MICROFLORA OF WHEAT AND WHEAT FLOUR FROM SIX AREAS OF THE UNITED STATES

R. F. ROGERS and C. W. HESSELTINE, Northern Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, Peoria, IL 61604

ABSTRACT

Cereal Chem. 55(6): 889-898

Bacterial counts in 54 wheat samples varying from 870 to 3,100,000 per gram generally were higher than in corresponding flour samples. Of 54 flour samples, bacterial counts per gram were less than 5,000 in 32 samples and less than 10,000 in 43. In 32 patent flours, bacterial counts per gram were less than 5,000 in 25 samples and less than 10,000 in 30. In most samples, fungal and actinomycete counts were inconsistent, but were lower than bacterial counts. Though psychrotrophic bacteria ranged from 0 to 10^6, counts of catalase-negative, fecal streptococci, aerobic thermophilic spore-forming, and flat sour bacteria were low when detected. Correlations are not evident among microbial counts in wheat and flour samples.

Wheat flour is used in canned foods, especially baby foods, and is a major ingredient in many nonsterile refrigerated and frozen convenience foods. Reported bacterial counts in wheat and flour vary considerably, ranging from a few hundred per gram to millions (1). Doty (2) has recommended bacterial limits in flour depending on its intended use, ie, 5,000 bacteria/g in TV dinners and meat pies, 10,000/g in fruit pies, and 15,000/g in canned biscuits. Some processors specify flour with less than 5,000 bacteria/g (3). The question is whether bacterial counts are relevant to flour quality.

Many other questions arise: Are fungal and actinomycete counts relative to bacterial counts in wheat and flour samples? What is the relationship between the different microbial counts in wheat and the flour milled from it? Does the microflora of flour reflect that of the grain before milling? Are these microorganisms responsible for spoilage of grain, its products, and byproducts? Do they represent health hazards? Within a region, are the microflora of the products similar?

For insight into these problems and to establish the microflora of domestic wheats and commercial flours, a survey was made of various mills throughout the United States in cooperation with the Millers' National Federation. Several facets of the survey have been reported elsewhere (3–5).

MATERIALS AND METHODS

Sampling

Representative flour mills in Kansas-Nebraska, the Pacific Northwest, Michigan-Indiana, Montana-North Dakota, Texas-Oklahoma, and the Southeast collected and sent 54 samples of locally grown wheat and its flours to our laboratory. At each mill, sampling was conducted only one day during the fall and winter. Only two Pacific Northwest mills processed locally grown wheat. Samples were typical wheats and flours having no known spoilage problems.

0009-0352/78/000099$03.00/0

TABLE I
Counts of Microorganisms in Wheat and Flour (Per Gram)

Kansas-Nebraska						Pacific	
Bacteria[a]		Fungi		Actinomycetes		Bacteria	
W[b]	F[c]	W	F	W	F	W	F
						Less than 5,000	
160	[0.8][d]	90	[270]	40	[60]	5.5	0.2
590	[1.3]	550	[1,000]	85	[80]		
3.7[e]		15		65			
	3.0		85		65		
35		220		35			
66	[3.2]	330	[2,000]	140	[25]		
93	[3.3]	390	[150]	125	[155]		
38	[3.6]	75	[600]	55	[10]		
97	[4.6]	330	[90]	100	[90]		
110	4.8	250	8,000	295	1,000		
140	[4.8]	170	[310]	20	[170]		
						5,000 to 10,000	
650	6.6	1,300	300	100	60	3.6	8.6
						More than 10,000	

Montana-North Dakota						Texas-		
						Less than 5,000		
						7.8	[0.46][d]	30
						4.3	[0.7]	150
						1.0	1.0	270
						0.87	1.3	110
						9.1	[1.4]	130
						0.89	[2.3]	50
						33	3.8	35
						44	[4.7]	350
						39	[4.9]	9,500
						5,000 to 10,000		
1,300	[5.0]	10,900	[210]	35	60			
490	[5.8]	2,200	[2,200]	40	[15]			
570	[6.8]	2,700	[230]	10	[0]			
1,500	69	32,000	360	10	70			
						More than 10,000		
780	10	1,900	200	45	25	122	[120]	50
3,100	[25]	86,000	[1,500]	15	[5]			
3,000		750	900	10	45			
2,000	39	1,600	300	15	0			
300	41	650	1,100	0	40			
1,600	45	3,100	700	20	15			
1,300	190	3,800	260	20	5			

[a] Bacteria/gram in thousands.
[b] W = wheat counts.
[c] F = flour counts.
[d] ☐ = Patent flours.
[e] Two wheats sent with one flour.
[f] Two flours sent with one wheat.

