EFFECT OF THE SUBFRACTIONS OF STARCH TAILINGS ON COOKIE DIAMETER[1]

WILLIAM F. SOLLARS AND SHEILA MACLEOD BOWIE[2]

ABSTRACT

Starch tailings isolated from Pacific Northwest wheat flours and substituted at 5 and 10% levels in a standard cookie flour caused large decreases in cookie diameter. The tailings were fractionated by defatting with boiling methanol, by sieving, and by alkaline extraction to remove polysaccharides. The pentosan-rich subfractions and the damaged starch had much larger diameter-decreasing effects than the original tailings. Proteins and enzymes appeared to have very little effect on diameter. Lipids and small-granule starch had small diameter effects. Thus, the diameter effect of tailings appeared to be a net result of the large diameter-decreasing effects of pentosans and damaged starch modified by the constituents with small effects.

The cookie baking test is probably the most important single test for evaluating the baking quality of soft wheat varieties. The importance of this test has led to several studies of the basic mechanism of the spreading of cookie dough during baking (1). According to the

[1]Manuscript received August 2, 1965. Contribution from the Western Wheat Quality Laboratory, Department of Agricultural Chemistry, College of Agriculture, Washington State University; and Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture. Scientific Paper No. 2695, College of Agriculture, Pullman. Presented at the 50th annual meeting, Kansas City, Mo., April 1965.

[2]Chemist and junior chemist, Western Wheat Quality Laboratory, Crops Research Division, U.S. Department of Agriculture, Pullman, Wash.

currently accepted explanation, the degree of spreading is related directly to the amount of available or "free" water (2). Flour constituents capable of "binding" water will lower cookie diameter.

In another approach to the problem, the starch tailings fraction was shown to be the major controlling factor in cookie diameter, which the tailings decidedly lowered (3,4). Reconstituted flours with tailings omitted gave cookies of extremely large spread and poor quality, whereas such flours with excess tailings yielded cookies with greatly reduced spread.

The reducing effect of tailings on cookie diameter is generally ascribed to the pentosans of the tailings (5). However, the tailings fraction is heterogeneous, it presents a difficult problem in subfractionation, and no systematic study of the effects of the individual constituents on cookie diameter has appeared. Several years ago an alkaline extraction procedure was developed at this laboratory for subfractionating tailings. This procedure was based on the work of Wolf *et al.* in extracting hemicelluloses from corn hulls (6). Recently, Kulp and Bechtel, in a bread-baking study (7), reported several methods for subfractionating or otherwise treating tailings.

These methods now make it possible to obtain tailings subfractions enriched in one or more constituents and to attempt the evaluation of the effect of these constituents on cookie diameter. The present study reports the application of these methods to the tailings from Pacific Northwest wheat flours.

Materials and Methods

Flours. Straight-grade, unbleached flours of 7–8% protein content were milled on a Buhler mill from pure variety composites. The varieties, Columbia, Omar, and Brevor, were used in this study. Columbia is a hard red winter wheat with poor cookie quality; Omar is a club wheat with good cookie quality; and Brevor is a soft common white winter wheat with excellent cookie quality.

Major Flour Fractions. Starch tailings, gluten, and prime starch were obtained by previously described methods (4). One uniform lot of tailings, about 600 g., was prepared from each flour by fractionating 4,000–5,000 g. flour in batches and compositing the dried tailings. The tailings fraction from each batch was suspended in water and lyophilized. The gluten and prime starch were air-dried.

Fractionation by Methanol Extraction. Tailings (100 g.) were refluxed with 1,000 ml. 85% methanol for 8 hr. and the solvent was decanted (7). This was repeated four times with fresh solvent each time. The residue was freed of solvent by air-drying. The solvent was

evaporated from the extract under vacuum below 40°C. The dried extract was re-extracted with ether and petroleum ether to obtain the lipids. The lipids in mixed ether solution were stored in the refrigerator, and baking studies were completed within 1 week.

Only part of the dried extract was soluble in mixed ethers. The remainder was easily soluble in water and was lyophilized to yield a somewhat hygroscopic solid. Baking studies with this material were completed within 1 week.

Fractionation by Sieving. Preliminary experiments were made by passing a thin slurry of tailings through one sieve at a time, mounted on a laboratory shaker (7). The slurry was passed successively through 100-, 200-, 300-, and 400-mesh sieves. The 100- and 300-mesh sieves retained very little material. For cookie-baking trials, only the 200- and 400-mesh sieves were used, and three fractions were collected – the materials retained on these two sieves and the material passing through the 400-mesh sieve. Each subfraction was resuspended in water, shelled, lyophilized, and rehydrated to 9–10% moisture.

Fractionation by Alkaline Extraction. The following procedure was developed after extensive experiments based on the work of Wolf *et al.* (6). Tailings (50 g.) were mixed with 500 ml. 0.5% potassium hydroxide in a Waring Blendor[3] for 10 sec. and the suspension was centrifuged. The supernatant was decanted and the residue was extracted three more times with 500 ml. water each time. Each of the four supernatants was neutralized to pH 6.8–7.0 and poured into 3 volumes of 95% ethanol. The mixture was centrifuged and the polysaccharide precipitates were recovered, combined, suspended in water, shelled, lyophilized, and rehydrated.

