Dried Japanese Noodles. I. Properties of Laboratory-Prepared Noodle Doughs from Sound and Damaged Wheat Flours[1]

M. M. BEAN, P. M. KEAGY, J. G. FULLINGTON, F. T. JONES, and D. K. MECHAM, Western Regional Research Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Berkeley, California 94710

ABSTRACT

Japanese-type noodles were prepared in the laboratory by using a farinograph to mix the stiff, salted doughs, which were sheeted and cut into thin strings with a household sheeter-noodle cutter. The cut noodles were hung to dry in a fermentation cabinet at 100°F. and 85% r.h. Doughs of unsatisfactory quality were sticky when cut or gave cut dough strings that stretched and sometimes broke while drying. Increasing salt content from 1 to 2% strengthened the dough strings and decreased their stickiness. Malted wheat flour added to unmalted flour or flour from laboratory-sprouted wheat gave poor noodle doughs at relatively low α-amylase levels, compared to those tolerated in bread doughs. However, further observations suggest that factors other than α-amylase are as significant with respect to noodle dough properties. They include the presence of protease, solubilized carbohydrate, or other modified constituents formed in damaged grain prior to milling, and fungal infestation of grain.

Japanese noodle-makers use large quantities of U.S. soft and hard wheat flours in a variety of products. Flours milled from blends composed chiefly of low-protein Western white wheat grown in the Pacific Northwest are preferred for many products because of the whiteness they impart to dried noodles. The noodles are made in a manner that in some steps resembles spaghetti manufacture. Flour is

[1]Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

wetted in a horizontal ribbon mixer. Instead of the extrusion process used in spaghetti manufacture, the wet particles are sheeted several times to form a dough. The gluten network is developed during the sheeting (1). Thin strings are cut from the sheeted dough, then hung over bamboo poles to dry in a controlled atmosphere.

The sensitivity of Japanese noodles to wheat quality was underscored in 1968 when flour milled from apparently sound Pacific Northwest wheat caused problems in noodle making. During drying, the thin strings stretched and broke. On the basis of reports that some wheat had suffered undetected sprout damage, studies were initiated at Western Regional Research Laboratory to attempt to control amylase activity in noodle doughs. An observation had been made that some naturally occurring phospholipids could inhibit wheat α-amylase activity in model systems (2). However, lack of appreciable success with this and other known amylase inhibitors in Japanese noodle doughs suggests that amylase may be a minor factor in the noodle-making problems associated with field-damaged wheats. This report and part II (3) describe experiments leading to that conclusion.

MATERIALS AND METHODS

Samples of damaged wheat which caused trouble in Japan were not available. Therefore, three different approaches were used to simulate the damaged wheat material: 1) adding malted wheat flour or enzyme preparations to sound, commercially milled flour; 2) germinating wheat in the laboratory; and 3) studying field-damaged wheat from the 1969 crop.

Wheats and Flours

One lot of soft wheat flour, commercially milled from a wheat mix that was primarily Gaines variety, was used. A commercial malted wheat flour having 67 SKB units of α-amylase activity was used as an α-amylase and protease source.

To simulate field sprouting, 10-lb. lots of Gaines variety wheat were steeped in tap water for 8 or 16 hr. and incubated in a warm fermentation cabinet for periods up to 24 hr. After drying to the original moisture in a tray dryer, they were tempered to 13.5% moisture and milled on a Brabender Quadrumat Sr. mill.

Two field-damaged samples of Burt variety wheat that had low falling numbers were located in Oregon in the 1969 crop through the Pacific Northwest Wheat Quality Survey reports.[2] They were tempered at 15% moisture and milled on the Brabender Quadrumat Sr. A sound sample of Burt flour, obtained from the same crop year, was used as a control.

All wheats and flours were stored at 0°F. until used. The composition of the flours is given in Table I. Gaines and Burt varieties are both acceptable for Japanese noodle products.