Northwest				Michigan-Indiana					
Fungi		Actinomycetes		Bacteria		Fungi		Actinomycetes	
W	F	W	F	W	F	W	F	W	F
bacteria/gram flour									
110	195	0	10	45	0.45	470	330	35	40
				280	0.64	3,500	400	65	85
				13	0.85	135	110	170	600
				91	1.3	190	200	110	45
				16	1.5	230	230	5	0
					3.3		1,500		70
				240		2,800		90	
					16		2,800		150
				21	3.9	75	240	35	75
bacteria/gram flour									
250	2,500	130	10	91	5.3	2,100	7,500	1,100	5,300
				68	5.4	470	900	15	100
				54	6.6	1,000	170	195	265
bacteria/gram flour									
				8.2	12	470	900	60	55
				16	12	17,000	8,200	155	230
Oklahoma				**Southeastern States**					
bacteria/gram flour									
1,200	90	50		61	0.13	280	190	340	20
150	25	10		61	0.96	50	150	5	5
1,300	100	110		97	1.2	235	130	65	35
800	40	80		69	1.4	265	110	45	10
190	75	130		97	4.1	750	490	75	15
270	95	550		57	4.4	550	1,400	80	110
1,500	15	5							
1,000	430	85							
9,500	75	130							
bacteria/gram flour									
				69	5.2	1,050	750	360	45
				67	5.5	2,300	290	90	145
bacteria/gram flour									
380	460	1,900							

Bacteriologic Examination

Graves and Hesseltine (4) described the method for enumerating aerobic fungi and Graves et al (3) for aerobic bacterial and actinomycete populations. Samples were either examined the day received or stored at 5° C until analyzed.

RESULTS

Bacterial, fungal, and actinomycete counts are the average count from duplicate plates. Samples are arranged according to increasing bacterial counts in the flour (Table I). Microbial counts of the wheat and corresponding flour sample may be compared. For example, the last count in the Kansas-Nebraska column represents a wheat sample having 650,000 bacteria, 1,300 fungi, and 100

