - Hays	T - Tribune
Hu - Hutchinson	

PLATE II

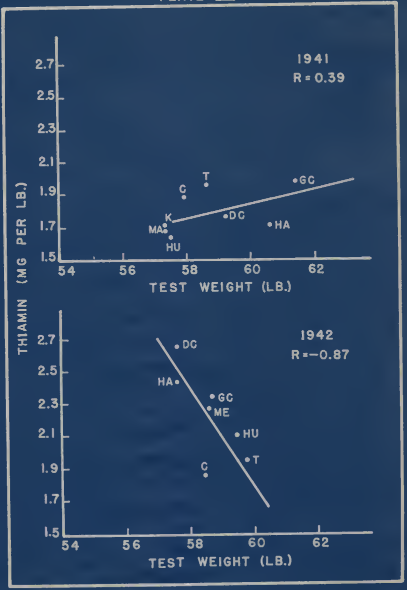

THIAMIN (MG PER LB.)
2.0
1.9
1.8
1.7
1.6
1.5
T
GC
ME
C
DC
K
HA
MA
HU
1941
R=−0.67
52
56
60
64
68
AVERAGE MINIMUM TEMPERATURE (F°)
2.7
2.5
2.3
2.1
1.9
1.7
1.5
DC
1942
R=−0.06
HA
GC
ME
HU
T
MA
C
K
52
56
60
64
68
AVERAGE MINIMUM TEMPERATURE (F°)

EXPLANATION OF PLATE III

Thiamin content and test weight for 1941 and 1942 wheat crops.

C	- Colby	K	- Kingman
DC	- Dodge City	Ma	- Manhattan
GC	- Garden City	Me	- Meade
Ha	- Hays	T	- Tribune
Hu	- Hutchinson		

PLATE III


1941
R = 0.39
THIAMIN (MG PER LB.)
2.7
2.5
2.3
2.1
1.9
1.7
1.5
T
C
GC
K
DC
MA
HA
HU
54
56
58
60
62
TEST WEIGHT (LB.)
1942
R = −0.87
DC
HA
GC
ME
HU
T
C
TEST WEIGHT (LB.)

data of Meade in 1941, and of Manhattan and Kingman in 1942 were omitted when the coefficients between thiamin content and test weight were calculated, as the wheat from these locations showed reduced test weights due to weathering. The average texture analysis, that is, percentage of vitreous kernels, for Manhattan and Kingman was 20 percent and 40 percent, respectively. Such data were not available for Meade.

Plate IV shows the relationship of thiamin content to the length of the filling and ripening period, that is, the number of days between heading and the date of ripening. For 1941 the points lay relatively close together, and what relationship there was tended to be positive, but was nonsignificant. The relationship for 1942 was just opposite to that for 1941; the correlation coefficient was negative but just lacked significance.

In 1942 the shorter the time between heading and the date of ripening, the higher the thiamin content. This fact supports the theory that high protein wheat will be high in thiamin content because longer ripening periods favor starch synthesis and bring about a decreased percentage of protein (Bailey, 1925). The results for 1941 for this same relationship fail to agree with the results for 1942.

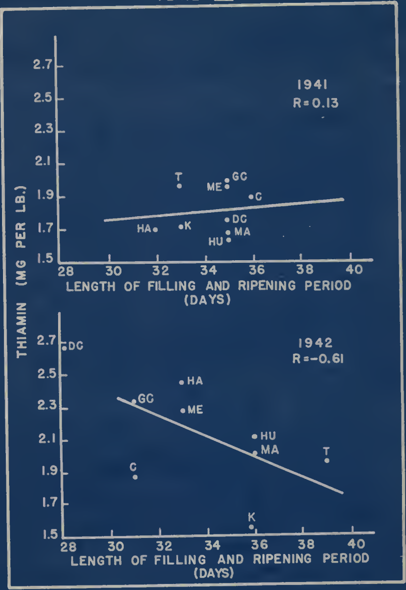
Plentiful rains during the ripening period are known to favor and accelerate the rate of starch synthesis. Plate V shows the relationship between thiamin content and total precipitation from heading to date of ripening to be nonsignificant for both years. In 1941 however, there was a very pronounced

EXPLANATION OF PLATE IV

Thiamin content and length of filling and ripening period (heading to date ripe) for 1941 and 1942 wheat crops.