The residue after centrifugation of the fourth extraction contained two layers, an upper, swollen, yellow gel layer and a lower, firm, white starch layer. The upper layer was removed with a square-tipped spatula and suspended in water. The lower layer was slurried with water. Both these subfractions were neutralized, shelled, lyophilized, and rehydrated.

Digestion of Tailings Protein. Portions of starch tailings (50 g. each) were incubated at 30°C. for 3 days with 500 ml. water, either 50 mg. trypsin or 50 mg. Pronase, 2 ml. toluene, and occasional shaking (7). A control received exactly the same treatment except no added enzyme; pH for all three treatments was kept in the range 6.8–7.0. After incubation, the digest was centrifuged. The residue was washed twice with distilled water. The final residue was suspended in water, lyophilized, and rehydrated.

[3]Mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

Deactivation of Tailings Enzymes. The enzymes of tailings were deactivated by two methods (7). Deactivation by ethanol was followed by solvent removal on a steam bath and air-drying under atmospheric conditions. Deactivation with 3% trichloroacetic acid in 90% n-butanol was followed by washing with ether, solvent removal on the steam bath, and air-drying. As a control, prime starch was treated by these two methods.

Ball-Milled Starch. A sample of prime starch was ball-milled 64 hr. in a laboratory mill.

Analytical Methods. Moisture, protein, and lipids by acid hydrolysis were determined by AACC methods (8). Pentosans were determined by a previously described method (9) which involved a redistillation and titration by the Hughes and Acree bromination method. Damaged starch was determined by the rapid method of Donelson and Yamazaki (10). Granule size distribution was determined by measuring 500 or more granules under a microscope and classifying them into five groups (11).

Cookie Baking Method. The micro baking procedure of Finney, Morris, and Yamazaki (12) was used. The average diameter of two cookies baked from a 40.0-g. sample of a standard cookie flour was determined. For 76 replications of the standard flour baked on 19 days over a period of 1 year, the average diameter was 9.13 cm., the standard deviation of a single observation was 0.113 cm., and the least significant difference at the 5% level was 0.038 cm.

The effect on cookie diameter of the major fractions and the subfractions of the tailings was determined by substituting 2.0 g. (5% level) and 4.0 g. (10% level) of the fraction for an equivalent amount of the 40.0 g. of the standard cookie flour. Constituents obtained in small amounts had to be tested at 0.1-, 0.5-, and 1.0-g. levels of substitution.

Most of the subfractions were obtained in aqueous suspension, lyophilized, equilibrated with the atmosphere to 9–10% moisture, and incorporated as dry materials. The lipids were added as aliquots dissolved in ether. The effect of ether on cookie diameter was determined. Wherever possible, the subfractions of a fractionation procedure were reconstituted to a tailings fraction and tested. When this was not possible, controls of either tailings or prime starch were subjected to the treatment to determine processing changes.

Results and Discussion

Influence of Tailings Moisture Level on Cookie Diameter. The tailings after lyophilization had a moisture content of about 4%. Portions

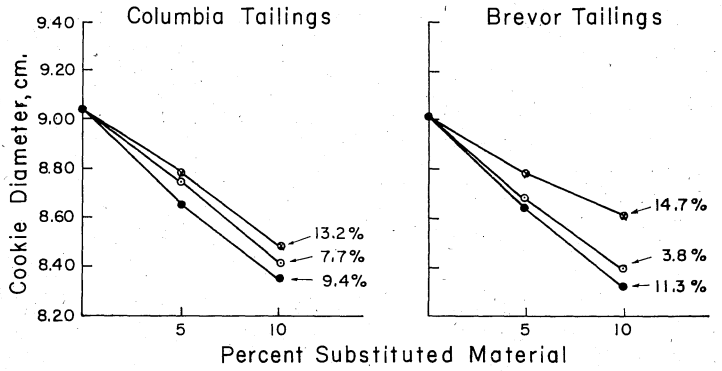

Fig. 1. Effect of tailings moisture content on cookie diameter. The figures designate the moisture content.

were taken from each composite of lyophilized tailings and rehydrated to various levels either in room atmosphere or in a fermentation cabinet. Figure 1 shows the results for Columbia and Brevor. Very little difference appeared in the diameter-decreasing effect from 3.8 to 11.3% moisture, but at 13.2 and 14.7% levels, the effect was slightly less, especially for Brevor tailings. Omar tailings tested at three moisture levels had a pattern similar to that of Columbia tailings, but Omar tailings had a diameter-decreasing effect only about 80% as large as that of Columbia and Brevor tailings. Subsequent preparations (except the lipids) were rehydrated in room atmosphere to the 9–10% moisture range.

At the 9–10% moisture level, the diameter-decreasing effect of the tailings was very stable. Portions of the original tailings used as controls at 3–4 months after preparation had the same depressing effect as when freshly prepared.