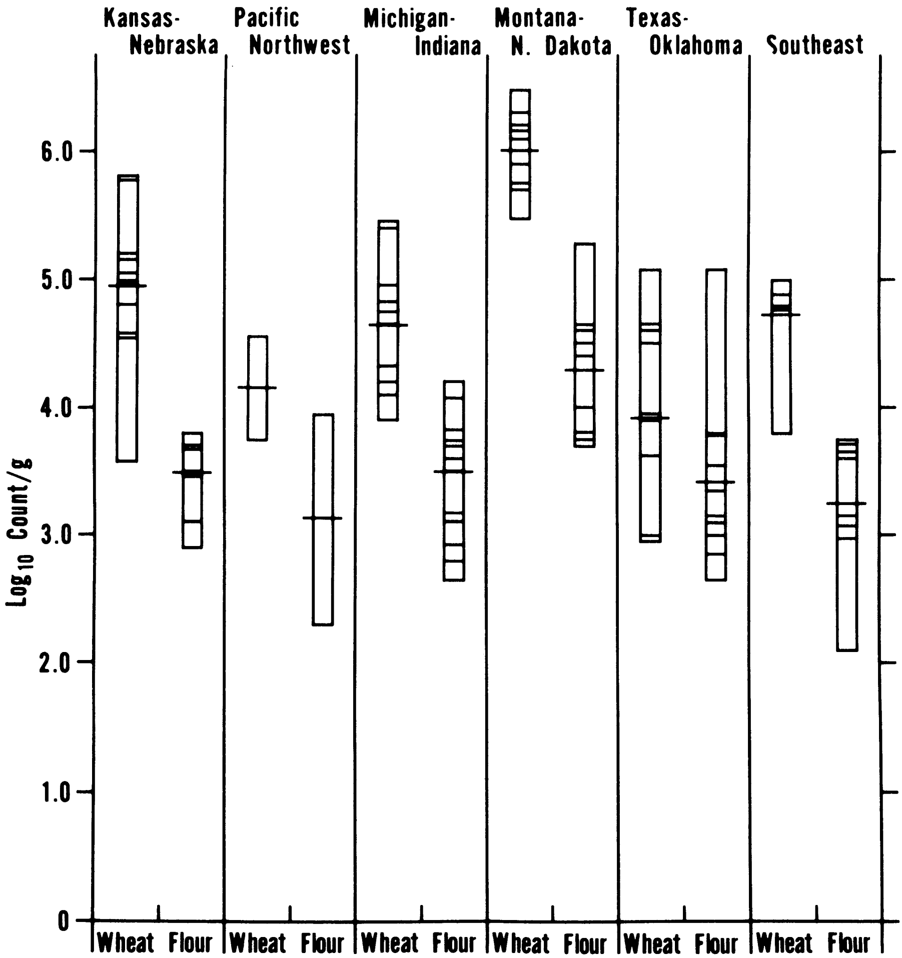

Fig. 1. Bacterial counts in wheat and flour samples from six areas of the United States.

actinomycetes per gram and its flour having 6,600 bacteria, 300 fungi, and 60 actinomycetes per gram.

Visual comparisons of counts in wheat and flour are shown in Fig. 1–3. The vertical bars represent the range of counts and the small horizontal lines are counts for each sample. The geometric means are depicted by longer horizontal lines.

Although bacterial counts in wheat samples ranged from 870 to 3,100,000 per gram, the geometric mean was 71,000 per gram. The lower geometric mean of flour samples (3,900 per gram) reflects generally lower bacterial counts, ranging from 130 to 190,000 per gram. Montana-North Dakota samples have higher counts, and six Montana-North Dakota flour counts exceeded 15,000 per gram (Fig. 1). Of 54 flour samples, however, the total bacterial count was less than 10,000 per gram in 43 samples analyzed (including 30 patent flours) and less than 5,000 in 32. Most bacterial counts were greater than fungal counts.

Fungal counts ranged from 15 to 86,000 per gram of wheat and from 85 to 9,500 per gram of flour; the geometric means were 520 and 540 per gram,

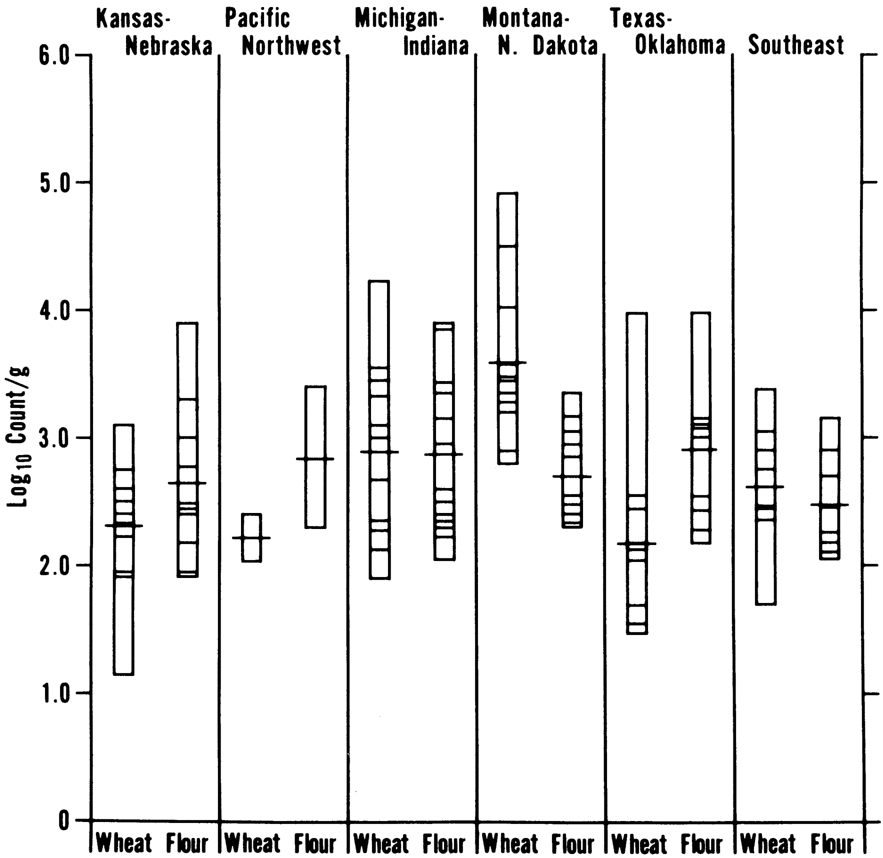

Fig. 2. Fungal counts in wheat and flour samples from six areas of the United States.

