

Mineral Components of Grain Dust¹

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ABSTRACT

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Particle size distribution patterns, protein and ash contents, and P, K, Mg, Ca, Zn, Fe, Mn, and Cu levels were determined in bin, belt, and cyclone grain dusts collected during handling of wheat, corn, grain sorghum, and soybeans in four commercial grain elevators. Generally, in the 2–125 μm particle size range, Gaussian size distribution was skewed, with particles in the 10–22 μm range making up the single largest fraction. Amounts of large particles (above 125 μm) were substantially larger in settled belt dusts than in airborne bin dusts. Relatively large differences in size distribution patterns were obtained for the tailing dust (collected by cyclone), which is the main dust source. Protein contents in grain dust were the same as for

wheat and grain sorghum grains but lower than for whole corn and soybean. Ash levels in dusts had high coefficients of variability and were substantially higher than in whole grains by a factor of 8.0–19.0 for wheat, 4.0–15.9 for corn, 4.5–9.1 for grain sorghum, and 4.0–4.5 for soybeans. Compared with whole grains, dusts were relatively low in P and high in other minerals, especially the minor ones present in trace amounts. Wheat cyclone dust contained less protein and ash and less of most mineral components than did bin or belt wheat dusts. Several statistically significant associations between dust components are recorded.

Several studies from our laboratories have been concerned with the composition of grain dust, including the potentially toxic and otherwise deleterious components (Martin and Lai,⁴ Martin and Sauer 1976). The minerals in grain dust are of interest to animal nutritionists as mineral components of rations or as possible toxic or deleterious components. Such information is needed to characterize grain dust and thus to improve its utilization. This is a continuation of those studies.

The specific objectives of this study were to 1) compare the mineral contents (total ash and individual elements) in dusts from various grains, 2) compare dusts and cereal grains as sources of minerals, 3) compare the mineral composition and particle size of dusts from various locations in an elevator, 4) determine variability in mineral contents of dusts from various grains and locations in the elevator, and 5) determine associations between these characteristics.

MATERIALS AND METHODS

Samples

Samples of grain dust were collected from wheat (predominantly hard red winter), corn, grain sorghum, and soybeans in four commercial grain elevators in central and eastern Kansas. One elevator did not handle soybeans. About 1 kg of dust discharged from the dust control systems on their bucket elevators (cyclone dust) were obtained. Dust samples were also collected from the dust settled around the belt (belt dust) and suspended in the bin overspace (bin dust). The cyclone dust made up by far the largest amount of dust in the elevators; the fine, airborne bin dust and the coarser, settled belt dust each made up a small portion of the total.

Determination of Particle Size Distribution

Particle size distributions of each type of grain dust were determined by sieving and the Whitby centrifugal sedimentation

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⁴ C. R. Martin and F. S. Lai. 1979. Physical and chemical composition of grain dust. Presented at the summer meeting of American Society of Agricultural Engineers, University of Manitoba, Winnipeg, Canada. Paper No. 79-3089, June 1979.

method (AACC 1975). Particles greater than 1,000 μm were discarded before analysis. Particles greater than 125 μm were determined by sieves and those smaller than 125 μm were separated into size groups by the sedimentation method. In the centrifugal sedimentation method, dust is allowed to settle in a capillary tube filled with a sedimentation liquid. The particle diameter obtained corresponds to the diameter of a sphere that falls with the same velocity as the real particles. Although the diameter is measured hydrodynamically, the distribution is obtained by measuring the cumulative volume of dust. Although the physical dimensions of dust particles differ, the distribution is equivalent to that for spheres that behave hydrodynamically in the same way as the actual dust sample.

Benzene was used as the sedimentation liquid. The dust was initially dispersed in a solution consisting of the sedimentation liquid and naphtha (50:50 by volume). The dispersing solution (20 ml) and dust (approximately 4 mg) were then placed on top of the sedimentation liquid in the tube. To decrease settling time, we centrifuged the tube at 600, 1,200, and 1,800 rpm. The particle size distribution was calculated from the ratio of the observed settlement height in the capillary, at the time corresponding to the desired particle size, to the height after all the particles had settled. The diameter of the largest particles that settled out was determined from the speed of the centrifuge and the length of time it was operated.