Table I gives the analytical data for the tailings. Usually, hard wheat flours have yielded a larger amount of tailings — one reason why these flours give smaller cookies. Protein and lipid contents of the tailings were nearly identical, but Columbia tailings had much more damaged starch, and Brevor tailings had a higher pentosan content. Size distribution of the starch granules of the tailings is given in Table I-B. A sample of Brevor prime starch is included for comparison. One characteristic of tailings is that over 85% of the starch granules are 5 μ and under, and over 97% are under 10 μ.

Effect of Lipids and Defatted Tailings from Methanol Extraction. Five extractions with boiling methanol lowered the lipid content from about 1.2 to 0.5% or less (Table II), but none of the tailings were completely defatted. The protein and pentosan content of the ex-

TABLE I

DATA FOR TAILINGS STARCH FRACTION

Tailings Source	A. Analytical Data				
	Yield Based on Parent Flour[a]	Protein	Pentosans	Lipids	Damaged Starch
	%	%	%	%	%
Columbia flour	19.9	2.70	3.45	1.25	15.1
Brevor flour	16.7	2.74	5.06	1.14	6.1
Omar flour	18.8	2.73	3.43	1.22	6.1

	B. Size Distribution of Starch Granules				
	Size of Starch Granules				
	5μ and Below	6–10μ	10–15μ	15–20μ	Over 20μ
	%	%	%	%	%
Brevor prime starch	42.2	18.4	8.5	10.4	20.5
Columbia tailings	92.8	5.1	0.9	0.6	0.6
Brevor tailings	88.3	9.1	0.8	1.1	0.7
Omar tailings	91.5	7.9	0.4	0.2	0.0

[a] All data on 14% moisture basis.

TABLE II

ANALYTICAL DATA FOR SUBFRACTIONS OBTAINED BY METHANOL EXTRACTION

Starting Material	Subfraction	Yield[a]	Protein	Pentosans	Lipids	Damaged Starch
		%	%	%	%	%
Columbia tailings	Residue	94.2	2.46	3.51	0.46	18.4
	Extract					
	Ether-soluble	0.5	12.2	...	...	...
	Water-soluble	1.8	12.8	...	...	...
	Recovery	96.5				
Brevor tailings	Residue	93.5	2.77	4.73	0.38	8.8
	Extract					
	Ether-soluble	0.6	16.5	...	...	...
	Water-soluble	0.9	4.35	...	...	...
	Recovery	95.0				
Omar tailings	Residue	92.8	2.42	3.37	0.51	9.4
	Extract					
	Ether-soluble	0.3	4.42	...	...	...
	Water-soluble	0.7	....	...	...	...
	Recovery	93.8				

[a] Data for residue are on 14% moisture basis; for the extract subfractions, on "as is" basis.

tracted residue showed very little change. Damaged starch increased 2–3%.

The extract, after removal of solvent, amounted to 1–2% of the original tailings but only part of this – about 0.5% of original tailings – was soluble in ether and hence lipid. The remainder was easily soluble in water. Both portions of the extract were higher in protein than the original tailings, thus accounting for the slight drop in protein content of the defatted tailings.

Figure 2 shows the effects of the subfractions and the tailings reconstituted from these subfractions. Exposure to boiling methanol for 40 hr. apparently did not damage the diameter-decreasing effect of the tailings, since the performance of reconstituted tailings closely paralleled the original tailings in this respect.

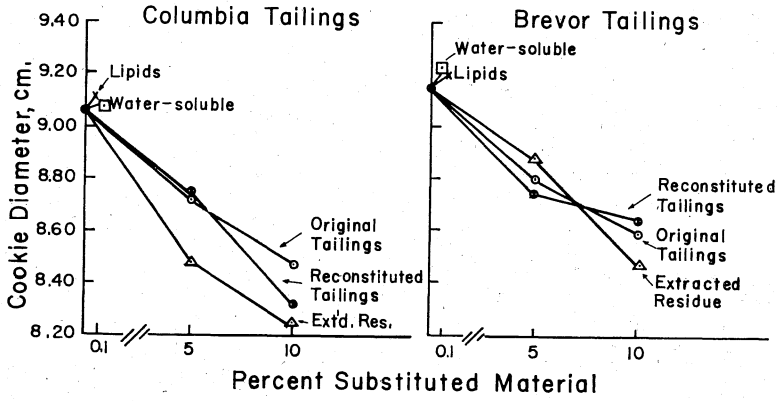

Fig. 2. Effect of the subfractions from methanol extraction of starch tailings and the tailings reconstituted from these subfractions.

The extracted residue, markedly lower in lipids, had a decidedly larger decreasing effect on diameter at both levels tested for Columbia and Omar tailings (data for Omar are not shown, for the sake of conciseness) and at one of the levels for Brevor. The methanol-extracted lipids do not appear to account for the diameter-decreasing effect of tailings. Direct evidence for this is found in the small increasing effects of both portions of the extracts. Testing of these materials had to be conducted at very low levels of substitution; hence, the effects produced on diameter were below the significant level but were consistently increasing effects. The lipids of tailings may play a small part in cookie quality, because their small increasing effects may counteract the large decreasing effects of other constituents.