respectively. Counts exceeding 1,000 were found in 18 wheat and 17 flour samples, including 9 patent flours. More wheat samples from Montana-North Dakota and Michigan-Indiana and more flour samples from Texas-Oklahoma and Michigan-Indiana revealed higher counts than from other areas (Fig. 2). Though some wheat and flour samples from all areas had high fungal counts, no trend was noted; the same was true of actinomycete counts.

Most actinomycete numbers were less than fungi, ranging to 1,100 per gram of wheat and to 5,300 per gram of flour; the geometric means were 49 and 45 per gram, respectively. Though actinomycetes were not detected in several samples, counts were less than 100 per gram in 36 wheat and 35 flour samples and exceeded 100 per gram in 32 samples, including 10 patent flours (Fig. 3). In most patent flours, however, the actinomycete count was low (Table I).

In addition, samples were examined for specific bacteria (Table II). Psychrotrophic bacteria were detected in most samples. Catalase-negative bacteria were found in 19 samples and fecal streptococci in 24; 78 samples contained aerobic thermophilic spore-forming bacteria, and 57 had flat sour bacteria. Most counts were 10 or less, but counts of psychrotrophic bacteria ranged from 0 to 3,000,000, and catalase-negative bacteria, up to 2,500.

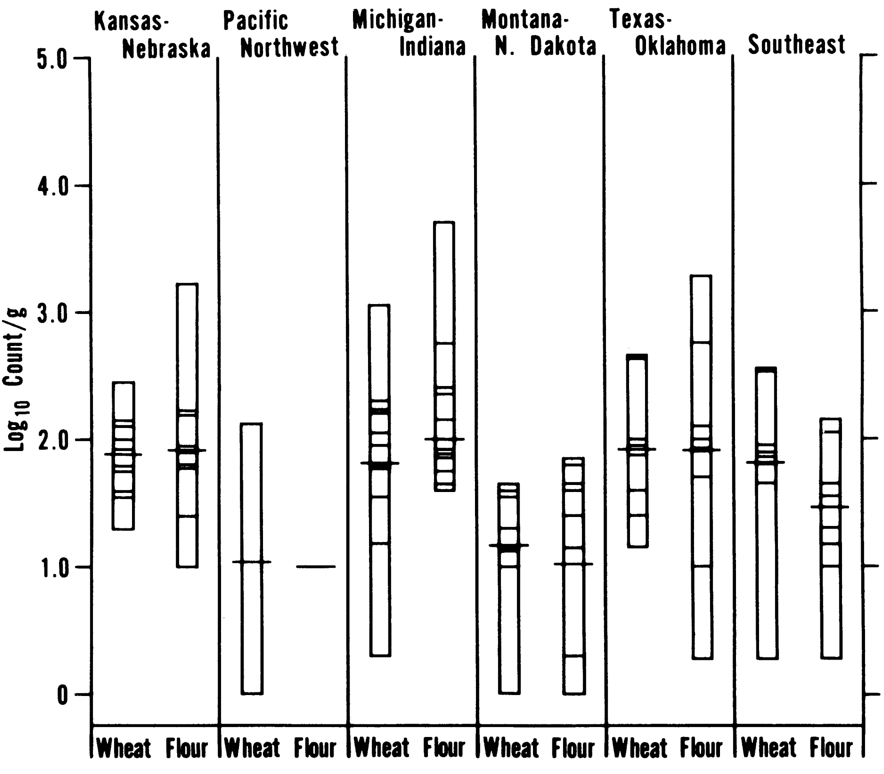

Fig. 3. Actinomycete counts in wheat and flour samples from six areas of the United States.