Noodle Preparation

A noodle preparation method intended to follow Japanese procedures as closely as possible using baking laboratory equipment was devised. Figure 1 shows a flow diagram of a Japanese process.[3] A horizontal ribbon mixer similar to that used in macaroni processing is used to wet the flour. The wet particles are then sheeted

[2]Goetz, Norman. Oregon State University, Corvallis. Personal communication.

[3]Shimidsu, H. Brief information on Japanese noodle. Personal communication (1970).

TABLE I. COMPOSITION OF FLOURS USED IN NOODLE DOUGH EXPERIMENTS, 14% m.b.

Sample	Protein %	Ash %
Gaines		
Commercially milled	8.3	0.51
Quadrumat milled	10.2	0.46
Burt		
Control[a]	10.3	0.53
A, Quadrumat milled	8.4	0.46
B, Quadrumat milled	8.4	0.54

[a]Received as flour from same crop year but grown in a different area.

through kneading rolls to form a dough sheet 12 to 16 in.wide. Two sheets are then put through the dough breaker together and rolled onto a spool. (The spools of dough become quite large, measuring more than 12 in. in diameter.) In the next step, dough strips from two spools are fed into another set of rolls and then sheeted continuously between a series of roll pairs having progressively narrower gaps. At the desired thickness of the dough sheet, noodles are cut, then dried or cooked, depending on the product.

In laboratory preparation for this study, stiff, salted doughs (50 g. flour, 1% salt, 32 to 35% absorption) were mixed at 63 r.p.m. in the small bowl of a farinograph but with the sensitivity setting for the 300-g. bowl. For larger samples using 150 g. flour, the 300-g. farinograph bowl was used on the Do-corder with the torque set for 5,000 meter-g. maximum. After the flour particles were wet and a coherent, homogenous dough formed, it was sheeted through a small noodle machine that had adjustments for variable roll settings. After the first sheeting, the dough was folded crosswise and sheeted again. The folding was repeated, then the dough sheeted four times at closer roll settings until it was approximately 2 mm. thick, then put through the cutting blades of the noodle machine. Noodles made in this

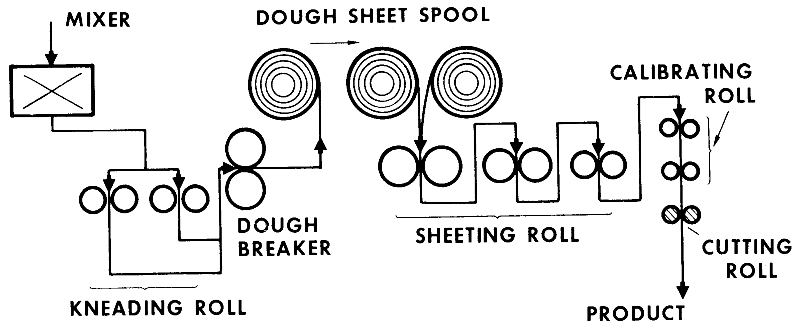

Fig. 1. Flow diagram of a Japanese noodle-making process.

