Effect of Fertilizer on Air Classification of Wheat Flours

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Flours from five varieties of hard red winter wheats, each grown in Oklahoma at seven fertilizer levels, were evaluated for response to fractionation by fine grinding and air classification. In general, the use of nitrogen and phosphorus in unequal proportions produced an increased protein shift when nitrogen predominated and a decreased protein shift when phosphorus predominated. Response to flour fractionation among the different wheat varieties was, in order: Concho (highest), Triumph, Comanche, Pawnee, and Ponca (lowest). Variations in protein shift owing to wheat variety were greater than those owing to fertilizer level.

INVESTIGATIONS of fine grinding and air classification of wheat flours at the Northern Regional Research Laboratory have shown that differences exist in the response of flours to protein shifting. These differences depend upon the class of wheat from which the flour came, the variety used, the geographical area in which a given variety grew, and the year-by-year variations in climatic conditions under which the same variety was grown in the same location (*3*, *5*).

The studies reported here show how different fertilizer levels applied to wheats affect the air classification of their flours. These studies at the Northern Laboratory were based on a series of popular hard red winter (HRW) wheats grown by the Oklahoma Experiment Station during 1961.

Materials and Methods

Five different HRW varieties were grown at seven different fertilizer levels (Table I) with varieties of similar response to fractionation listed together. The five varieties can be considered as only three general groups that are arranged as minimum, intermediate, and finally maximum hardness. Concho had the minimum protein for whole grain and produced a high grain yield. Pawnee was the reverse, with maximum whole grain protein and minimum grain yield. Comanche data placed it in the intermediate position as shown.

In Table I the two fertilizer reference levels used in this series are indicated in bold face: **0–0–0,** no fertilizer; and **40–40–0** or balanced, normal fertilizer. For comparative purposes, the seven levels can be considered in two ways, as shown by the A and B arrangements. The one-component grouping, A-1, includes three fertilizer levels: phosphorus only, unfertilized, and nitrogen only. The A-2 or two-component grouping includes four fertilizer levels arranged as increasing nitrogen. The seven levels of the B arrangement start with the unfertilized and are arranged in terms of increasing nitrogen. The underlined 40 in the center or P_2O_5 position indicates that it is often held constant at this value.

Table I. Five Varieties of Hard Red Winter Wheats Grown in Oklahoma

Varieties	Seven Fertilizer Levels: A arrangement, A-1, one component (N_2–P_2O_5–K)	Seven Fertilizer Levels: B arrangement, increasing nitrogen order (N_2–P_2O_5–K)
	0–40–0	
Concho	**0–0–0**	**0–0–0**
Triumph	40–0–0	
	A-2, two	0–40–0
Comanche	*components*	20–40–0
Pawnee	20–40–0	
Ponca	40–80–0	40–80–0
	40–40–0	**40–40–0**
	80–40–0	40–0–0
		80–40–0

The 35 wheat samples were furnished in 15-pound lots, so a special procedure was required to handle these small amounts. A conventional Buhler mill was used to prepare straight grade flour at 68% extraction from each of the samples after they had received regular cleaning and tempering. This treatment yielded about 10 pounds of flour from each wheat sample. The flour was then divided into two 5-pound lots, one to be air-classified on an as-milled basis and the other to be air-classified after fine grinding by one pass through an Alpine pin mill at 18,000 r.p.m.

All the flour fractionations were made with a laboratory model Pillsbury classifier. The entire flour sample was fed to the unit at its lowest cut point, and the resulting finest or high-protein fraction was taken off. The classifier was readjusted to a slightly coarser setting and a two-part separation was again made from the coarse fraction just obtained. This repetitive procedure was followed through four cycles or settings to produce four sized fractions and one coarse residue for each of the 70 flour samples fractionated.

For each classification the original flour plus the five individual fractions were analyzed for moisture, protein, ash, and maltose value by AACC methods (*1*). Protein shift was calculated from the protein values for the individual, separated fractions. It equaled the sum of the protein shifted out of the lower protein fractions and the protein shifted into higher protein fractions (*2*).