Effect of Subfraction from Sieving. Table III-A gives the analytical data. The material retained on the 200-mesh sieve was 19–27% of the total and had much higher protein and pentosan contents than the original tailings, but the damaged starch and lipids showed little change. The material retained by the 400-mesh sieve amounted to less than 10% of the total and was similar in composition to that retained on the 200-mesh sieve. Thus there is some justification for using only the 400-mesh sieve and combining these two subfractions, as is often done (7).

TABLE III
SUBFRACTIONS OBTAINED BY SIEVING TAILINGS

A. ANALYTICAL DATA

STARTING MATERIAL	SUBFRACTION	YIELD [a]	PROTEIN	PENTOSANS	LIPIDS	DAMAGED STARCH
		%	%	%	%	%
Columbia tailings	Over 200	19.6	7.41	13.4	...	14.5
	Over 400	5.2	7.06	11.5	...	...
	Through 400	68.1	0.82	0.56	1.12	9.7
	Recovery	92.9				
Brevor tailings	Over 200	27.0	5.57	11.3	...	10.3
	Over 400	9.1	6.74	12.6	...	7.8
	Through 400	58.9	0.95	0.98	0.95	6.3
	Recovery	95.0				
Omar tailings	Over 200	19.0	10.6	9.49	1.40	...
	Over 400	8.2	6.43	8.56	1.49	8.0
	Through 400	62.9	0.85	0.68	1.03	...
	Recovery	90.1				

B. DISTRIBUTION OF STARCH GRANULES

		SIZE OF STARCH GRANULES				
		5μ and Below	6–10μ	10–15μ	15–20μ	Over 20μ
		%	%	%	%	%
Columbia tailings	Through 400	95.7	2.9	0.6	0.4	0.4
Brevor tailings	Through 400	92.1	6.8	0.2	0.7	0.2
Omar tailings	Through 400	97.0	2.8	0.2	0.0	0.0

[a] All data on 14% moisture basis.

The material passing through the 400-mesh sieve comprised 59–68% of the total and had protein and pentosan contents between 0.5 and 1.0%. Mechanical sieving effected a partial separation of the tailings into subfractions enriched in proteins and pentosans and a subfraction with lower though still substantial amounts of these constituents compared with the original tailings. Some loss occurred in this separation, mostly from material adhering to the sieves.

Granule size distribution is given in Table III-B. The material passing through the 400-mesh sieve had larger amounts of granules under 5 μ than the original tailings.

The effect on cookie diameter of the subfractions from the sieving separations and the tailings reconstituted from these subfractions is shown in Fig. 3. The reconstituted tailings had a somewhat smaller effect than the original tailings. This may indicate some damage during sieving.

The subfractions enriched in proteins and pentosans had much

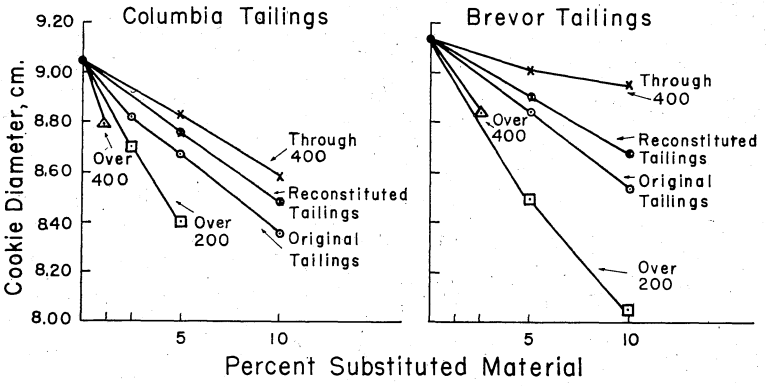

Fig. 3. Effect of the subfractions from sieving separations and the tailings reconstituted from these subfractions.

larger diameter-decreasing effects than the original tailings; this could be due to either the proteins or the pentosans. The subfraction which was lower in protein and pentosans but higher in small-granule starch had smaller diameter-decreasing effects; this subfraction from Brevor had almost no effect. The diameter-decreasing effect of the tailings does not appear to be caused by the small-granule starch.

Effect of Subfractions from Alkaline Extraction. The analytical data and granule size distribution (feasible for the starch residue only) are given in Table IV. The effect on cookie diameter is shown in Fig. 4. The extracted material was only a small part of the total tailings, but it was greatly enriched in protein and pentosan and it had a very large decreasing effect on diameter at the one low level tested. Extraction with 0.5% potassium hydroxide removed only about 20% of the total pentosans in tailings. Nearly all of the remaining pentosans were in the swollen gel. The gel had a diameter-decreasing effect decidedly larger than that of the original tailings and was higher in pentosan and damaged starch but lower (under 1%) in protein. The starch residue was very low in protein and pentosans and moderately lower in damaged starch, and it had little or no effect on cookie diameter as compared with the original tailings.