Analytical Procedures

Moisture, ash, and protein were determined as described by AACC methods. Phosphorus was determined by the AOAC colorimetric—molybdenum blue—method (1975). For mineral analyses by atomic absorption spectroscopy, the samples (1 g, each in duplicate) were wet-ashed with nitric-perchloric-sulfuric acid according to the method of Liu et al (1974). A Perkin-Elmer model 360 atomic absorption spectrophotometer was used to measure absorption. Instrument variables were adjusted to optimum according to the manufacturer's instructions. An air-acetylene flame was used for all elements except Ca and Mg, for which a nitrous oxide-acetylene flame was used. The concentration values were read directly after standard and sample solutions diluted from primary standard solutions and original sample digest solutions were aspirated. Distilled water, standards, and blanks were

aspirated after every 4–6 samples. A 1,500-ppm Na^+ solution was used in the dilution for determining K to minimize ionization of K in the air-acetylene flame. A 1,500-ppm La^{+++} solution was used in the dilution for determining Ca. All analytical results are expressed on a moisture-free basis.

RESULTS AND DISCUSSION

Particle Size

Distribution diagrams for dusts from four grains, for each of three locations in the elevator, are shown in Figs. 1–3. In nearly all cases, dusts in the 2–125 μm range showed a skewed Gaussian distribution, with the 10–22 μm range making up the single largest fraction.

For the four bin dusts (Fig. 1), the fraction in the 88–125 μm range was relatively small compared to the other size fractions. This reflects the fact that the bin dusts represent fine airborne dust. The proportion of large-sized particles (above 125 μm) was relatively large in the four belt dusts, especially for wheat and sorghum (Fig. 2). Relatively large differences in distribution patterns among the four grains were obtained for dusts (tailings) from the cyclone, the main dust source (Fig. 3). The grain sorghum and especially the soybean cyclone dusts were particularly rich in the coarse fraction.

Composition

Data on protein, ash, P, K, Mg, Ca, Zn, Fe, Mn, and Cu of grain dusts from wheat, corn, grain sorghum, and soybeans from the three locations in the elevator are summarized and compared with the composition of whole grain in Table I. For each dust type, average values and coefficients of variation are given. The mineral components in the dust made up only part of the total ash. Only components of nutritional significance were analyzed. Additional major components presumably are Si and Al.

The protein contents of the wheat dusts were comparable to the content of the whole grain; coefficients of variation of dusts from various locations in the elevator were relatively small. The average ash contents of the dust were 8.0–19.0 times the ash of whole grain; all coefficients of variation were high, but the one for the cyclone dust was substantially lower than those for bin or belt dusts. Wheat dusts and whole wheat contained comparable amounts of P, but the dusts were substantially richer in other minerals (K, Zn, Fe, Cu, and particularly Ca and Mn). No consistent pattern was found for

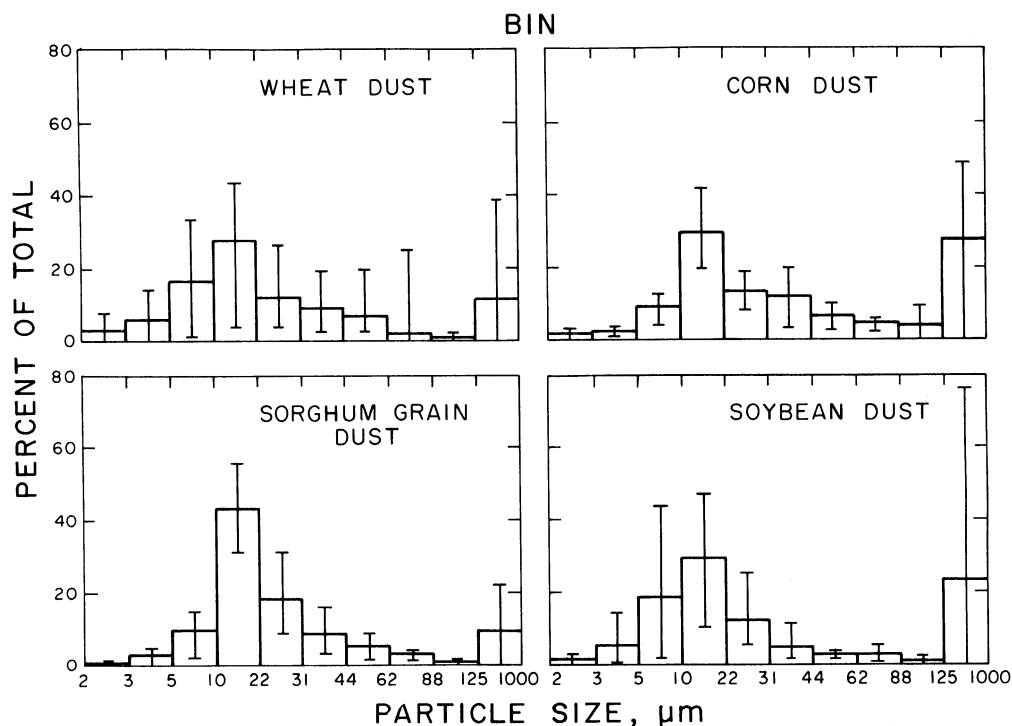


Fig. 1. Particle size distribution of wheat, corn, sorghum, and soybean bin dusts that vary in particle size.