C - Colby
DC - Dodge City
GC - Garden City
Ha - Hays
Hu - Hutchinson
K - Kingman
Ma - Manhattan
Me - Meade
T - Tribune

PLATE IV

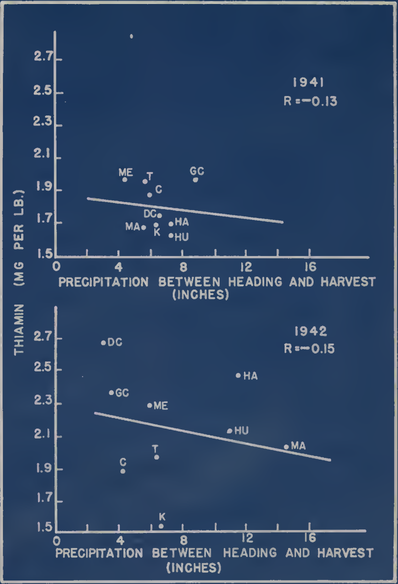

1941
R=0.13
THIAMIN (MG PER LB.)
2.7
2.5
2.3
2.1
1.9
1.7
1.5
T
GC
ME
C
DC
HA
K
MA
HU
28
30
32
34
36
38
40
LENGTH OF FILLING AND RIPENING PERIOD
(DAYS)
1942
R=-0.61
DC
HA
GC
ME
HU
MA
T
C
K
LENGTH OF FILLING AND RIPENING PERIOD
(DAYS)

EXPLANATION OF PLATE V

Thiamin content and total precipitation between heading and harvest for 1941 and 1942 wheat crops.

C - Colby	K - Kingman
DC - Dodge City	Ma - Manhattan
GC - Garden City	Me - Meade
Ha - Hays	T - Tribune
Hu - Hutchinson	

PLATE V


1941
R = −0.13
ME
T
C
GC
DC
MA
K
HA
HU
2.7
2.5
2.3
2.1
1.9
1.7
1.5
0
4
8
12
16
PRECIPITATION BETWEEN HEADING AND HARVEST
(INCHES)
THIAMIN (MG PER LB.)
1942
R = −0.15
DC
GC
ME
HA
HU
MA
T
C
K
PRECIPITATION BETWEEN HEADING AND HARVEST
(INCHES)

trend which showed a negative relationship between thiamin content and precipitation. The amount of precipitation at Garden City, however, was considerably out-of-line, and the resulting correlation coefficient was nonsignificant. The 1942 data also indicated that there existed a negative relationship between these two factors, but for this particular season the points were widely scattered.

The results in Tables 4 and 5 indicate differences due to both variety and location. When these data were analyzed statistically, it was found that there existed a significant difference between both varieties and locations.

From the data presented, no definite and conclusive statements can be made in regard to what influences the thiamin content of wheat. However, a theory may be advanced purely from the trends indicated. Evidently from the results obtained it seems that the soil is of secondary importance in influencing thiamin content of wheat. The relationships between thiamin and ash contents or between thiamin and protein contents for the pure varieties were statistically nonsignificant. Some trends, however, were noted. From the 1942 test weight values it appeared that the thiamin content was lower at high test weights. This relation was not evident from the 1941 data, but it might possibly have been due to the fact that in 1942 there was very much less precipitation during the earlier part of the growing season and that the rains did not come until much later. Therefore, not so much fluctuation in the test weights could be expected as would have been the case in 1941, when rains were plentiful throughout the period studied. In 1941 the average test weights ranged from 54 to 62 pounds, but in 1942 the range was only from 55 to 60 pounds. Consequently for 1942 much less variation in test weights was noted.

Bailey (1925) maintained that a longer growing season with cool temperature and abundant supply of moisture favors starch production. In 1941 no relation was found between the filling and ripening period and thiamin content, but in 1942 a negative relation was strongly indicated. The 1942 season had much more rainfall and cooler temperatures during the last three weeks of the ripening period than did the preceding season, and therefore, the latter part of the 1942 season might be expected to be much more favorable to the synthesis of starch than 1941.

A study of the effects of total precipitation from heading to harvest in relation to thiamin content shows the trend to be negative for 1941 and 1942. This finding indicates that conditions favoring starch formation also favor lower thiamin content for wheat.

From the foregoing facts it appears quite definitely that thiamin is negatively related with starch synthesis; that is, when factors are favorable for starch production, the thiamin content of the resulting wheats is lower. Factors which are favorable to starch formation will result in wheat with a lower percentage of protein, and factors unfavorable to starch production will generally produce wheat with a high percentage of protein and ash. The thiamin content of wheat appears to be related to factors or conditions that result in higher percentages of protein as indicated by the 1942 data.

In summarizing, it appears that thiamin is associated with environmental conditions which favor high protein and high ash contents of wheat. Apparently there did exist, however, some unknown factor which was not taken into consideration and which tended to make the correlation between thiamin and wheat protein or ash contents nonsignificant. Another possible explanation why wheat protein or wheat ash could not be definitely correlated with thiamin may be excessive variation within the small number of samples used in this investigation.