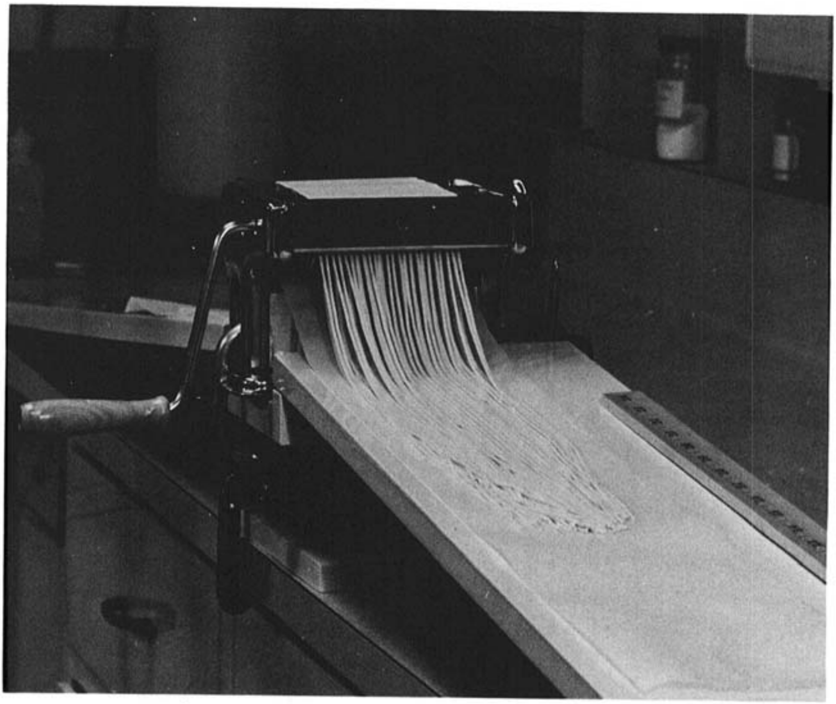

Fig. 2. Laboratory preparation of Japanese noodles: cutting noodles from sheeted doughs.

manner resembled the Japanese product and those made with unsound flour exhibited the same problems noted in Japan.

Figure 2 shows the noodle machine mounted on a slanted board. As cutting proceeded, the noodles were conveyed along the board by a movable parchment paper strip. This arrangement minimized stretching and handling during cutting. The noodle strands generally measured 36 to 48 in. in length, depending on how much extension occurred during sheeting.

Twelve noodle strips per mix were hung to dry in a fermentation cabinet held at 100°F. and 85% r.h. They were hung on glass rods that were covered with nylon net to prevent the noodles from slipping. Each strip measured 24 in. long when cut off 1 in. above the floor of the cabinet. Noodles from sound flour would stretch about 1 in. during the first 30 min. of drying, then shrink back to their original length or shorter. Noodles from damaged flour would stretch 2 to 4 in., then break and fall to the floor. After some treatments noodles stretched considerably more before breaking. In order to record these differences some noodles were draped between rods set 23 in. apart. The draped section measured 24 in. This length had been marked off with a felt pen while the strands were flat on the cutting board. Initial stretching caused them to sag 4.5 in. below a horizontal line across the rods. Subsequent sagging measured only 1 to 2 in. for noodles from sound flour. Beyond that the sag was indicative of defects associated with wheat damage.

α-Amylase activity was determined by three AACC methods (4): the amylograph method (22-10) using 65 g. flour, the falling number method (56-81), and the SKB method (22-01). The amylograph method was modified by substituting distilled water for buffer to remove inhibitory effects of the buffer, and by mixing the slurry in a 1,000-ml. beaker. The flour was sifted into 350 ml. water stirred with a magnetic bar rapidly enough to maintain a vortex. The remaining 110 ml. water was used to transfer the slurry into the amylograph bowl.

Protease determinations were made by the method of Kaminski and Bushuk (5).

Total carbohydrate determinations were made on water-soluble extracts by the method of DuBois et al. (6).

Photomicrographs of wheat starch were made with a Jeolco Scanning Electron Microscope with a 25-kv. beam. Samples were mounted on metal slides and shadowed with gold. A tilt angle of 45° was used for all samples.

RESULTS AND DISCUSSION

Response to Malted Wheat Flour

Japanese noodle doughs were found to be damaged by levels of malted wheat flour that usually improve bread doughs. Table II shows this sensitivity in raw noodle doughs containing 1% salt. In these doughs, mechanically damaged starch would be expected to supply the only substrate for amylase activity. Nevertheless, as little as 0.4% malted wheat flour produced soft, sticky noodle doughs and 0.5% caused noodles to sag significantly more and to fall during drying.