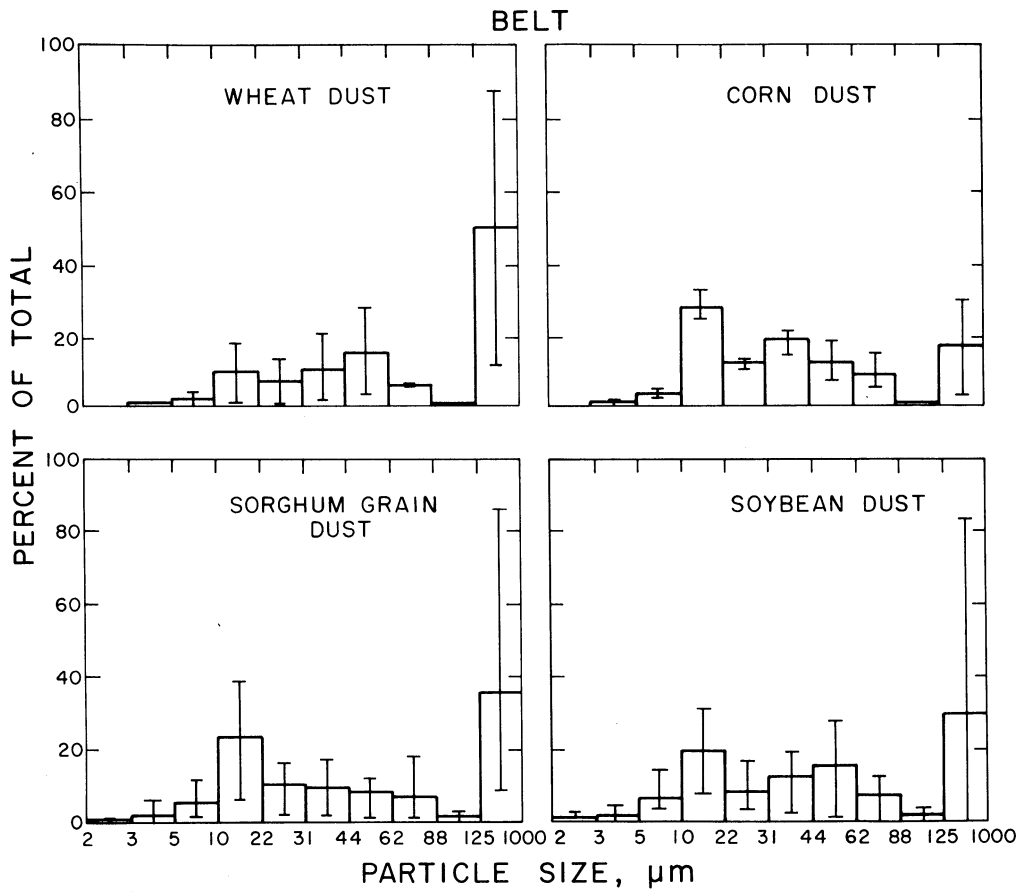


Fig. 2. Particle size distribution of wheat, corn, sorghum, and soybean belt dusts that vary in particle size.