The tailings reconstituted from these three subfractions had a diameter-decreasing effect somewhat greater than that of the original tailings. Exposure to 0.5% potassium hydroxide may have caused some damage.

The alkaline extraction procedure furnished additional evidence of the large decreasing effect on cookie diameter of a material high in protein and pentosans. It also furnished a material very low in proteins and

TABLE IV

SUBFRACTIONS FROM ALKALINE EXTRACTION OF TAILINGS

STARTING MATERIAL	SUBFRACTION	YIELD [a]	PROTEIN	PENTOSANS	LIPIDS	DAMAGED STARCH
		A. ANALYTICAL DATA				
		%	%	%	%	%
Columbia tailings	Extract	4.3	16.8	18.0	...	...
	Gel	55.4	0.61	4.58	1.28	20.5
	Starch residue	37.1	0.16	0.20	0.91	10.2
	Recovery	96.8				
Brevor tailings	Extract	5.2	19.4	26.1	...	...
	Gel	49.5	0.65	5.59	1.03	13.4
	Starch residue	43.1	0.22	0.43	0.85	3.0
	Recovery	97.8				
Omar tailings	Extract	3.3	...	20.8	...	...
	Gel	50.2	0.79	4.34	1.24	...
	Starch residue	41.7	0.25	...	...	...
	Recovery	95.2				

		SIZE OF STARCH GRANULES				
		5μ and Below	6–10μ	10–15μ	15–20μ	Over 20μ
		B. DISTRIBUTION OF STARCH GRANULES				
		%	%	%	%	%
Columbia	Starch residue	96.6	2.8	0.3	0.0	0.3
Brevor	Starch residue	86.3	8.8	1.8	0.9	2.2
Omar	Starch residue	97.0	1.4	0.0	0.0	1.6

[a] All data on 14% moisture basis.

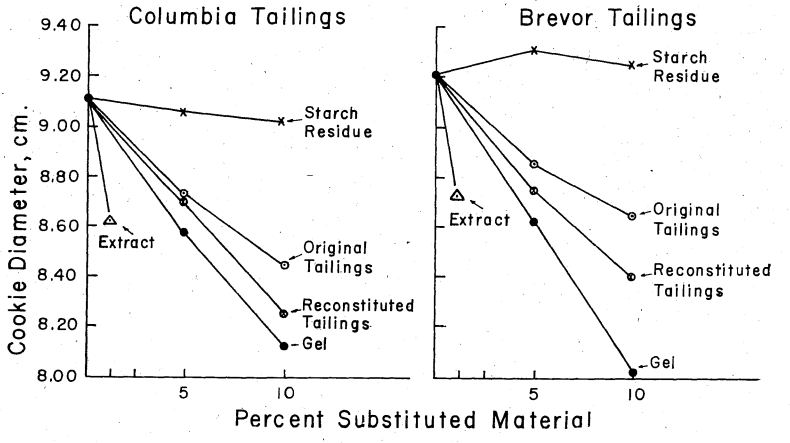

Fig. 4. Effect of the subfractions from the alkaline extraction separation.

pentosans that had a very small effect on cookie diameter. The gel subfraction provided evidence that the protein may not be causing the diameter-decreasing effect, since the gel was low in protein but had a

TABLE V

ANALYTICAL DATA FOR TAILINGS DIGESTED WITH PROTEOLYTIC ENZYMES

STARTING MATERIAL (TAILINGS)	TREATMENT	RECOVERY [a]	PROTEIN	PENTOSANS	LIPIDS	DAMAGED STARCH
		%	%	%	%	%
Columbia	Control [b]	92	2.44	3.71	1.18	15.5
	Pronase	77	0.33	4.30	1.18	11.9
	Trypsin	88	0.65	4.05	1.10	14.0
Brevor	Control	95	2.73	4.98	1.05	6.3
	Pronase	90	0.42	4.84	1.07	7.7
	Trypsin	91	0.80	5.22	0.90	5.6
Omar	Pronase	88	0.46	4.06	1.27	...
	Trypsin [c]	88	1.00	4.25	...	...

[a] All data on 14% moisture basis.
[b] The control received exactly the same digestion treatment except that no enzyme was added.
[c] The trypsin-treated Omar tailings received incubation for 24 hr.

large decreasing effect. The starch residue had an additional characteristic: nearly all the granules in this subfraction were very small, averaging about 2 μ.

Effect of Digestion with Proteolytic Enzymes. Both Pronase and trypsin markedly lowered protein content of tailings, as shown in Table V, Pronase being somewhat more effective. Since protein content actually was measured as nitrogen by the Kjeldahl method, the slight residual "protein," especially for Pronase-treated samples, might be tightly bound or inaccessible protein or it might be some nonprotein nitrogen compound. Some loss of material occurred during the 3-day incubation period. Pentosan and lipid content increased slightly, probably as a result of the removal of protein material, but damaged starch varied only slightly from that of the original tailings; and the proteolytic enzymes did not appear to attack the damaged starch granules.