It has generally been assumed that wheat with a high thiamin content would yield a flour that was higher in thiamin content than a flour milled from a wheat low in thiamin content. The results obtained in this study as shown in Tables 4 to 7 inclusive indicate that a wheat high in thiamin content does not necessarily mean that the resulting flour milled from this wheat will be higher in thiamin content than flour milled from a wheat of low potency. Statistically, no relationship was established between the thiamin content of wheat and flour for either 1941 or 1942. In fact for 1941 there existed a slight negative trend between the thiamin content of wheat and flour. The failure of high thiamin content wheats to result in flours higher in thiamin content than flours milled from lower thiamin content wheats may have been due to varietal differences, or to the fact that the thiamin was not laid down in the same fashion in the various parts of the berry from one wheat to another, or to differences in milling characteristics of the wheat.

The flours used in this investigation were patent flours which were milled to an approximately uniform ash content of about 0.425 percent. Table 16 shows the thiamin content of flours milled on the Kansas State College 65-bbl. mill and the Allis Chalmers experimental mill. From the experimental mill both straight and patent flours were available, but from the 65-bbl. mill only a straight flour was available. Table 16 shows that the thiamin contents of the flours milled on the large mill and the experimental mill are, for all practical purposes, identical and that any slight variability existing was well within the experimental error.

All the patent flours with the exception of Pawnee were lower in thiamin content than the straights. The Pawnee patent was the same as the straight, for the straight for this variety milled out at a 0.40 percent ash content. The patent flours were expected to be lower in thiamin content than the straight flours because in blending a patent to a 0.425 percent ash content the fourth and low-grade flour streams were generally omitted. It is considered that these patent flours represent the type of flours which would be obtainable from similar wheat if a commercial flour of the designated ash content were to be milled from such wheat.

Table 16. Comparison of the thiamin content of flours milled on the 65-bbl. mill and experimental mill (Thiamin, protein, and ash contents on 15% moisture basis).

Serial no.	Variety	Wheat thiamin ug/g	Mill and grade	Yield[1] %	Patent %	Clear %	Flour thiamin ug/g	Protein %	Ash %
4060	Tenmarq	3.25	65-bbl. St	71.1			1.37	11.4	.44
C720			Exp St	71.8			1.45	11.9	.46
C721			Exp Pat 96%	72.5	69.6	2.9	1.06	11.4	.42
4058	Pawnee	2.50	65-bbl. St	75.2			1.24	11.9	.38
C722			Exp St	75.5			1.28	12.2	.40
C723			Exp Pat 100%	73.9	73.9	0.0	1.28*	12.0	.40
4056	Turkey	2.30	65-bbl. St	73.0			1.16	11.6	.42
C716			Exp St	74.7			1.22	11.9	.46
C717			Exp Pat 95%	72.6	69.0	3.6	.89	11.6	.42
4057	Chiefkan	2.44	65-bbl. St	69.6			1.10	12.4	.51
C724			Exp St	73.1			1.22	12.8	.52
C725			Exp Pat 88%	72.6	63.8	8.8	.90	12.6	.48
4059	Blackhull	2.64	65-bbl. St	69.3			1.10	12.2	.42
C718			Exp St	69.9			1.18	12.6	.45
C719			Exp Pat 94%	69.8	65.6	4.2	.86	12.2	.42

[1] Dry moisture basis.
* Same as straight flour.

The thiamin contents of both the straight and patent flours showed the same trend; namely, the variety which produced a straight flour that was highest in thiamin or B_1 content, likewise produced a patent flour which was the highest of all the patent flours. Tenmarq yielded a straight flour which possessed more B_1 than all the other straight flours from the various varieties; likewise the Tenmarq patent was higher in thiamin content than all the other patent flours. The Turkey and Chiefkan straight and patent flours were the next highest in thiamin content of all the other straight and patent flours. The Blackhull straight flour was the lowest in thiamin content of all the straights, and likewise the patent flour was lowest of all the patents. Therefore, the same trend was indicated regardless of whether the flours in question were straight or patent flours milled to a constant ash basis.

From the data given in Table 16 it may be concluded that the thiamin contents of the flour samples used in this study would be quite comparable with the thiamin contents of the flours had they been milled on a commercial mill.

SUMMARY AND CONCLUSIONS

1. A study was made with five winter wheat and two soft wheat varieties grown in Kansas to ascertain the effect of weather, variety, and location upon the vitamin B_1 content of the wheat. In addition, the thiamin content was determined on

the flour for each respective wheat, and the relation between thiamin contents of the wheats and flours was studied.

2. Seasonal variation influenced the thiamin content of wheat. The thiamin content of the 1942 wheat crop was 15 percent higher than that of the 1941 crop; also the ash and protein contents were considerably higher than those of 1941.

3. Thiamin content of wheat was influenced by both variety and location. The differences due to variety and location are significantly different as shown by an analysis of variance.

