PHYSICAL DOUGH, BAKING, AND NUTRITIONAL QUALITIES OF STRAIGHT-GRADE AND EXTENDED-EXTRACTION FLOURS[1]

C. A. WATSON, W. C. SHUEY, R. D. CRAWFORD[2], and M. R. GUMBMANN[3]

Cereal Chem. 54(3): 657-664

ABSTRACT

Straight-grade and extended-extraction (about 80%) flours were produced from six samples of hard red spring wheat. Mixograms and baking qualities of the two flours were similar for each wheat variety. The nutritional value of the extended-extraction flours was generally better than that of the straight-grade flours.

Recently, Nesheim (1) emphasized the need to study the feasibility of retaining in flour as much of the indigenous nutrient content of wheat as possible without impairing its end-use quality. If this is to be done, changes may be required in processing technology, in criteria of quality evaluation, and in consumer preference. If flour is to retain more of the minerals and dietary fiber of wheat, milling to a longer extraction is necessary. Hence, quality control and the baking industry may have to accept flour with a higher ash content and darker color, and the consumer may have to accept a darker loaf of bread.

Shuey *et al.* (2) recently reviewed the literature on milling and flour extraction rates. Jones and Moran (3) reported on the chemical and nutrient contents of 23 individual flour streams with a total flour extraction of 80%. Higher amounts of minerals, protein, fiber, and B-vitamins were present in the tail-end streams than in the head-end mill streams. Sikka *et al.* (4) observed that a blended atta flour, made primarily of the low-grade, tail-end flour streams (25–35% of the wheat kernel), had better protein efficiency ratio (PER), net protein retention (NPR), and amino acid balance than whole atta, bran, or white flour.

Fellers *et al.* (5) made a protein concentrate by dry milling (9% moisture) wheat millfeeds in a Brabender Quadrumat Senior flour mill. The protein concentrate contained more thiamine, folic acid, and choline, about the same PER and lysine content, and less niacin and pantothenic acid than the millfeed from which it was obtained.

Shuey *et al.* (2) reported a method of obtaining 80% extraction flours by tail-end regrinding and redressing. The physical dough, baking, and nutritional data for those flours are presented here.

MATERIALS AND METHODS

The wheat samples, milling procedure, and chemical assays have been described (2). Mixograms were obtained by approved methods (6), the flours

[1]Cooperative investigation, North Central Region, Agricultural Research Service, U.S. Department of Agriculture; and the Department of Cereal Chemistry and Technology, North Dakota State University, Fargo. Published with the approval of the Director of the Agricultural Experiment Station, North Dakota State University, Fargo, as Journal Series No. 737.

Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

[2]Respectively: Research Chemist, Research Food Technologist, and Technician, North Central Region, Agricultural Research Service, U.S. Department of Agriculture, North Dakota State University, Fargo, ND 58102.

[3]Research Chemist, Western Regional Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Berkeley, CA 94710.

TABLE I
Diet Fed to Rats to Determine the Protein Efficiency Ratio (PER) of the Straight-Grade (SG) and Extended-Extraction (EE) Flours

	Amount in Each Diet[a]										
	1 %	2 %	3 %	4 %	5 %	6 %	7 %	8 %	9 %	10 %	11 %
Casein (ANRC)	10.97	...	...	...	...	...	...	...	...	...	...
Corn oil	8.00	7.11	7.19	7.23	7.14	6.97	7.10	7.22	7.06	7.09	7.02
Moisture	7.44	...	...	...	...	...	...	...	...	...	...
Salts XIV + Zn + Co	5.00	4.71	4.68	4.65	4.67	4.63	4.59	4.55	4.52	4.59	4.54
Cellulose	3.00	2.73	2.80	2.79	2.77	...	2.74	2.74	2.60	2.62	2.51
Vitamins (N.B. Co.)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Corn starch	20.00	10.00	10.00	10.00	5.48	0.86	10.00	10.00	10.00	8.06	1.96
Dextrose	43.59	4.91	5.85	3.45	...	...	9.05	8.51	6.62	...	...
Flour	...	68.54	67.48	69.88	77.94	85.54	64.52	64.98	67.20	75.64	81.97
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[a]Diet 1, protein supplied by casein (ANRC); diets 2–6, straight-grade flours; diets 7–11, extended-extraction flours. Diets 2 and 7, Chris; 3 and 8, Waldron; 4 and 9, Prodax; 5 and 10 Kitt; 6 and 11, Era (50:50 blend of Minot, N. Dak., and Crookston, Minn., samples).