Results and Discussion

As the wheat samples furnished by the experiment station were produced

Table II. Whole Grain Protein Content of Five Wheat Varieties from Seven Fertilizer Treatments in 1961 at Perkins, Okla. (*5*)

(% protein = % N × 5.7, 14% H_2O basis)

Fertilizer Treatments, Lb./Acre: N	P_2O_5	K	Protein Content, %: Concho	Triumph	Comanche	Pawnee	Ponca	Av.
0	0	0	11.55	11.50	10.80	11.55	11.35	11.35
0	40	0	9.90	10.00	10.50	10.90	10.00	10.26
20	40	0	10.60	11.25	11.30	11.40	10.65	11.04
40	80	0	10.80	11.35	11.30	11.40	11.50	11.27
40	40	0	11.50	12.35	12.30	13.05	11.85	12.21
40	0	0	11.70	13.55	13.10	13.80	13.25	13.08
80	40	0	13.00	13.90	13.70	13.90	13.90	13.68
		Av.	11.29	11.99	11.86	12.29	11.79	

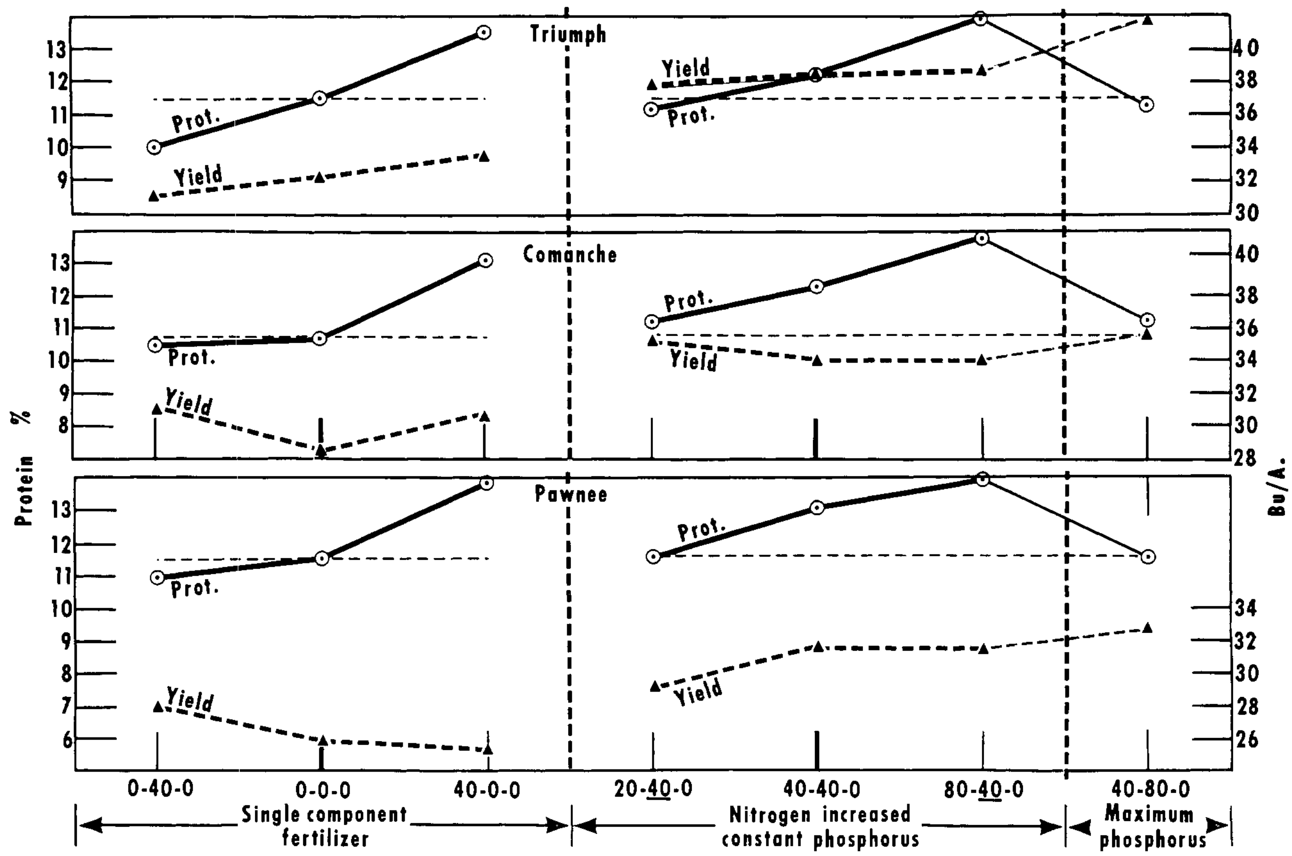

Figure 1. Relation of wheat protein and grain yield to fertilizer level for three HRW varieties grown in Oklahoma

Table III. Whole Grain Yield of Five Wheat Varieties from Seven Fertilizer Treatments in 1961 at Perkins, Okla. (*5*)