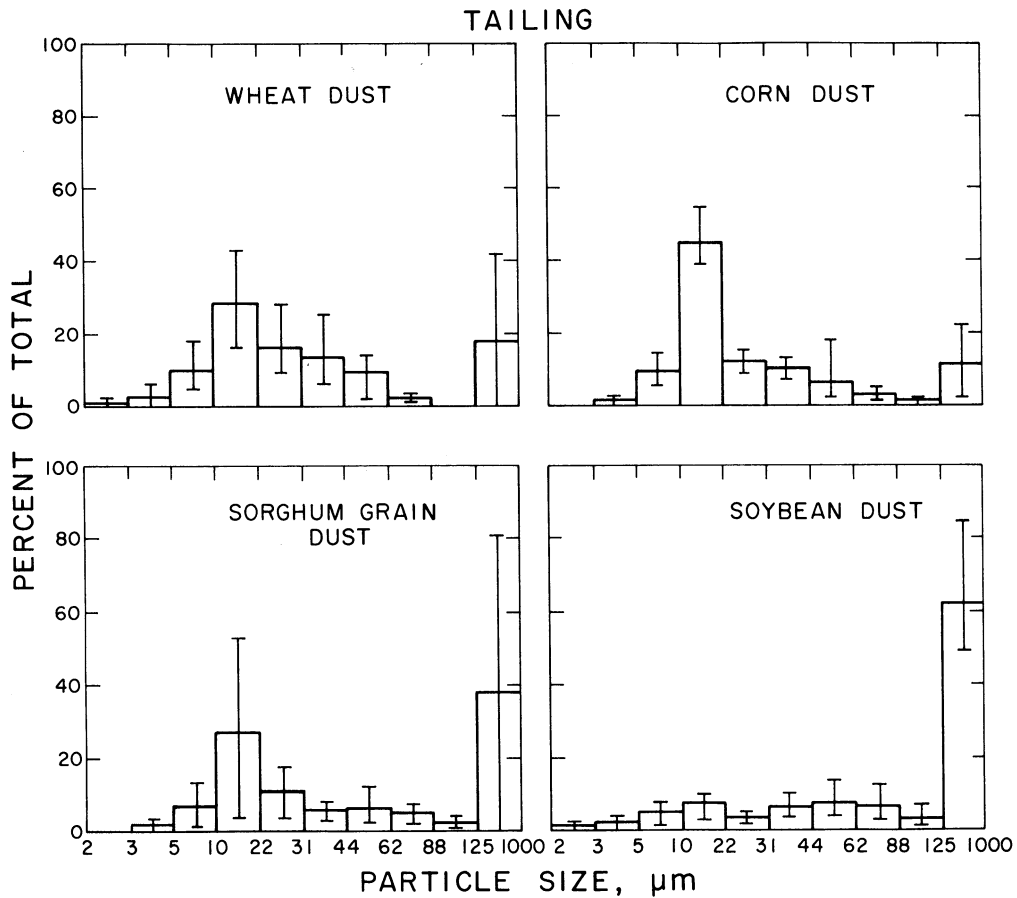


Fig. 3. Particle size distribution of wheat, corn, sorghum, and soybean cyclone (tailing) dusts that vary in particle size.

coefficients of variation for individual components from various locations in the elevator.

Corn dusts contained less protein and substantially more (4.0–15.9 times more) ash than did whole corn. Corn dusts were relatively lower in P, comparable in K and Mg, and richer in Ca, Zn, Fe, and especially Mn and Cu than was the grain. Generally, a relatively stable composition (especially for the cyclone dust), as denoted by moderate coefficient of variation, was recorded.

Protein contents were comparable and ash contents substantially higher (4.6–9.1 times) in grain sorghum dusts than in the whole grain. The dusts were lower than or comparable to the grain in P, K, and Mg and substantially richer in the minor mineral components. The coefficients of variation for ash and mineral components of the dusts varied widely and inconsistently.

Soybean dusts had substantially lower protein levels than did the whole beans. A more realistic approach would have been to compare soybean hulls, which contain only 9% protein (Smith and Circle 1978); total ash in the hulls is somewhat lower (4.0–4.5%) than in the whole beans. Soybean dust contained 4.7–6.5 times as much ash but only about 0.4 as much P and less than 0.4 as much K as the beans. The dusts and beans contained comparable amounts of Mg and were rich in Ca, Zn, Fe, Mn, and Cu. Generally, most coefficients of variation of soybean dusts were relatively small.

Comparison by location in the elevator for all grain types permitted no generalizations, with the possible exception that wheat cyclone dust contained the lowest total protein and ash. A

similar trend was shown for soybean dust.

Relating particle size distribution patterns and nutrient composition is difficult because dusts from all three locations in the elevator contained various sizes of particles, which generally centered around the 10–22 μm cut. Admittedly, the patterns for different elevator locations differed, but the ranges (Figs. 1–3, Table I) make generalizations impossible. Within those limitations, however, definite trends in particle size distribution patterns and associated composition, as affected by type of grain and location in the elevator, were deduced on the basis of significant correlation coefficients. At the 1% level of significance, significant correlations included those: in wheat bin dust between Mg and K and between Cu and Fe; in corn cyclone dust between Mg and protein, Zn and Mg, Fe and Mg, Fe and Zn, and Mn and Fe; in corn bin dust between Fe and K; in sorghum belt dust between Fe and protein; and in soybean bin dust between Mg and K. Those results should facilitate estimation of the value of grain dusts as a source of minerals and their utilization in feeds.