TABLE II
Milling and Analytical Data for Six Hard Red Spring Wheat Samples Milled to Straight-Grade and to 80% Extraction Flours

		Straight-Grade Flour				Extended-Extraction Flour			
Variety	Origin	Extraction %	Ash[a] %	Protein[a] %	Agtron color	Extraction %	Ash[a] %	Protein[a] %	Agtron color
Chris	Crookston, Minn.	74.8	0.42	14.7	58.0	80.1	0.63	15.5	34.0
Waldron	Casselton, N. Dak.	72.0	0.47	14.9	53.5	78.7	0.70	15.4	29.0
Prodax	Casselton, N. Dak.	69.6	0.50	14.5	50.5	77.4	0.72	15.0	24.5
Kitt	Plentywood, Mont.	73.7	0.42	12.9	70.0	79.7	0.54	13.2	53.5
Era (blend)[b]		77.2	0.43	11.7	67.0	81.5	0.57	12.1	47.2

[a]14% Moisture basis.
[b]50:50 Blend of Minot, N. Dak., and Crookston, Minn., samples.

were baked as described by Shuey and Gilles (7), and color of the samples was determined by the method of Patton and Dishaw (8). Thiamine was determined by approved methods (6) and lysine by the method described by Ahmed and McDonald (9).

The PERs of the flours were determined at the Western Regional Research Center, Agricultural Research Service, USDA, Berkeley, Calif. The diets fed to the rats are shown in Table I. All diets contained 10% protein, 8% fat, 5% salts

TABLE III
Mixogram Class and Baking Data for the Straight-Grade (SG) and Extended-Extraction (EE) Flours

Variety and Extraction	Mixogram Class	Potassium Bromate ppm	Absorption %	Mix Time min	Loaf Volume cc	Crust Color[a]	Crumb[a] Color	Crumb[a] Grain
Chris								
SG	4	10	61.8	2.8	950	102	102	90
EE	4	25	62.5	2.5	940	102	100	91
Waldron								
SG	4	10	63.9	2.8	975	101	100	89
EE	5	25	63.0	2.8	1000	103	98	91
Prodax								
SG	6	10	62.0	3.8	925	103	101	90
EE	5	25	62.6	3.8	900	102	99	89
Kitt								
SG	5	15	60.5	3.5	925	102	101	90
EE	5	25	62.3	3.5	945	102	101	92
Era (blend)[b]								
SG	5	10	58.8	4.0	902	102	105	90
EE	5	20	59.5	3.6	825	102	100	90

[a]The higher values indicate better color and grain.
[b]50:50 Blend of Minot, N. Dak., and Crookston, Minn., samples.

TABLE IV
Crude Fiber, Fat, Thiamine, and Lysine Content of the Straight-Grade (SG) and Extended-Extraction (EE) Flours[a]

Variety	Fiber SG %	Fiber EE %	Fat SG %	Fat EE %	Thiamine SG γ/g	Thiamine EE γ/g	Lysine SG g/16 g N	Lysine EE g/16 g N
Chris	0.4	0.4	1.3	1.4	1.59	3.60	1.75	2.09
Waldron	0.3	0.4	1.2	1.2	1.55	3.22	1.75	2.00
Prodax	0.3	0.6	1.1	1.4	1.46	3.75	1.94	2.04
Kitt	0.3	0.5	1.1	1.2	1.06	2.43	1.87	1.94
Era (blend)[b]	0.3	0.6	1.1	1.2	1.56	2.94	2.02	2.14

[a]14% Moisture basis.
[b]50:50 Blend of Minot, N. Dak., and Crookston, Minn., samples.

XIV plus Zn and Co, 3% cellulose, 2% vitamins (N.B. Co.), 20% starch, and 44% dextrose. Each diet was fed to five male weanling rats (Sprague-Dawley strain) per group. The age of the rats at the beginning of the test was 21 days and the average weight was 55 g.

RESULTS AND DISCUSSION

The identity and milling data of the wheats and the ash, protein, and Agtron color values of the flours are reported in Table II. The average yield of the