Somewhat conflicting results occurred in cookie baking trials with treated tailings (Fig. 5). At most levels of testing, the treated tailings

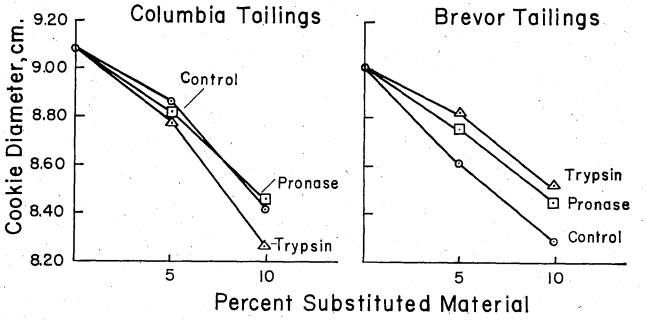

Fig. 5. Effect of starch tailings preparations after treatment with proteolytic enzymes.

from Columbia and Omar had virtually the same diameter effect as the control. Removal of most of the protein from these tailings did not appear to alter the diameter effect. Enzyme-treated Brevor tailings had appreciably smaller diameter-decreasing effects than the control (Fig. 5). It may be that in Brevor tailings the protein contributes to the decreasing effect.

Effect of Deactivating the Enzymes of Tailings. The influence of enzymes on the baking quality of soft wheat flour is usually considered negligible. However, Perten has recently reported that there is a 30- to 40-sec. interval between starch gelatinization and enzyme inactivation during the baking process (13). It is possible that amylases or other enzymes could affect the cookie diameter before inactivation. Consequently, the native enzymes of tailings were deactivated by standard procedures (7). Figure 6 shows that tailings deactivated by ethanol

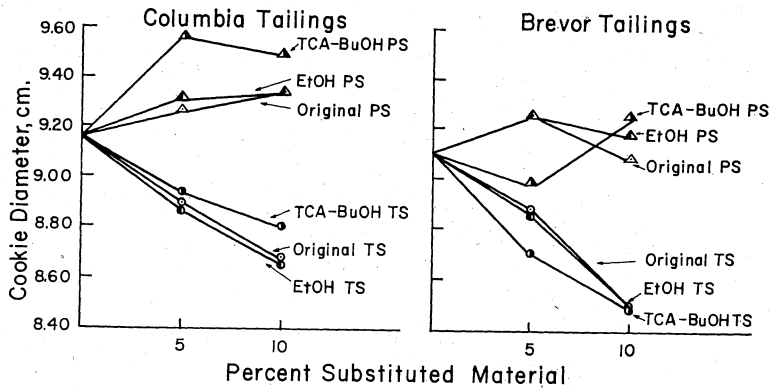

Fig. 6. Effect of deactivating the enzymes of tailings. PS, prime starch; TS, tailings starch; EtOH, inactivated by ethanol treatment; TCA-BuOH, inactivated by trichloroacetic acid in 90% n-butanol.

treatment had virtually the same effect on cookie diameter as the original tailings. Tailings treated with trichloroacetic acid (TCA) in 90% n-butanol gave somewhat different effects from those of the original tailings. The changes could be due to enzyme destruction or to the effect of the reagents themselves (TCA and butanol) on the tailings.

To distinguish between these two possibilities, Kulp and Bechtel (7) applied the deactivation procedures to prime starch which they stated to be free of enzymes. Their example was followed; Fig. 6 shows that ethanol treatment of prime starch caused only very slight changes from the original starch; but TCA in butanol resulted in decided differences in effect on cookie diameter. Thus, it appears that the enzymes of tailings have no effect on diameter.

TABLE VI
ANALYTICAL DATA FOR TAILINGS TREATED TO DEACTIVATE ENZYMES

STARTING MATERIAL (TAILINGS)	TREATMENT	RECOVERY [a]	PROTEIN	PENTOSANS	LIPIDS	DAMAGED STARCH
		%	%	%	%	%
Columbia	Ethanol	101	2.73	3.37	1.23	12.2
Brevor	Ethanol	99	2.75	4.34	0.99	...
Columbia	TCA-Butanol	102	2.69	3.09	1.21	12.3
Brevor	TCA-Butanol	103	2.79	4.29	1.22	...

[a] All data on 14% moisture basis.

Table VI gives analytical data for the treated tailings. The brief exposure of tailings to ethanol or TCA in butanol did not cause any significant change in analytical data. Lipid content, in particular, was not affected greatly.

Effect of Damaged Starch. The ball-milled Brevor prime starch had a damaged-starch content of 92.0% compared with 9.4% damaged starch in the original prime starch. The ball-milled starch sharply decreased cookie diameter (Fig. 7). However, Brevor tailings with only

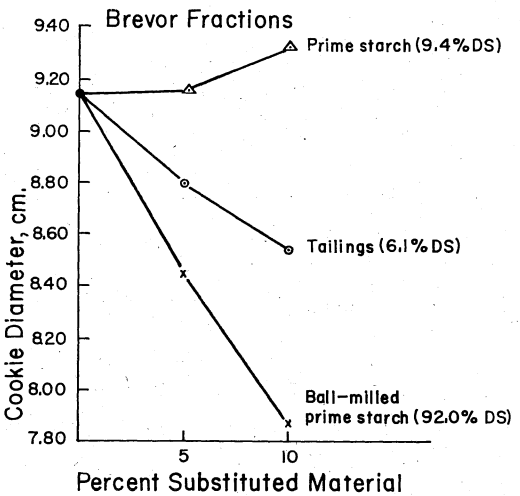

Fig. 7. Effect on cookie diameter of ball-milled starch. The figures in parentheses are the percent damaged starch.