4. The thiamin content of hard winter wheat varieties ranked as follows for 1941: Turkey (highest), Tenmarq, Blackhull, Nebred, and Chiefkan; for 1942: Tenmarq (highest), Nebred, Blackhull, Turkey, and Chiefkan. The flours for the same varieties for 1941 ranked as follows: Blackhull (highest), Nebred, Chiefkan, Tenmarq, and Turkey; for 1942: Nebred (highest), Blackhull, Tenmarq, Turkey, and Chiefkan.

5. No significant relationship could be found between the thiamin and wheat ash or wheat protein contents although a trend was noted.

6. The thiamin content of wheat appeared to be negatively related with conditions favoring starch synthesis.

7. There appeared to be some factors which were not taken into consideration in this study and which may have prohibited the correlation of wheat ash or wheat protein with thiamin content; or else there was an excessive variation within the samples used.

8. Conditions favoring high percentage protein and ash content wheats appeared to favor high thiamin content wheat.

9. No correlation was found between the thiamin content of wheat and flour milled from the wheat; therefore, high thiamin content wheat does not necessarily mean that the flour milled from this wheat will be higher than flour milled from a low thiamin content wheat.

10. The thiamin contents obtained for the patent flours used in this study would be comparable with those of the flours had they been milled on a commercial mill.

STATISTICAL ANALYSIS

Not all of the varieties of wheat used in this study were available from each of the 11 locations in Kansas. In order to simplify the statistical analysis of the results, the data from each year for both wheat and flour were broken down into the following three blocks: (1) a five-variety, nine-location block, (2) a three-variety, 11-location block, and (3) a two-variety, three-location block. This breakdown of the data was necessary to insure solid blocks of data for the simplification of the analysis of variance.

The first block was composed of Turkey, Blackhull, Tenmarq, Nebred, and Chiefkan grown at Hays, Garden City, Meade, Dodge City, Hutchinson, Kingman, Colby, Tribune, and Manhattan. The second block consisted of Turkey, Blackhull, and Tenmarq grown at Hays, Garden City, Meade, Dodge City, Hutchinson, Kingman, Colby, Tribune, Manhattan, Thayer, and Columbus; while the third block consisted of Kawvale and Clarkan grown at Manhattan, Thayer, and Columbus.

In 1941 the Turkey and Blackhull flour samples were missing from Columbus, and in 1942 the Blackhull wheat was not available from Tribune. Values were supplied for the missing data with the aid of the following formula as given by Snedecor (1940):

$$X = \frac{tT + bB - S}{(t-1)(b-1)}$$

where

X = estimated value for missing sample
t = number of varieties
b = number of locations
T = sum of all locations within the same variety as the missing sample
B = sum of all the varieties within the same location as the missing sample
S = sum of all observed values

In blocks where the missing values were calculated the analysis of variance had one modification: the number of degrees of freedom for location by variety interaction and the error term (determination within subclass) each was decreased by unity, and thus the total was decreased by two times unity.

For each block (both wheat and flour) on which the analysis of variance was performed, if the locations or varieties gave a significant F-test, a t-test ($t = \frac{\bar{d}}{s_{\bar{d}}}$) was used to determine which varieties and locations were contributing to this significance. In all cases the interaction term was used as the variance and $s_{\bar{d}}$ was calculated using the following formula:

$$s_{\bar{d}} = \sqrt{\frac{2V}{n}}$$

There was a very definite interaction between variety and location as every block (both wheat and flour) gave a highly significant interaction when compared with the error term. This interaction indicated that the varieties failed to line up the same from one location to another. When both variety and location were tested, the interaction was used as the error term.

Table 17 shows the analysis of variance for the five-variety, nine-location block for 1941 wheats.

Table 17. Analysis of variance for the five-variety, nine-location block, 1941 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	8	8.03	1.00	2.13	2.25	3.12
Varieties	4	8.12	2.03	4.32**	2.67	3.97
Interaction (Loc x Var)	32	14.90	.47	15.16**	1.71	2.13
Determination within sub-class	45	1.38	.031			
Total	89	32.43				

** Highly significant.

For Table 17 the locations were nonsignificant, but the varieties gave a highly significant F-test. Using the t-test it was found that a difference of 0.47 micrograms was required for the five percent level of significance and 0.63 micrograms for the one percent level when comparing the average thiamin content of one variety with another over all stations. It was found that Turkey was significantly higher in thiamin content than Blackhull, Nebred, and Chiefkan, and that Tenmarq was significantly higher than Chiefkan.

The analysis of variance for the three-variety, 11-location block for 1941 wheats is given in Table 18. The locations as indicated gave a significant F-ratio and were thereby analyzed further by means of the t-test. It was found that the least significant difference for the five percent level was 0.22 micrograms, and 0.29 micrograms for the one percent level when the average thiamin content of one location was compared with

Table 18. Analysis of variance for the three-variety, eleven-location block, 1941 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	10	9.87	.99	3.09*	2.35	3.37
Varieties	2	1.58	.79	2.47	3.49	5.85
Interaction (Loc x Var)	20	6.34	.32	11.43**	1.90	2.49
Determination within sub-class	33	.92	.028			
Total	65	18.71				

* Significant.