DISCUSSION

The microflora of the wheat and flour samples examined was heterogenous. Bacteria, fungi, and actinomycetes were found in most samples. Organisms common to both wheat and flour, such as psychrotrophic bacteria, fecal streptococci, catalase-negative bacteria, aerobic thermophilic spore-forming bacteria, flat sour bacteria, *Aureobasidium pullulans* (5), and *Streptomyces albus* (3), survived the milling processes.

During milling, however, up to 95% of the microbial population may be removed with the feed fractions (6). When counts are compared (Table I) in flour and in wheat from which the flour was milled, the bacterial population in most flours was about one-tenth that in wheat. This indicates that modern flour milling operations are efficient in reducing the number of bacteria.

Even though bacterial numbers were less in flour than in wheat, the fungal and actinomycete counts in flour were not always lower. Larger numbers in flour could be due to conditions favoring growth of microorganisms originally present in the grain, to dispersion of spores during sample handling, or to contaminants in the mill (7). Similar counts in wheat and flour, but a different flora, suggest that mill contaminants have replaced organisms originally present. Similar counts (due to replacement) and lower counts might be the result of selective removal of organisms during milling, eg, a yeast (*Cryptococcus albidus*) was common among wheat samples but was not detected in any flour samples examined (5). Fungal and actinomycete counts are unrelated between wheat and flour samples.

If Doty's (2) suggestions of bacterial counts in flour are considered, 32 samples had less than 5,000 per gram, 43 had less than 10,000 per gram, but 7 had more than 15,000 per gram. Of 32 patent flours, bacterial counts were less than 10,000 per gram in 30 samples, but fungal and actinomycete counts were inconsistent. Bacterial counts and fungal or actinomycete counts however, are unrelated in flour samples (Table I). For example, a flour sample from Texas-Oklahoma with less than 5,000 bacteria/g contained the highest fungal count (9,500 per gram), and the highest actinomycete count of 5,300 per gram in a Michigan-Indiana sample had 5,300 bacteria and 7,500 fungal propagules/g.

Quality of flour based on total bacterial numbers supplies no information about bacterial flora. Certain bacteria might indicate possible health hazards and others might cause spoilage of the product. Detection of these bacteria (Table II) might be a warning to various industries, but established tolerances were exceeded in only a few samples. Aerobic thermophilic spore-forming bacteria, which may cause spoilage in canned foods, were present in 78 wheat and flour samples, but the National Canners Association's recommendations (8) were exceeded in only 5 flour samples. Flat sour bacteria are a group of thermophilic spore-forming bacteria that cause food to turn sour; they were detected in 57 wheat and flour samples, but counts exceeded the National Canners Association's recommendations (8) in only 2 Kansas-Nebraska flour samples.

Though fecal streptococci were detected in 24 samples, the 20 per gram tolerance (8) was exceeded in only 2 flour samples. Lactic acid bacteria have been implicated in spoilage of refrigerated canned biscuits, but 100 per gram are tolerated by industry (9). Flour may be the source of such contamination. Lactic acid bacteria were detected in 13 flour samples, and 6 exceeded the tolerance.

TABLE II
Wheat and Flour Samples Tabulated by Area and Count Range of Specific Bacteria

		Count Range Per Gram							
		Psychrotrophic Bacteria							
Area and Sample	Number of Samples	0	<10	10^1	10^2	10^3	10^4	10^5	10^6
Kansas-Nebraska									
Wheat	11	2					6	3	
Flour	10	1		1	6	2			
Pacific Northwest									
Wheat	2			1			1		
Flour	2	1				1			
Michigan-Indiana									
Wheat	12					3	7	2	
Flour	13				6	5	2		
Montana-N. Dakota									
Wheat	11						1	6	4
Flour	11					7	3	1	
Texas-Oklahoma									
Wheat	10			1	3	2	4		
Flour	10	1			1	3	5		
Southeast									
Wheat	8			1	5	2			
Flour	8			1	5	2			
Total wheat	54	2		3	8	7	19	11	4
Total flour	54	3		2	18	20	10	1	0
Total samples	108	5		5	26	27	29	12	4

Organisms important to the chilled and frozen food industries are able to withstand cold temperatures. These psychrotrophic bacteria were detected in most wheat and flour samples, and counts exceeded 100 per gram in 31 flour and 41 wheat samples.