6.1% damaged starch had a decreasing effect about half as great as that of the ball-milled starch. While the damaged starch undoubtedly contributes to the effect of the tailings, most of the tailings effect must be due to constituents other than damaged starch.

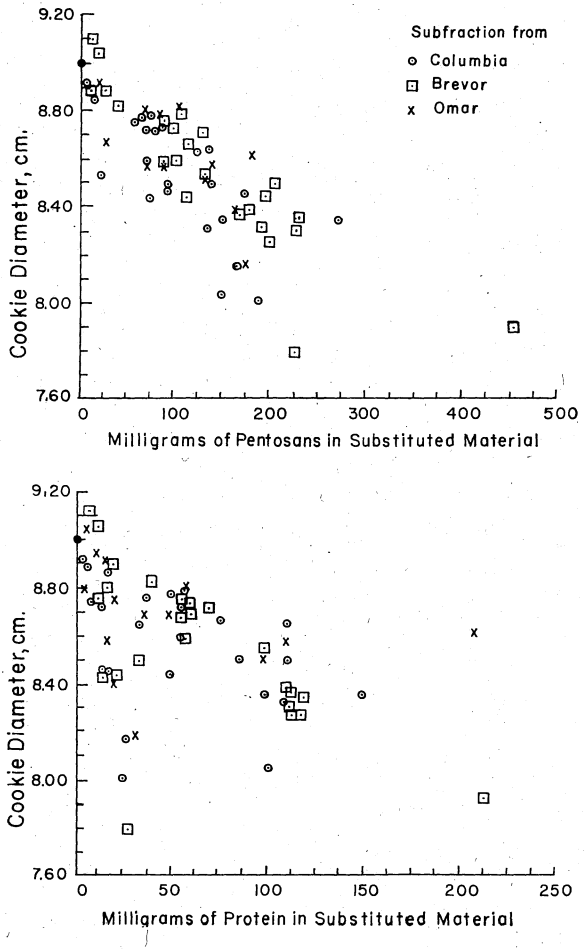

Fig. 8 (A and B). Relation between added pentosans and proteins, and cookie diameter.

Relation between Individual Constituents and Cookie Diameter. The amount of individual constituents added in the previously described experiments was calculated from the weight of added subfraction and the percent constituents (as percent protein, etc.), and is compared with cookie diameter (Fig. 8). It should be stressed that these are strictly quantitative relations, and no account has been taken of possible qualitative differences among the proteins, pentosans, and lipids. Furthermore, any alteration due to processing during the various treatments has been ignored.

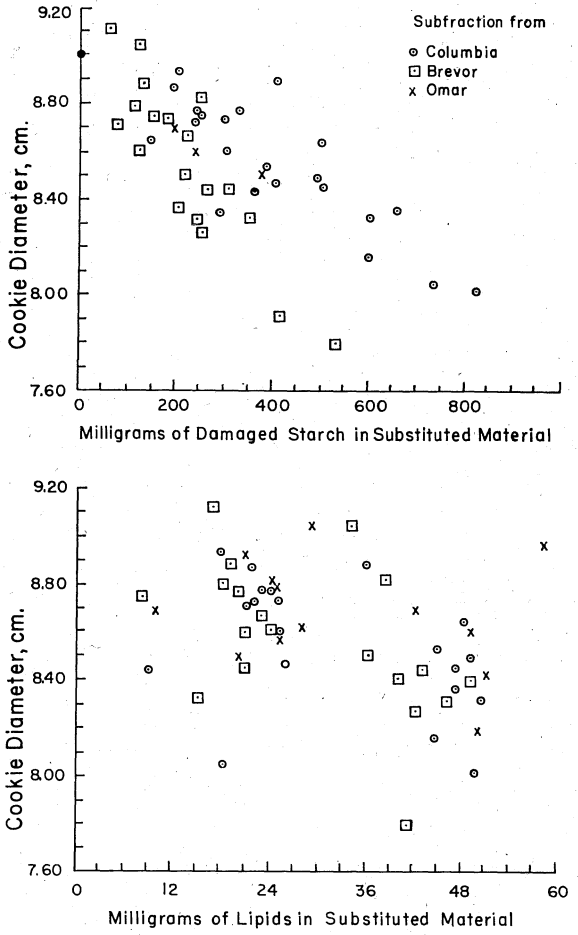

Fig. 8 (C and D). Relation between added damaged starch and lipids, and cookie diameter.

There was a high relationship between either added pentosans or added damaged starch and decrease in cookie diameter. A low relationship existed between added proteins or added lipids and decrease in cookie diameter.