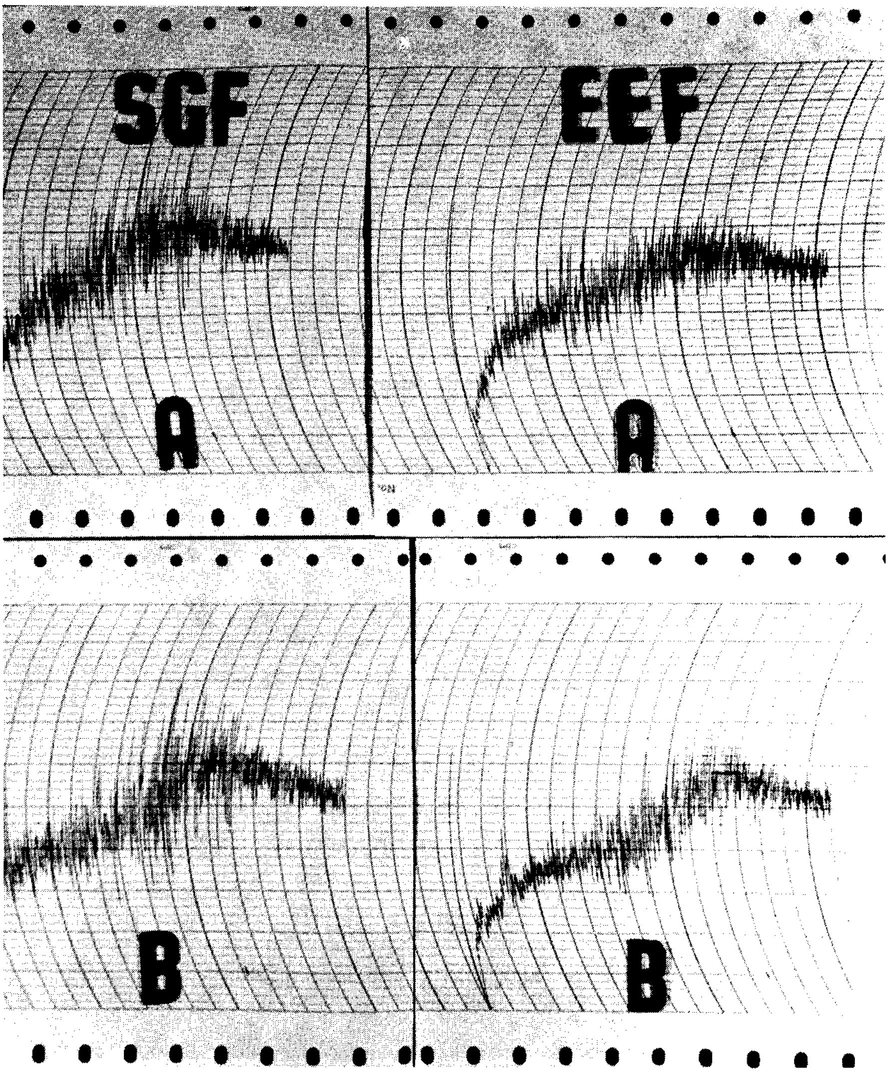

Fig. 1. Comparison of mixograms of straight-grade (SG) and extended-extraction (EE) flours.

TABLE V
Results of Protein Efficiency Ratio (PER) Assay for the Straight-Grade (SG) and Extended-Extraction (EE) Flours

Diet and Dietary Source of Protein[a]	Final Body Weight ± S.E.[b]	Total Feed Consumption ± S.E.	PER[c]		% Digestibility[d]	
			Actual ± S.E.	Adjusted	Diet	Nitrogen
1 Casein (ANRC)	188 ± 17a[e]	394 ± 48a	3.35 ± 0.05a	2.50	95	93
Straight-Grade						
2 Chris	71 ± 2b	171 ± 13b	0.94 ± 0.07bc	0.70	94	88
3 Waldron	74 ± 2b	185 ± 9b	1.02 ± 0.08bc	0.76	94	88
4 Prodax	68 ± 3b	159 ± 10b	0.77 ± 0.11c	0.57	94	88
5 Kitt	72 ± 2b	175 ± 12b	0.96 ± 0.05bc	0.72	94	87
6 Era (blend)[f]	75 ± 3b	188 ± 11b	1.07 ± 0.08 b	0.80	96	87
Extended-Extraction						
7 Chris	73 ± 3b	181 ± 15b	1.00 ± 0.07bc	0.75	94	87
8 Waldron	74 ± 3b	184 ± 10b	1.05 ± 0.10bc	0.78	94	86
9 Prodax	78 ± 2b	203 ± 7b	1.13 ± 0.04b	0.84	94	86
10 Kitt	73 ± 2b	185 ± 12b	0.93 ± 0.09bc	0.69	94	88
11 Era (blend)[f]	79 ± 5b	199 ± 18b	1.17 ± 0.15b	0.87	93	85