Associations with Fe may be fortuitous because the dusts contained exceptionally high levels of Fe (compared to the grains), presumably from contamination during processing. Additional work is needed to establish whether other associations truly reflect the concomitant presence of two components in particles originating from specific grain tissues or from soil and whether those associations in specific dusts at various locations in the elevator reflect segregation by particle size.

TABLE I
Protein and Mineral Contents^a of Grain Dusts from Different Sources

	Protein (%)	Total Ash (%)	Minerals in Ash							
			P (%)	K (%)	Mg (%)	Ca (%)	Zn (ppm)	Fe (%)	Mn (ppm)	Cu (ppm)
Wheat dust										
Bin	12.5 (14.5)	16.6 (45.9)	0.384 (27.3)	0.480 (42.0)	0.247 (15.5)	0.754 (96.4)	134 (38.0)	0.429 (71.1)	236 (41.8)	14.5 (28.9)
Belt	15.2 (5.90)	35.5 (95.7)	0.408 (13.5)	0.506 (49.4)	0.352 (26.4)	0.627 (40.3)	135 (21.2)	0.270 (27.7)	171 (15.2)	11.4 (7.35)
Cyclone	10.4 (10.7)	15.0 (23.0)	0.303 (14.8)	0.712 (80.3)	0.231 (16.0)	0.576 (17.7)	99.4 (42.9)	0.216 (51.0)	147 (9.24)	46.3 (140)
Whole wheat ^b	14.8	1.87	0.344	0.414	0.180	0.037	24.0	0.0044	37.9	5.1
Corn dust										
Bin	8.32 (26.0)	5.59 (69.7)	0.253 (49.5)	0.173 (43.4)	0.135 (46.4)	0.178 (61.3)	142 (37.3)	0.164 (10.7)	43.2 (62.5)	8.63 (30.4)
Belt	8.01 (9.74)	22.2 (122.0)	0.214 (17.7)	0.481 (54.7)	0.119 (27.4)	0.174 (43.5)	77.0 (52.2)	0.182 (67.9)	70.0 (67.3)	46.6 (69.8)
Cyclone	7.12 (10.1)	8.42 (59.7)	0.157 (9.43)	0.390 (19.7)	0.0909 (43.8)	0.215 (38.7)	90.1 (11.1)	0.125 (62.0)	52.2 (67.2)	13.9 (126)
Whole corn ^{c,d}	12.2	1.4	0.330	0.297	0.108	0.0051	19.6	0.00203	5.60	2.6
Sorghum dust										
Bin	9.71 (6.23)	11.9 (37.0)	0.221 (17.2)	0.370 (65.0)	0.177 (20.9)	0.339 (46.1)	104 (54.9)	0.247 (44.8)	86.2 (25.9)	12.5 (24.9)
Belt	8.97 (27.0)	20.1 (105.0)	0.258 (25.2)	0.268 (21.7)	0.171 (30.1)	0.280 (23.0)	86.3 (44.7)	0.270 (71.8)	90.8 (36.0)	10.9 (35.5)
Cyclone	9.76 (15.3)	10.2 (31.5)	0.322 (15.3)	0.533 (61.1)	0.203 (15.1)	0.252 (23.6)	72.8 (30.2)	0.130 (36.2)	64.7 (30.0)	27.6 (90.4)
Whole sorghum ^e	8.8	2.20	0.49	0.40	0.18	0.025	37	0.0067	21	5.4
Soybean dust										
Bin	16.1 (20.1)	32.0 (45.6)	0.282 (10.6)	0.419 (15.1)	0.302 (19.0)	1.34 (79.9)	292 (39.9)	0.920 (35.8)	278 (26.2)	27.7 (25.7)
Belt	15.1 (17.7)	23.6 (48.4)	0.273 (11.8)	0.404 (33.5)	0.281 (8.63)	0.600 (10.4)	141 (34.7)	1.12 (29.4)	208 (50.3)	18.5 (25.9)
Cyclone	13.8 (66.3)	23.0 (45.1)	0.287 (27.3)	0.721 (70.4)	0.289 (15.5)	0.724 (7.87)	131 (27.5)	0.368 (34.5)	109 (23.2)	59.5 (117)
Whole soybeans ^f	40.0	4.9	0.659	1.83	0.31	0.24	18	0.0080	28	12

^aAverages (moisture-free basis) from four elevators for wheat, corn, and sorghum and from three elevators for soybeans. Coefficients of variation (%) are given in parentheses.