Figure 9 shows the combined effect of added pentosans and damaged starch compared with cookie diameter. Since the amounts of pentosans and damaged starch in the original tailings were of approximately the same order of magnitude, simple addition of the amounts was employed. The relationship with cookie diameter was improved.

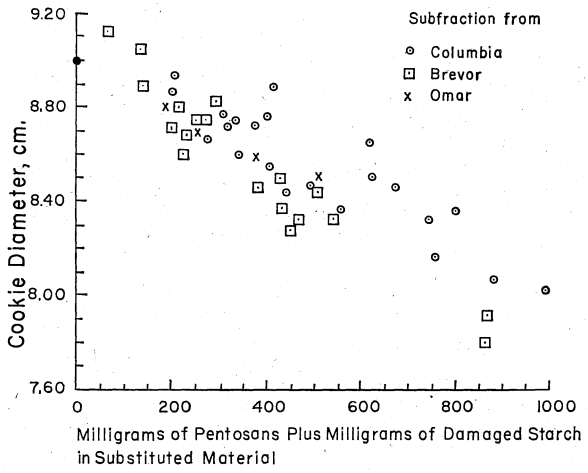

Fig. 9. Relation between added pentosans and added damaged starch *vs.* cookie diameter.

Conclusions

The pentosan-rich subfractions of wheat flour tailings had large diameter-decreasing effects in cookie-baking, and the damaged starch of tailings had moderate decreasing effects. The pentosan-rich subfractions were prepared by two different methods, sieving and alkaline extraction. These subfractions were also high in protein content, but, for Columbia and Omar tailings, removal of the protein from the tailings did not change the diameter effect.

Subfractions enriched in small-granule starch but low in pentosans, proteins, and damaged starch had only small effects (usually increasing) on diameter. Lipids of tailings had small but consistently increasing effects and were present in such small amounts as to be insignificant in effect on diameter. The enzymes of tailings did not affect the diameter.

Thus it appeared that the net effect of the tailings on cookie diameter was a result of the large decreasing effect of the pentosans and the moderate decreasing effect of the damaged starch modified by the very small effects (either decreasing or increasing) of the small-granule starch and the lipids.

Perhaps it should be reiterated that complete absence of pentosans from soft wheat flours is not desirable. Satisfactory cookie quality appears to be the net result of a number of quality factors; without some pentosans present to act as a regulatory factor, abnormally large

cookies of poor appearance might result (9). Addition of pentosans was reported to improve a cake flour of marginal quality (5).

In 1960, Gilles commented on the lack of progress concerning the physical and baking properties of the cereal pentosans (5). Since then some information has been reported on baking properties (7), but today there is still very little known about the physical properties of the wheat flour pentosans and their interactions with proteins and starch. Particularly lacking are methods for isolating pentosans of a high degree of purity.

Literature Cited

1. YAMAZAKI, W. T. The application of heat in the testing of flours for cookie quality. Cereal Chem. **36:** 59–69 (1959).
2. FUHR, F. R. Cookie spread, its effects on production and quality. Bakers Dig. **36** (4): 56–58, 78 (1962).
3. YAMAZAKI, W. T. The concentration of a factor in soft wheat flours affecting cookie quality. Cereal Chem. **32:** 26–37 (1955).
4. SOLLARS, W. F. Evaluation of flour fractions for their importance to cookie quality. Cereal Chem. **33:** 121–128 (1956).
5. GILLES, K. A. The present status of the role of pentosans in wheat flour quality. Bakers Dig. **34** (5): 47–52 (1960).
6. WOLF, M. J., MACMASTERS, MAJEL M., CANNON, J. A., ROSEWALL, E. C., and RIST, C. E. Preparation and some properties of hemicelluloses from corn hulls. Cereal Chem. **30:** 451– 470 (1953).
7. KULP, K., and BECHTEL, W. G. The effect of tailings of wheat flour and its subfractions on the quality of bread. Cereal Chem. **40:** 665–675 (1963).
8. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Cereal laboratory methods (7th ed.). The Association: St. Paul, Minn. (1962).
9. SOLLARS, W. F. Effects of the water-soluble constituents of wheat flour on cookie diameter. Cereal Chem. **36:** 498–513 (1959).
10. DONELSON, J. R., and YAMAZAKI, W. T. Note on a rapid method for the estimation of damaged starch in soft wheat flours. Cereal Chem. **39:** 460–462 (1962).
11. SCHMORAK, J., MEJZLER, D., and LEWIN, M. A study of the mild oxidation of wheat starch and waxy maize starch by sodium hypochlorite in the alkaline pH range. Stärke **14:** 278–290 (1962).
12. FINNEY, K. F., MORRIS, V. H., and YAMAZAKI, W. T. Micro versus macro cookie baking procedures for evaluating the cookie quality of wheat varieties. Cereal Chem. **27:** 42–49 (1950).
13. PERTEN, H. Application of the falling number method for evaluating alpha-amylase activity. Cereal Chem. **41:** 127–140 (1964).