[a]All diets calculated to contain 10% protein.
[b]Five male weanling rats per group, Sprague-Dawley strain; initial age, 21 days; initial average weight, 55 g. S.E. = Standard error.
[c]PER (protein efficiency ratio) = weight gain/protein intake. Adjusted = ANRC adjusted/ANRC actual × actual (flour).
[d]Digestibility: Diet = (feed intake − fecal weight)/feed intake × 100. Nitrogen = (N intake − fecal N)/N intake × 100.
[e]Duncan's Multiple Range Test. Means without letter in common are significantly different: $P < 0.05$.
[f]50:50 Blend of Minot, N. Dak., and Crookston, Minn., samples.

extended-extraction (EE) flours was 6.0% greater than that of the straight-grade (SG) flours. As reported (2), the correlation coefficient between the SG and the EE flour percentages was 0.99. The EE flours had higher protein and ash contents and lower Agtron color values than the SG flours.

Mixograms of the SG and EE flours were nearly identical, as shown by the class designation in Table III. Mixograms of the SG flours averaged 0.1 min longer than those of the EE flours. Figure 1 compares mixograms of SG and EE flours.

The EE flours required considerably more potassium bromate than the SG flours (Table III). Absorptions of the EE flours were generally slightly higher than those of the SG flours because of the higher protein content of the former. Mixing times of the EE flours were equal to or slightly shorter than those of the SG flours. The loaf volumes (standard deviation was 24 cc) of the breads made from the EE and SG flours were not significantly different. Bread crust color, crumb color, and grain of the EE and SG flours were about the same. In general, doughs of both flours handled similarly and made equally good bread. Results of a test panel (data not reported) showed no preference of bread baked from the SG and EE flours.

Crude fiber content was greater in EE than in SG flours by 89% for the semidwarf varieties (Prodax, Kitt, and Era), and by 14% for the conventional height varieties (Table IV). Fat contents of the EE and SG flours were essentially the same. Thiamine and lysine contents of the EE flours were considerably higher than those of the SG flours. The average increases for thiamine and lysine were 12.2 and 9.1%, respectively. Prodax was followed by Chris and then Waldron in thiamine content. The semidwarf and conventional height varieties did not seem to differ in thiamine content. The increases in lysine of the semidwarf and conventional height varieties were 5 and 17%, respectively.

The PER values of all the flours were considerably lower than the PER of casein (Table V). The only significant varietal difference in PER values was between Prodax (SG) and Prodax (EE) and Era (SG and EE). The average adjusted PER of the SG flours was 0.71 compared to 0.79 for the EE flours. The nutritional data appear to agree with those reported elsewhere (3,4).

Our data indicate that the current flour extraction rates of wheat can be increased by at least 5%. The increase would not substantially affect the quality of the bread but would increase its nutritional value with respect to its mineral, thiamine, and lysine content.

Literature Cited

1. NESHEIM, R. O. Recommended fortification policy for cereal-grain products. Proc. 9th Nat. Conf. Wheat Util. Research, ARS-NC-40. Agricultural Research Service, USDA: Washington, D.C. (1976).
2. SHUEY, W. C., MANEVAL, R. D., and DICK, J. W. Eighty percent extraction flour by tail-end regrinding and redressing. Cereal Chem. 54: 42 (1977).
3. JONES, C. R., and MORAN, T. A study of the mill streams composing 80% extraction flour with particular reference to their nutrient content. Cereal Chem. 23: 248 (1946).
4. SIKKA, K. C., JOHARI, R. P., DUGGAL, S. K., AHUJA, V. P., and SUSTIN, A. Comparative nutritive value and amino acid content of different extractions of wheat. J. Agr. Food Chem. 23: 24 (1975).
5. FELLERS, D. A., SHEPHERD, A. D., BELLARD, N. J., MOSSMAN, A. P., JOHNSTON, P. H., and WASSERMAN, T. Protein concentrates by dry milling of wheat millfeeds. II. Compositional aspects. Cereal Chem. 45: 520 (1968).

6. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Method 54-40, approved April 1961; Method 86-80, approved May 1960. The Association: St. Paul, Minn.
7. SHUEY, W. C., and GILLES, K. A. Rheological properties of water-extracted air-classified spring wheat flours. Cereal Chem. 50: 281 (1973).
8. PATTON, J., and DISHAW, M. Flour color evaluation with the green Agtron. Cereal Sci. Today 13: 163 (1968).
9. AHMED, S., and McDONALD, C. E. Amino acid composition, protein fractions and baking quality of Triticale. In: Triticale: First man-made cereal, ed. by C. C. Tsen, p. 137. Amer. Ass. Cereal Chem.: St. Paul, Minn. (1974).

[Received August 30, 1976. Accepted November 23, 1976]