** Highly significant.

another over all varieties. The t-test indicated that the thiamin content of wheat from Tribune was significantly higher than that from all other stations. The thiamin content of wheat from Garden City was significantly higher than that from all other stations except that of Tribune. The thiamin contents of wheats from Meade and Columbus were not significantly different but were significantly higher than the thiamin contents of wheats from Hays, Colby, Manhattan, Thayer, and Hutchinson. The thiamin content of wheat from Dodge City was not significantly higher than the thiamin contents of wheats from Manhattan, Thayer and Hutchinson. The thiamin contents of wheats from Kingman, Hays, Colby, and Manhattan were significantly higher than the thiamin contents of wheats from Thayer and Hutchinson.

In Table 19 is given the analysis of variance for the two-variety, three-location block for 1941 wheats. The locations yielded a significant F-ratio and the data for the locations were further examined for significance by means of the t-test. It was found that the least significant difference required for the five percent level of significance was 1.10 micrograms and 2.53 micrograms for the one percent level. The t-test indicated that wheat from Columbus was significantly higher in thiamin content than wheat from Thayer.

Table 19. Analysis of variance for the two-variety, three location block, 1941 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	2	2.65	1.33	22.16*	19.00	99.01
Variety	1	.06	.06	.46	18.51	98.49
Interaction (Loc x Var)	2	.26	.13	13.00**	5.14	10.92
Determination within sub-class	6	.07	.01			
Total	11	3.04				

* Significant.

**Highly significant.

The analysis of variance for the five-variety, nine-location block for the 1941 flours is given in Table 20. This table showed that neither the varieties nor locations were significantly different; therefore no t-test was performed on the data.

Table 20. Analysis of variance for the five-variety, nine-location block, 1941 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	8	.69	.086	1.34	2.25	3.12
Varieties	4	.23	.056	.88	2.67	3.97
Interaction (Loc x Var)	32	2.06	.064	16.00**		
Determination within sub-class	45	.20	.004			
Total	89	3.18				

** Highly significant.

Table 21 shows the analysis of variance for the three-variety, 11-location block for the 1941 flours. As given in Table 21 the locations were significantly different. The least significant difference was 0.30 micrograms and 0.41 micrograms for the five percent and one percent levels respectively when the average thiamin content of one location was compared with another over all varieties. The t-test was used and the average thiamin contents of the locations were compared to see which were significantly different. The flour from Columbus was shown to be significantly higher in thiamin content than all other stations and flour from Garden City was significantly higher in thiamin content than flour from Colby, and the thiamin contents of flour from all other locations were not significantly different.

Table 21. Analysis of variance for the three-variety, 11-location block, 1941 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	10	1.45	.145	2.46*	2.41	3.51
Varieties	2	.23	.12	1.97	3.55	6.01
Interaction (Loc x Var)	18	1.10	.061	16.94**	1.95	2.59
Determination within sub-class	31	.11	.0036			
Total	61	2.89				

* Significant.

** Highly significant.

In Table 22 is given the analysis of variance for the two-variety, three-location block for the 1941 flours. The locations and varieties both failed to give a significant F-ratio; therefore no t-test was performed on the data.

Table 22. Analysis of variance for two-variety, three-location block, 1941 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	2	1.41	.71	5.46	19.00	99.01
Varieties	1	.88	.88	6.77	18.51	98.49
Interaction (Loc x Var)	2	.26	.13	18.57**	5.14	10.92
Determination within sub-class	6	.04	.007			
Total	11	2.59				

** Highly significant.

In Table 23 is listed the analysis of variance for the five-variety, nine-location block for the 1942 wheats. Both the locations and varieties gave a highly significant F-ratio, and each of these sources was analyzed further by the t-test. It was found that the least significant differences for comparing the average thiamin content of one variety with another over all stations were 0.42 micrograms and 0.56 micrograms for the five percent and one percent levels respectively. The t-test indicated that Tenmarq was significantly higher in thiamin content than Blackhull, Turkey, and Chiefkan; also it showed that Nebred, Blackhull, and Turkey were significantly higher in thiamin content than Chiefkan.