This sensitivity contrasts with that found in bread dough systems. Commercial bread flours normally contain 0.2 to 0.3% of added malted wheat or barley flours. However, bad effects are not observed until considerably higher levels are added, and with the malted wheat flour used in this work up to 2% could be tolerated in a straight-dough system fermented for 3 hr. Johnson and Miller (7) concluded that 12 and 24 times the standard amount (0.25%) of malted wheat flour in their baking work could be added safely to a straight-dough formula. Their malted wheat flour had an α-amylase activity of 48 SKB units. When added at 12 or 24 times the standard level (3 or 6%), it contributed 1.44 or 2.88 SKB units. This level of α-amylase activity corresponds to approximately 2 to 4% of the malted wheat flour used in our experiments.

In a later paper, Johnson and Miller (8) observed that α-amylase from malted wheat flour had decreased dough consistency (as measured by the farinograph) after 3 hr. fermentation. However, increasing the level of α-amylase 20-fold had no larger effect than the standard level, which "suggests that the quantity of starch substrate which is susceptible to attack is limited." If the effects in a bread dough given 3 hr. fermentation are this limited, the effects of α-amylase in a noodle dough at lower moisture content, under drying conditions and in shorter time, would be expected to be relatively smaller and definitely limited.

Amylograph peak viscosity and falling number values (Table II) show the expected effects of increasing α-amylase content. The relative effect of low levels of the enzyme is somewhat less for the falling number method, reflecting the shorter time for exposure of gelatinized starch to active enzyme. The trend of effects from amylograph through falling numbers and bread dough consistency values makes it seem unlikely that the sensitivity of noodle doughs to malted wheat flour above about 0.5% can be related to the α-amylase content.

TABLE II. EFFECT OF INCREMENTS OF MALTED WHEAT FLOUR ON SEVERAL PROPERTIES OF A COMMERCIAL SOFT WHEAT FLOUR (Primarily Gaines variety)

Malted Wheat Flour Level %	Amylograph Peak Viscosity[a] B.U.	Falling Number sec.	Estimated SKB[b] units	Noodle Dough[c] Properties, Handling	Sag[d] in.
0	535	452	---	Good, pliable (none fell)	1.5
0.1	220	316	0.067	---	
0.2	150	270	0.13	Fair, slightly soft (none fell)	1.5
0.4	120	208	0.26	Soft, slightly sticky	2
0.5	85	182	0.33	Soft, sticky (fell)	3
1.0	60	159	0.67	Soft, sticky (fell)	3

[a]Based on 65 g. flour, 460 ml. water.
[b]Based on malted wheat flour = 67 SKB (value for the commercial flour was too small to measure).
[c]Doughs contained 1% salt (flour basis).
[d]Distance below a 4.5 in. initial sag.

TABLE III. SOME PROPERTIES OF WHEAT FLOURS FROM DAMAGED KERNELS

Wheat Sample	Amylograph Peak Viscosity[a] B.U.	Falling Number sec.	SKB units	Noodle Dough[d] Properties, Handling	Sag[e] in.
A. Laboratory-germinated, Gaines variety					
Control	880	570	---	Good, pliable	
No obvious sprouts[b]	180	200	0.33	Soft and sticky	
Visible sprouts[c]	45	100	0.83	Soft and sticky	
B. Field samples, Burt variety					
Control	530	405	---	Good	1.5
A	320	379	<0.05	Slightly soft	2.5
B	150	206	0.19	Soft and sticky	4

[a]Based on 65 g. flour, 460 ml. water.
[b]Steeped 16 hr., incubated 7 hr.
[c]Steeped 8 hr., incubated 16 hr.
[d]Doughs contained 1% salt (flour basis).
[e]Distance below a 4.5 in. initial sag.