On a geographic basis, regional differences may be noted. Wheat and flour samples from Montana-North Dakota had higher, and Texas-Oklahoma lower, bacterial counts than those from other areas. Bacteria require moisture for growth and are able to tolerate cool temperatures, but only spore-forming bacteria can withstand prolonged arid conditions combined with heat. Flours containing higher psychrotrophic counts came from Michigan-Indiana and Montana-North Dakota, while more aerobic thermophilic spore-forming and flat sour bacteria were detected in Kansas-Nebraska flours.

Elevated counts of fungi and actinomycetes do not correlate with high bacterial counts. High fungal counts in wheat and flour samples came from all areas, especially nine Montana-North Dakota wheat, five Texas-Oklahoma flour, and three Montana-North Dakota flour samples. Little relationship exists between elevated fungal counts and other high counts. High actinomycete counts were noted in five wheat samples from both Michigan-Indiana and Kansas-Nebraska, and in five Texas-Oklahoma, six Michigan-Indiana, three Kansas-Nebraska, and two Southeastern flour samples.

Since correlations are not evident among individual samples, an independent phenomenon is suggested, ie, samples with high bacterial counts may not always

Catalase-Negative Bacteria					Fecal Streptococci				Aerobic Spore-Forming Bacteria				Flat Sour Bacteria		
0	<10	10^1	10^2	10^3	0	<10	10^1	10^2	0	<10	10^1	10^2	0	<10	10^1
10				1	8	2	1		3	8			5	6	
6		4			9	1			3	3	2	2	5	3	2
1		1			2				1	1			2		
1			1		2				2				2		
11				1	8	3	1		4	7	1		5	6	1
13					11	1	1		1	11	1		4	9	
11					8	2	1		4	7			7	4	
6		1	3	1	8	3			4	7			4	7	
9			1		8	2			3	7			5	5	
9		1			6	3	1		1	9			2	8	
6	1		1		6	1	1		3	5			5	3	
6	1		1		8				1	7			5	3	
48	1	1	2	2	40	10	4	0	18	35	1	0	29	24	1
41	1	6	5	1	44	8	2	0	12	37	3	2	22	30	2
89	2	7	7	3	84	18	6	0	30	72	4	2	51	54	3

have high numbers of fungi or actinomycetes nor will high counts in wheat indicate high flour counts. Generally, however, bacteria are the predominant organisms, followed by fungi and actinomycetes in both wheat and flour.

This survey illustrates the heterogeneity of the microflora and the complexity of microbial problems associated with wheat and flour milled from it.

Acknowledgment

We express our appreciation to the Millers' National Federation for assistance in securing wheat and flour samples.

Literature Cited

1. FRAZIER, W. C. Food Microbiology. p. 180. McGraw-Hill: New York (1967).
2. DOTY, J. Bacteria control in flour milling operation. Am. Miller Process. 89: 7, 20 (1961).
3. GRAVES, R. R., ROGERS, R. F., LYONS, A. J., Jr., and HESSELTINE, C. W. Bacterial and actinomycete flora of Kansas-Nebraska and Pacific Northwest wheat and flour. Cereal Chem. 44: 288 (1967).
4. GRAVES, R. R., and HESSELTINE, C. W. Fungi in flour and refrigerated dough products. Mycopathol. Mycol. Appl. 29: 277 (1966).
5. KURTZMAN, C. P., WICKERHAM, L. J., and HESSELTINE, C. W. Yeasts from wheat and flour. Mycologia 57: 542 (1970).
6. PFEIFER, V. F., and GRAVES, R. R. Microbiology of wheat and flour: Reduction of microbial population during milling. Proc. Fourth Natl. Conf. Wheat Util. Res., Boise, Idaho. pp. 60-64. U.S. Dep. Agric. ARS-74-35 (1965).

7. HESSELTINE, C. W., and GRAVES, R. R. Microbiology of flours. Econ. Bot. 20: 156 (1966).
8. NATIONAL CANNERS ASSOCIATION. Bacterial standard for sugar (and starch). The Association: Washington, DC (mimeographed sheets) (1949).
9. CANCO TECHNICAL SERVICE. Bacteriological control of refrigerated biscuit packing operations. p. 2. Research and Development Department, Maywood, IL (1959).

[Received May 9, 1977. Accepted March 13, 1978]