Fertilizer Treatments, Lb./Acre			Whole Grain Yield, Bu./Acre					
N	P_2O_5	K	Concho	Triumph	Comanche	Pawnee	Ponca	Av.
0	0	0	32.4	32.3	28.6	25.9	28.4	29.5[a]
0	40	0	31.1	31.4	31.2	28.2	27.1	29.8
20	40	0	35.7	37.9	35.3	29.2	33.5	34.3
40	80	0	39.0	42.0	35.7	33.0	35.7	37.1[b]
40	40	0	37.9	38.5	34.2	31.9	33.6	35.2
40	0	0	34.3	33.5	30.8	25.4	30.5	30.9
80	40	0	38.9	39.1	34.2	31.7	34.2	35.6
		Av.	35.6	36.4	32.9	29.3	31.9	

[a] Low.
[b] High.

under a wide range of fertilizer levels, variations in the protein content of the whole grain and in the acreage yields are to be expected.

Table II shows whole grain protein contents, and Table III shows yields for these Perkins, Okla., wheats (*4*).

Figure 1 was prepared from the agronomy data for the three representative varieties Triumph, Comanche, and Pawnee in order to show trends related to the protein and yield values, depicted by the elevation and slopes of the lines with respect to each other and to the horizontal reference line. The left half shows single-component fertilizers arranged around the zero fertilizer level; the right half shows two-component fertilizers with the 40–40–0 as the center point. Protein is shown by the upper, solid lines, and yield by the lower, heavy, broken lines. The thin, horizontal, broken line serves as a reference and is the wheat protein content of zero fertilizer level in each case.

First, consider the protein values. Disregarding 40–80–0, the plots of both halves of Figure 1 all show positive slopes, indicating increased wheat protein when nitrogen is increased. In contrast, the broken lines for yields are essentially flat, indicating that yield does not change much with respect to the zero level in the A-1 grouping, or to the 40–40–0 level in the A-2 grouping. However, the yield level at 40–40–0 is always greater than at 0–0–0. For the three representative varieties fertilized with two components, Triumph yield was highest, an average of 39.2 bushels per acre; the Comanche average was 34.8; and the Pawnee average, the lowest, was 31.3.

Figure 2 shows variations in protein content for straight-grade, Buhler-milled flours from Triumph and Ponca, these being representative of the five varieties studied. Protein values are compared against fertilizer levels arranged as increasing nitrogen. The original grain was uniformly higher in total protein than the Buhler-milled flour.

Protein values always dropped from the starting or zero reference level when phosphorus only was applied, then proceeded upward as nitrogen was added or increased. Protein values for whole grain and Buhler-milled flour parallel each other and indicated a general similarity at the various levels. The protein for Triumph flour varied from 8.2 to 12.6%; for Ponca flour, from 8.9 to 12.8%. The total range in protein content for the as-milled flours was from 8.2 to 12.8%.

Figure 3 is a simplified form of the plot for protein *vs.* fertilizer for Concho HRW wheat flour. It shows original, as well as minimum and maximum flour proteins, and where these occur with regard to fertilizer level. It is typical of a consistent trend observed in all five wheats used in these studies.

Table IV summarizes information from air classification of flours from three of the five varieties. Concho represents low hardness, HRW; Comanche, inter-

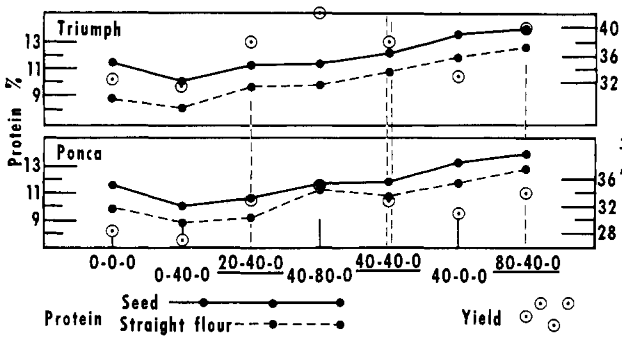

Figure 2. Relation of wheat and flour protein and grain yield to fertilizer level for two HRW varieties grown in Oklahoma

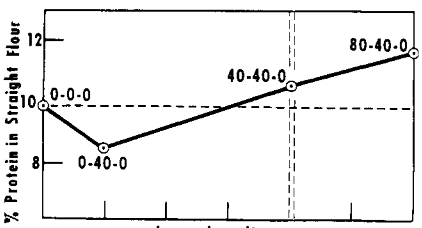

Figure 3. Relation of protein content to fertilizer level for Concho HRW wheat flour