Table 23. Analysis of variance for the five-variety, nine-location block, 1942 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	8	46.62	5.83	15.34**	2.26	3.15
Varieties	4	14.32	3.58	9.42**	2.58	4.00
Interaction (Loc x Var)	31	11.70	.38	19.00**	1.71	2.14
Determination within sub-class	44	.94	.02			
Total	87	73.58				

** Highly significant.

For Table 23 the least significant differences for comparing the average thiamin content of one location with another over all varieties were found to be 0.56 micrograms for the five percent level and 0.76 micrograms for the one percent level. From the t-test it was shown that wheat from Dodge City was significantly higher in B_1 content than the wheats from all other remaining eight locations. The thiamin content of wheat from Hays was significantly higher than the thiamin contents of wheats from Hutchinson, Manhattan, Tribune, Colby, and Kingman. The thiamin content of wheat from Garden City was significantly higher than the thiamin contents of wheats from Manhattan, Tribune, Colby, and Kingman. The thiamin content of wheat from Meade was significantly higher than wheats from Manhattan, Tribune, Colby, and Kingman. The thiamin contents of wheats from Hutchinson, Tribune, and Colby were all significantly higher than that of wheat from Kingman.

The analysis of variance for the three-variety, 11-location block for the 1942 wheats is given in Table 24. The F-ratio for both locations and varieties was highly significant; therefore the t-test was used in studying further the location and varietal differences. A comparison of the average thiamin content of one variety with that of another over all locations showed the least significant differences to be 0.34 micrograms and 0.47 micrograms for the five percent and one percent levels respectively. The t-test showed that Tenmarq was significantly higher in thiamin content than Turkey and Blackhull.

Table 24. Analysis of variance for the three-variety, eleven-location block, 1942 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	10	37.87	3.79	12.63**	2.38	3.43
Varieties	2	3.72	1.86	6.20**	3.32	5.93
Interaction (Loc x Var)	19	5.78	.30	15.00**	1.92	2.54
Determination within sub-class	32	.71	.02			
Total	63	48.08				

** Highly significant.

A comparison of the thiamin content of the varieties of one station with that of another over all varieties showed the least significant differences to be 0.56 micrograms and 0.91 micrograms for the five percent and one percent levels respectively. The wheat from Dodge City gave higher values than wheats from Hays and Garden City, and the wheat from Hays gave higher values than the wheat from Garden City. From the t-test it was shown that the thiamin contents of wheats from Dodge City and Hays were not significantly different and also that the thiamin contents of wheats from Hays and Garden City were not significantly different. Excluding these two exceptions, wheats from Dodge City and Hays were significantly higher in thiamin content than wheats from all the other locations. It was also shown that the thiamin contents of wheats from Garden City and Meade were significantly higher than the thiamin contents of wheats from Columbus, Colby, Thayer, and Kingman. The thiamin content of wheat from Tribune was significantly higher than the thiamin contents of wheats from Colby, Thayer, and Kingman. The thiamin contents of wheats from Hutchinson and Manhattan were significantly higher than the thiamin contents of the wheats from Thayer and Kingman, and also, the wheats from Columbus and Colby were significantly higher in vitamin B_1 content than the wheat from Kingman.

In Table 25 is given the analysis of variance for the two-variety, three-location block for the 1942 wheats. The locations and varieties as shown gave a nonsignificant F-ratio; and, therefore, no t-test was performed on this data.

Table 25. Analysis of variance for the two-variety, three-location block, 1942 wheat.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	2	2.30	1.15	1.77	19.00	99.01
Varieties	1	.11	.11	.17	18.51	98.49
Interaction (Loc x Var)	2	1.29	.65	19.70**	5.14	10.92
Determination within subclass	6	.20	.033			
Total	11	3.88				

** Highly significant.

In Table 26 is given the analysis of variance for the five-variety, nine-location block for the 1942 flours. Locations and varieties both gave highly significant F-ratios, and it was therefore permissible to use the t-test and compare the individual locations and varieties. For comparing the average thiamin content of one location with that of another over all varieties the least significant differences were found to be 0.25 micrograms and 0.33 micrograms for the five percent and one percent levels respectively. The t-test indicated that the thiamin contents of flours from Manhattan, Tribune, Meade, Hutchinson, Hays, and Garden City were significantly higher in thiamin contents than flours from Dodge City, Colby, and Kingman.

Table 26. Analysis of variance for the five-variety, nine-location block, 1942 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	8	4.38	.55	7.53**	2.26	3.15
Varieties	4	1.47	.37	5.07**	2.68	4.00
Interaction (Loc x Var)	31	2.26	.073	24.33**	1.71	2.14
Determination within sub-class	44	.15	.0034			
Total	87	8.26				

** Highly significant.

For comparing the average thiamin content of one variety with that of another over all locations the least significant differences were found to be 0.18 micrograms and 0.25 micrograms for the five percent and one percent levels respectively. From the t-test it was concluded that Nebred was not significantly higher in thiamin content than Blackhull, but was significantly higher than the thiamin contents of Tenmarq, Turkey, and Chiefkan, and that the thiamin content of Blackhull was significantly higher than the thiamin contents of Turkey and Chiefkan.