Salt Levels

In Japan, salt levels of 2 and 3% are often used in various types of noodles[3] (9). When salt was increased to 2% in laboratory-prepared noodles, doughs containing 0.5% malted wheat flour became less sticky and were easier to handle. At salt levels above 2%, higher levels of malted wheat flour (up to 5%) were necessary (2) to simulate the problems. These noodles stretched considerably without breaking,

TABLE IV. FEDERAL GRAIN INSPECTOR'S EVALUATION OF DAMAGED WHEATS

Wheat Sample	Analysis of 30 g. Test Sample
Lab-germinated	
No obvious sprouts[a]	29% sprout damage
Visible sprouts[a]	53% sprout damage
Field samples	
A	No sprout damage
B	4% shriveled or distorted kernels
	2 kernels have fungal infection
	several show evidence of rust and foot rot

[a]Appearance as judged by laboratory personnel.

apparently strengthened by the higher salt level.The stretchy quality of the doughs suggested that protease activity may be exerting a significant effect and may have been inhibited by 2% salt when the low level (0.5%) of malted wheat flour was used. McDonald and Chen (10) showed that a level of salt present in bread dough (0.05M) markedly inhibited flour protease activity.

Protease activity is known to increase in wheat during germination. Bean and Fullington (2) showed that considerably more protease was extractable from

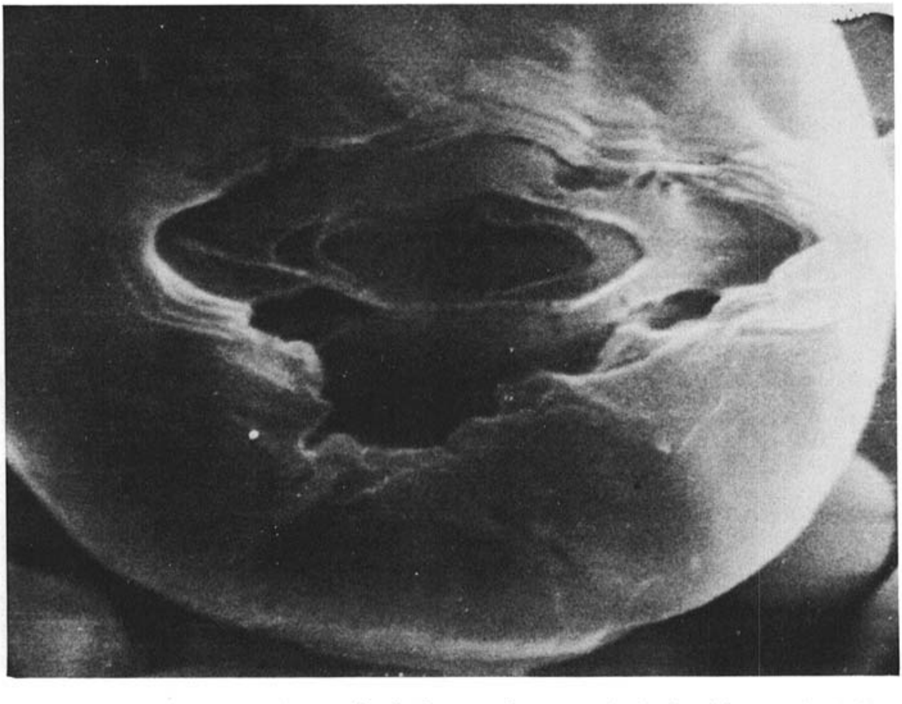

Fig. 3A. Scanning electron micrograph of wheat starch preparation isolated from malted wheat flour.

malted wheat flour than from sound flour. Quantitative determinations of protease were not made, but the qualitative determinations of protease activity (5) in the laboratory-germinated wheats, which are described in Table III, indicated that protease increased with increasing sprout damage. Of the two prominent proteases solubilized in 0.1% NaCl, the electrophoretically faster moving component at pH 3.1 increased markedly with sprouting while the other decreased slightly. Only one prominent protease species was soluble in water and increased slightly with sprout damage. This may be the same species as the faster moving component of the salt extract described above. No change in protease was apparent in the acetic acid-solubles at these levels of sprout damage. No increase in protease was distinguishable in the Burt samples, but this may be consistent with the apparent lack of sprouting in these samples as discussed in the next section.

Differential inactivation experiments implicating protease in noodle dough behavior are described in part II of this paper (3).