^bFrom Toepfer et al (1972).

^cFrom Pietz et al (1978).

^dFrom Arnold et al (1977).

^eFrom Wall and Blessin (1970).

^fFrom Smith and Circle (1978).

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A Mechanism for the Oxidative Gelation of Wheat Flour Water-Soluble Pentosans¹

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ABSTRACT

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The oxidative gelation of wheat flour water-soluble pentosans was studied with viscometry. Such common oxidants as potassium bromate, potassium iodate, and ascorbic acid did not increase the viscosity of wheat flour water solubles, but hydrogen peroxide, ammonium persulfate, and formamidine disulfide did. Hydrogen peroxide was effective only in the presence of the enzyme peroxidase, which flour contains. The enzyme tyrosinase was also effective in increasing viscosity. Ferulic acid, fumaric acid, and cysteine stopped formation of the gel when hydrogen peroxide

was added. Vanillic acid had no effect on gel formation. These results suggest a mechanism involving the addition of a protein radical to the activated double bond of ferulic acid. The ferulic acid is esterified to the arabinoxyylan fraction of pentosan. The resultant cross-linking is responsible for the oxidative gelation of wheat flour water solubles. The gelation appears to be responsible for some, but not all, oxidative changes in bread doughs.

Durham (1925) reported that adding hydrogen peroxide to a flour-water slurry increased the slurry's viscosity. Baker et al (1943) showed that the water-soluble pentosans were responsible for the increases in viscosity. Udy (1956) studied the viscometry of flour-water extracts and concluded that 95% of the intrinsic viscosity was due to the polysaccharides and 5% to the soluble protein, with essentially no viscosity coming from the other soluble components.

Neukom and coworkers (Fausch et al 1963; Geismann and Neukom 1971, 1973a, 1973b; Markwalder and Neukom 1976; Neukom 1976; Neukom et al 1967) studied water-soluble pentosans and the oxidative gelation phenomena. Their work has been recently reviewed (Neukom and Markwalder 1978), and several possible structures for the gel were suggested.

The work of Fincher et al (1974) and Fincher and Stone (1974) showed that wheat flour water-soluble pentosans are composed primarily of two fractions, an arabinoxyylan and a peptide-bound arabinogalactan. Their work clarified the confusing literature on water-soluble pentosans.

Yeh et al (1980) showed ferulic acid to be associated only with the largest molecular weight part of the arabinoxyylan fraction and the level of ferulic acid to decrease as dough is overmixed. Sidhu et al (1980b) showed that when a mixture of wheat flour water solubles

and ¹⁴C-cysteine was irradiated with ultraviolet light, the cysteine was bound to the water-soluble pentosans.

We investigated the gel formed by wheat flour water-soluble pentosans when hydrogen peroxide was added and looked at effects of certain compounds rheologically active in dough on formation of that gel. From these data, we hoped to learn more about the mechanism of the oxidative gelation reaction.

MATERIALS AND METHODS

Materials

Enzymes. Bovine liver catalase, E.C. 1.11.1.6 (9,200 units per milligram of protein), type I horseradish peroxidase (94 purpurogallin units per milligram), and mushroom tyrosinase, E.C. 1.14.18.11 (2,230 units per milligram) were obtained from Sigma Chemical Co., St. Louis, MO.

Chemicals. Ferulic acid (4-hydroxy-3-methoxycinnamic acid), phenylthiocarbamide (1-phenyl-2-thiourea), formamidine disulfide HCl, and L-cysteine HCl were obtained from Sigma Chemical Co.; trans-cinnamic acid, 3-(*p*-hydroxyphenyl) propionic acid (98%), and vanillic (4-hydroxy-3-methoxybenzoic) acid (97%) were obtained from Aldrich Chemical Co., Milwaukee, WI; reagent grade H₂O₂ (30%) and fumaric acid were from Fisher Scientific Co., Fair Lawn, NJ. All other chemicals were reagent grade.

Flour. The flour was experimentally milled from a composite of many varieties of hard red winter wheat harvested at a number of locations. The flour, which was not treated, contained 11.5% protein and 0.42% ash.

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