In Table 27 is given the analysis of variance for the three-variety, 11-location block for the 1942 flours. The data in Table 27 indicates that both locations and varieties were highly significant. The least significant differences for comparing the average thiamin content of one location with that of another over all varieties were found to be 0.19 micrograms for the five percent level of significance and 0.27 micrograms for the one percent level. The t-test indicated that the thiamin content of flour from Columbus was significantly higher than that of flour from all other stations except that of Hutchinson. The thiamin content of flour from Hutchinson was significantly higher than the thiamin contents of flours from Thayer, Garden City, Meade, Colby, Dodge City, and Kingman. The thiamin content of flour from Manhattan was significantly higher than the thiamin contents of flours from Garden City, Meade, Colby, Dodge City and Kingman. The thiamin contents of flours from Hays, Tribune, Thayer, and Garden City were significantly higher than those of flours from Colby, Dodge City, and Kingman; and the thiamin contents of flours from Meade, Colby, and Dodge City were significantly higher than that of the flour from Kingman.

A comparison of the average thiamin content of one variety with another over all stations showed that the least significant differences were 0.10 micrograms and 0.14 micrograms for the five percent and one percent levels of significance respectively. From the t-test it was concluded that the 1942 Blackhull flour was significantly higher in thiamin content than the thiamin contents of Tenmarq and Turkey, and that the thiamin content of Tenmarq was significantly higher than that of Turkey.

Table 27. Analysis of variance for the three-variety, 11-location block, 1942 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	10	3.84	.38	14.62**	2.38	3.43
Varieties	2	.88	.44	16.92**	3.52	5.93
Interaction (Loc x Var)	19	.50	.026	6.84**	1.92	2.54
Determination within sub-class	32	.12	.0038			
Total	63	5.34				

** Highly significant.

The analysis of variance for the two-variety, three-location block for the 1942 flours is given in Table 28. Here it is shown that neither the location nor the variety gave significant F-ratios; therefore the data were not further analyzed.

Table 28. Analysis of variance for the two-variety, three-location block, 1942 flour.

Source of variation	Degrees of freedom	Sums of squares	Estimate of variance	F	5% point	1% point
Locations	2	.58	.29	.94	19.00	99.01
Variety	1	1.18	1.18	3.81	18.51	98.49
Interaction (Loc x Var)	2	.62	.31	62.00**	5.14	10.92
Determination within sub-class	6	.03	.005			
Total	11	2.41				

** Highly significant.

The complete statistical analysis of the two years' data may be summarized as follows:

1. For the 1941 wheats both location and variety influenced the thiamin content. Turkey was the variety highest in thiamin content, and except for Tenmarq it was significantly higher than all other varieties. The wheats from Tribune and Garden City were not significantly different but were significantly higher in thiamin content than were the wheats from the other stations.

2. The thiamin content of the 1941 flours were not influenced by location or variety. Blackhull, Chiefkan, and Nebred were highest in B_1 content; Tenmarq was next highest; and Turkey was lowest. The differences between varieties were not statistically different. The flours from Columbus, Kingman, and Garden City were highest in thiamin content.

3. For the 1942 wheats both location and variety influenced the vitamin B_1 content of wheat. The thiamin content of Tenmarq was significantly higher than that of Blackhull, Turkey, and Chiefkan, but was not significantly greater in thiamin content than Nebred. The wheat from Dodge City was significantly higher in thiamin content than the wheats from all stations with the exception of the wheat from Hays.

4. For the 1942 flours both the locations and varieties influenced the thiamin content. Nebred and Blackhull were not significantly different, but were significantly higher than Tenmarq, Turkey, and Chiefkan. The flours from Columbus and Manhattan were slightly higher than the flours from all other locations.

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LITERATURE CITED

Bailey, C. H.
Minnesota wheat investigations. Series I. Minn. Agr. Expt. Sta. Bul. 131: 3-42. 1913.

——— The Chemistry of wheat flour. New York. Chem. Catalog Co. 289 p. 1925.

Bayfield, E. G.
The influence of climate, soil, and fertilizers upon quality of soft winter wheat. Ohio Agr. Expt. Sta. Bul. 563: 3-81. 1930.

Cardwell, A. B. and Flora, S. D.
Kansas weather and climate. Kans. Agr. Expt. Sta. Bul. 302. 108 p. 1942.

Conner, R. T. and Straub, G. J.
The thiamin and riboflavin contents of wheat and corn. Cereal Chem. 18: 671-677. 1941.

Davis, Floyd E. and Pallesen, J. E.
Effect of the amount and distribution of rainfall and evaporation during the growing season on yields of corn and spring wheat. Jour. Agr. Res. 60: 1-23. 1940.

Harris, Leslie J.
The vitamin B_1 potency of wheat as influenced by soil treatment. Jour. Agr. Sci. 24: 410-415. 1934.

Hennessy, D. J.
A standard thiochrome assay for the determination of thiamin in cereal products. Amer. Assoc. Cereal Chem. News Letter No. 55. 39 p. 1942.