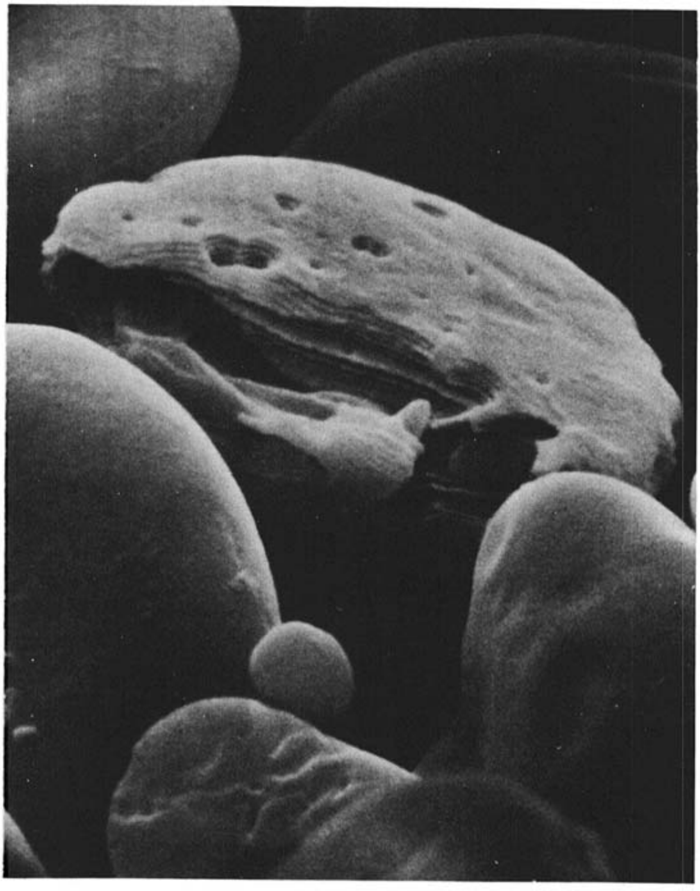

Fig. 3B. Scanning electron micrograph of wheat starch granules after incubation with malted wheat flour extract.

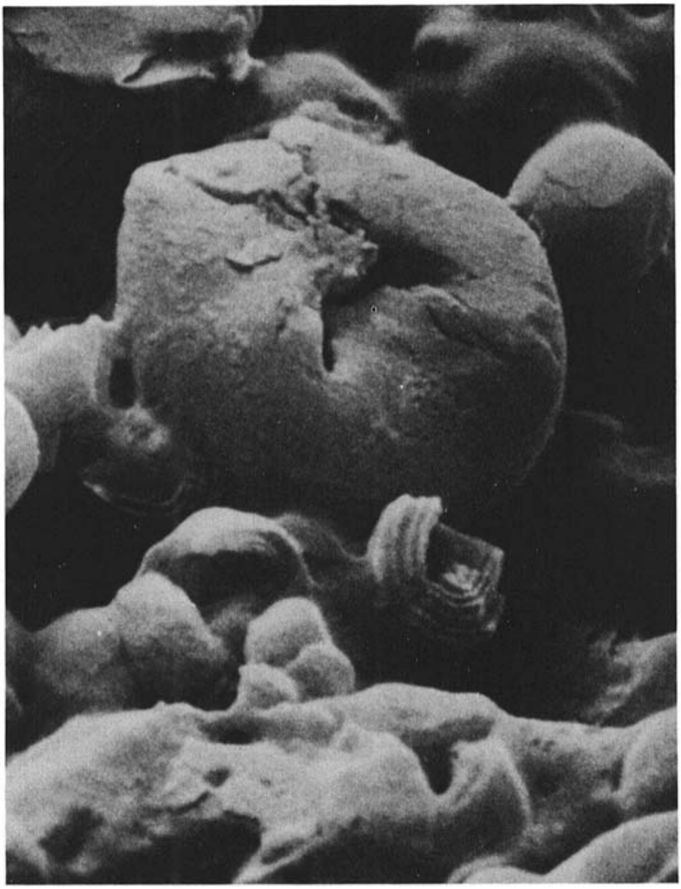

Fig. 3C. Scanning electron micrograph of section of sprouted wheat kernel, near germ end.