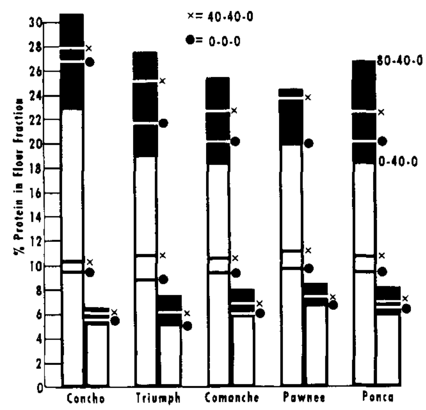

Figure 4. Variations in high- and low-protein fractions

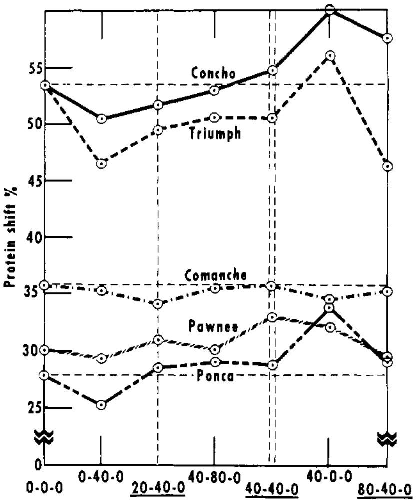

Figure 5. Relation of protein shift to fertilizer level for Oklahoma HRW

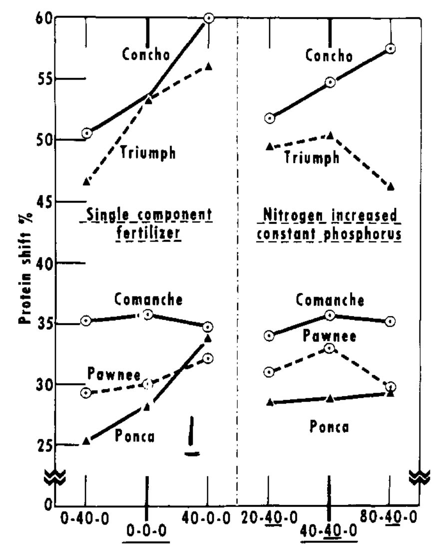

Figure 6. Relation of protein shift to fertilizer level for Oklahoma HRW

mediate; and Ponca, high. The fertilizer levels are shown as the A arrangement, as described in Table I, with single-component fertilizers given first, followed by two-component fertilizers. Reference levels are indicated again in bold face.

All the straight flours had nearly the same percentage of protein when 40–40–0 was used, ranging from 10.5 to 11.1%, but those from the harder varieties gave lower protein shifts. The extent of variations in grain yield and protein, as well as protein shift, depended upon the amount of the fertilizer change. Changes in protein content of the wheat flour were greater than yield changes. Grain yields for any given variety were close to one of two levels, a lower one for single-component fertilizer and an upper one for two-component fertilizers.

Phosphorus alone was not as beneficial as when used in conjunction with nitrogen. This condition was indicated by minimum values for grain yield, wheat and flour protein, and protein shift when only phosphorus was added. Starchy fractions of lowest protein content were obtained when only phosphorus was used, but at the same time the parent flours were also lowest in protein content.

Balanced fertilizer like 40–40–0 gave good values for grain yield, wheat and flour protein, and protein shift at levels dependent upon the particular variety. The softest variety, Concho, showed most improvement in protein shift as the relative quantity of applied nitrogen increased. Highest values for wheat and flour protein were obtained with fertilization at the 80–40–0 level, but the incremental gain would need to be evaluated in terms of the extra fertilizer cost to find out if this level is economical.

In order to make better simultaneous comparisons of the results from all five hard red winter varieties, this summary information has been plotted in Figures 4, 5, and 6, which clearly illustrate the relationships for high- and low-protein values and also for protein shifting.

The bar charts in Figure 4 represent variations in high- and low-protein fractions at various fertilizer levels for each variety. The shaded upper sections represent the variations. Protein contents were always highest for 80–40–0 and lowest for 0–40–0. The × and ● in the shaded ends represent 40–40–0 and 0–0–0, respectively; in the lower part of the tall bars they represent the protein contents of the as-milled flours at the 40–40–0 and 0–0–0 fertilizer levels, respectively.

In Figure 4, range in values for high-protein fractions averaged 7.4% (average of shaded tops of tall bars), whereas for low-protein fractions it averaged 2.0% (average of shaded tops of short bars).

Figure 5 shows how each of the five varieties varies in protein shift as the nitrogen content of the fertilizer is increased. Disregarding the 80–40–0 level, the same general upward pattern is observed as for the protein content of the flour shown in Figure 3. Concho and Triumph had the highest values of protein shifting, with Pawnee and Ponca the lowest. Comanche is between these groups and changed very little in protein shift with change in fertilizer level.