Hoffman, Charles, Schweitzer, T. R. and Dalby, Gaston
The thiamin content of whole wheat and clear flours. Cereal Chem. 17: 733-736. 1940.

Hunt, C. H.
The influence of fertilizers on the vitamin B content of wheat. Ohio Agr. Expt. Sta. Bul. 415: 1-41. 1927.

Johannson, H. and Rich, C. E.
The variability in the thiamin content of western Canadian hard red spring wheat of the 1940 crop. Cereal Chem. 19: 308-313. 1942.

Kharchenko, V. A.
Nitrogen in wheat grains and their size in dependence on precipitation and temperature. Ann. Inst. Agron. Moscou. 9: 304-311. Abs. in Exp. Sta. Rec. 16: 260. 1903.

LeClerc, J. A.
Tri-local experiments on the influence of environment on the composition of wheat. U. S. Dept. Agr. Bur. Chem. Bul. 128: 7-18. 1910.

LeClerc, J. A. and Yoder, P. A.
Environmental influences on the physical and chemical characteristics of wheat. Jour. Agr. Res. 1: 275-291. 1914.

Leong, P. C.
Effect of soil treatment on the vitamin B_1 content of wheat and barley. Biochem. Jour. 33: 1397-1399. 1939.

Lyon, T. L.
The relation of wheat to climate and soil. Proc. Amer. Soc. Agron. 1: 108-125. 1910.

Mangels, C. E.
Effect of climate and other factors on the protein content of North Dakota wheat. Cereal Chem. 2: 288-297. 1925.

Melikov, P.
Investigation of the wheat of southern Russia. Zhur. Opuitn. Agron. 1: 256-267. Abs. in Exp. Sta. Rec. 13: 451. 1900.

Neidig, Ray E. and Snyder, Robert S.
The relation of moisture and available nitrogen to the yield and protein content of wheat. Soil Sci. 18: 173-179. 1924.

Nordgren, Robert and Andrews, John S.
The thiamin content of cereal grains. Cereal Chem. 18: 802-811. 1941.

Ploti Agricultural Experiment Station
Report of the chemical laboratory for the year 1901. Sept. Rep. An. Sta. Expt. Agron. Ploty. Abs. in Expt. Sta. Rec. 14: 340. 1901.

Shaw, G. W.
Studies upon influences affecting the protein content of wheat. Calif. Univ. Pub., Agr. Sci. 1:63-126. 1913.

Shaw, G. W. and Walters, E. H.
A progress report upon soil and climatic factors influencing the composition of wheat. Calif. Agr. Expt. Sta. Bul. 216: 549-574. 1911.

Shetlar, M. R. and Lyman, J. F.
Thiamin content of typical soft wheat mill streams. Cereal Chem. 18: 666-671. 1941.

Smith, C. G. and Fellers, C. R.
Vitamin C content of 21 Massachusetts grown varieties of apples. Amer. Soc. Hort. Sci. Proc. 31: 89-95. 1934.

Snedecor, George W.
Statistical methods. Ames, Iowa. Iowa State Col. Press. 414 p. 1940.

Snyder, Harry
The draft of the wheat plant upon the soil in different stages of its growth. Minn. Agr. Expt. Sta. Bul. 29: 147-158. 1893.

__________ Influence of fertilizers upon the composition of wheat. Amer. Chem. Soc. Jour. 30: 604-608. 1908.

Soule, Andrew M. and Vanatter, Phares O.
Influence of climate and soil on the composition and milling qualities of winter wheat. Tenn. Agr. Expt. Sta. Bul. 16: 51-88. 1903.

Swanson, C. O.
Factors which influence the quantity of protein in wheat. Cereal Chem. 1: 279-288. 1924.

__________ Wheat and flour quality. Minneapolis, Minn. Burgess. 211 p. 1941.

Thatcher, R. W.
Wheat and flour investigations. Wash. Agr. Expt. Sta. Bul. 91: 3-30. 1910a.

__________ Factors which determine the composition of wheat. Proc. Amer. Soc. Agron. 1: 131-135. 1910b.

__________ The chemical composition of wheat. Wash. Agr. Expt. Sta. Bul. 111: 7-51. 1913.

Tollens, B.
The ash constituents of plants; their estimation and their importance to agriculture chemistry and agriculture. Expt. Sta. Rec. 13: 305-317. 1901.

Tressler, Donald K., Mack, Guilford L., and King, C. G.
Factors influencing the vitamin C content of vegetables. Amer. Jour. Pub. Health. 26: 905-909. 1936.

Widtsoe, John A.
Irrigation experiments in 1901. Utah Agr. Expt. Sta. Bul. 80: 69-199. 1902.

Wiley, H. W.
Influence of environment on the chemical composition of plants. U. S. Dept. Agr. Yearbook. 1901: 299-318.