Another arrangement of protein shift is shown in Figure 6 for the five varieties. The left half shows results for single-component fertilizer and the relationship to 0–0–0; the right half shows various ratio forms of two-component fertilizers related to 40–40–0. It is clearly apparent that Concho, Triumph, and Ponca showed the most change in protein shift due to variation in fertilizer.

A comparative study of the data obtained from this series warrants the following conclusions.

Increased amounts of nitrogen fertilizers increased protein content in the wheat and flour, as well as in the high-

Table IV. Air Classification of Three Varieties of HRW Wheats Grown in Oklahoma in 1961

Fertilizer Level	Wheat Yield, Bu./A.	Straight Flour[a] Protein,[b] %	Flour Fractionations: High protein, %	Low protein, %	Coarse residue, % yield	Protein shift, %
			CONCHO			
0–40–0	31.1	8.4	22.8	5.1	21.6	50.6
0– 0–0	**32.4**	**9.8**	**26.8**	**5.7**	**20.1**	**53.5**
40– 0–0	34.3	9.9	28.4	5.4	18.0	60.7
20–40–0	35.7	8.8	23.6	5.2	20.3	51.8
40–80–0	39.0	9.9	26.2	5.7	21.5	53.3
40–40–0	**37.9**	**10.5**	**27.9**	**6.1**	**19.7**	**54.6**
80–40–0	38.9	11.6	30.7	6.5	18.0	57.2
			COMANCHE			
0–40–0	31.2	8.7	18.2	5.7	27.7	35.0
0– 0–0	**28.6**	**9.4**	**20.1**	**6.0**	**28.2**	**35.8**
40– 0–0	30.8	11.4	23.3	7.4	25.0	34.6
20–40–0	35.3	10.5	22.8	7.2	26.5	33.8
40–80–0	35.7	9.7	20.6	6.1	26.5	35.5
40–40–0	**34.2**	**10.5**	**22.7**	**6.9**	**26.0**	**35.9**
80–40–0	34.2	12.2	25.5	8.1	22.9	35.1
			PONCA			
0–40–0	27.1	8.9	18.2	5.9	31.8	25.2
0– 0–0	**28.4**	**9.4**	**20.1**	**6.5**	**30.6**	**28.2**
40– 0–0	30.5	11.7	26.4	7.7	26.7	33.9
20–40–0	33.5	9.4	19.6	6.3	29.2	28.6
40–80–0	35.7	11.1	23.0	7.5	29.0	29.1
40–40–0	**33.6**	**10.7**	**22.5**	**7.0**	**28.1**	**28.8**
80–40–0	34.2	12.8	26.8	8.2	26.9	29.5

[a] Buhler-milled.
[b] Protein, 14% H_2O basis.

and low-protein fractions separated by fine grinding and air classification. Protein shift increased slightly in most cases.

Increased amounts of phosphorus fertilizers lowered protein content in the wheat and flour, and in most cases reduced the protein content of the high- and low-protein fractions. Protein shift decreased slightly.

Response to fractionation of the five varieties was, in order: Concho, 54.5% (average protein shift index); Triumph, 50.4%; Comanche, 35.1%; Pawnee, 30.6%; Ponca, 29.0%.

Concho variety yielded the greatest range of fractions; these varied from 5.1 to 30.7% protein. Pawnee yielded the smallest range of fractions; these varied from 6.6 to 24.5% protein.

At any level of fertilization, the wheats of minimum hardness, Concho and Triumph, yielded fine fractions of the highest protein content, as well as starch fractions of lowest protein content. The highest protein fraction, obtained from Concho at 80–40–0 (the heaviest level of fertilizer used) contained 30.7% protein. The lowest protein fractions from Concho and Triumph at 0–40–0 contained about 5.0% protein.

Changes in fractionation response owing to changes in fertilizer level were greater for Concho, Triumph, and Ponca varieties than for Comanche and Pawnee.

Flour hardness, as measured by coarse residue for any given variety after the fine grinding and air classification, decreased with increasing protein content of the flour in most cases and the protein shift increased.

Summary

The softer HRW varieties were affected more by fertilizer changes than the harder ones.

Moderate increases in nitrogen fertilizer produced moderate increases in wheat and flour protein, protein shift, and grain yield.

Phosphorus aided the grain yield but had a diminishing effect on wheat and flour protein and on protein shift.

Protein shifting was influenced much more by changes in variety than by changes in fertilizer.

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