Damage in the Kernel

Addition of malted wheat flour to sound flour to simulate sprouted-wheat problems has limitations when searching for the components responsible for damage to dough properties. First, the array of enzymes may be significantly different in the field-sprouted wheats from those produced under the carefully controlled conditions of commercial malting. Secondly, degradation of the major components, starch and protein, and consequent changes in physical properties may have started in the field-sprouted kernels. Slight changes in a major portion of these components could affect dough properties. Also it should be recognized that field *damage* may involve other changes than those produced by field *sprouting*. Malted wheat flour additions could only be considered to partially simulate the latter.

To simulate field sprouting conditions more closely, wheat of Gaines variety was steeped in the laboratory. The pertinent characteristics of two samples given different incubation times are shown in Table III-A. Only one sample appeared to laboratory personnel to have visible sprouts. Both treated samples had significant α-amylase activity and made poor noodles when 1% salt was used in the dough.

Table III-B describes flours milled from two field-damaged Burt variety wheat samples along with another Burt wheat used as a control. Sample B of this set had significant amylase activity by all three testing methods and made poor noodles. They stretched significantly more than those prepared from flour at the same amylase activity levels from laboratory-sprouted wheat and from sound flours containing malted wheat flour. This suggested possibly a different array of enzymes or physical alterations in the field-damaged wheat. The varietal differences may be implicated, also. However, Burt variety is among those acceptable for Japanese noodles.

Further evidence that suggests different responsible components in the field-damaged wheats was provided by a Federal Grain Inspector's analysis of the four wheats discussed above.[4] His results on 30 g. test samples are summarized in Table IV. The laboratory-treated sample considered by laboratory personnel to have no obvious sprouts had 29% sprout damage, and the visibly sprouted wheat had 53% sprout-damaged kernels. Such wheats would not pass grain inspection. These results contrast with his observations on the field samples. In spite of measurable amylase activity by conventional methods, especially in the B sample, he found no sprout damage. He suggested instead that the B sample had 4% shriveled or distorted kernels which included two kernels with fungal infection and several showing evidence of rust and foot rot. At the 4% damage level, this wheat would pass grain inspection and move into commercial channels.

The discrepancy between measurable amylase activity and visible sprout damage has been reported before by other workers (11,12). The results shown here, especially with the field-damaged B sample, suggest the possibility that growth of fungi or disease damage to the wheat plant may be producing enzyme systems or physical alterations that affect noodle dough properties in the same way as sprout damage. It was noted earlier that no increase in protease, expected with sprouting, was found in these samples by the method of Kaminski and Bushuk (5). It appears that wheat with such defects as noted by grain inspectors should be assessed further for their effects on functional properties of sensitive end-product, e.g., noodles.

Starch Granules

While attention is usually centered on enzyme activity in sprouted or otherwise damaged wheats, alteration of the major flour components also might influence functional flour properties. Some starch degradation during sprouting of laboratory wheats was suggested by increases in soluble carbohydrates of 17 and 29% for the laboratory-germinated samples described in Table III. The soluble carbohydrate values for the three samples were 52 mg. per g. for the parent, 61 mg. per g. for the sample with no visible sprouts, and 67 mg. per g. for the visibly sprouted sample.

Examination of flours from these wheats by light and scanning electron microscopy did not show significant differences in degradation of starch granules. However, other reports (13–15) that include scanning electron microscope pictures of granules from sprouted wheats show that both surface and internal modifications occur during amylase attack. Figure 3 shows examples of degradation in three

[4] Browning, John A, Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture. Personal communication.

starch preparations. Figure 3A shows a granule isolated from malted wheat flour, therefore damaged during germination in the kernel. Figure 3B shows commercial wheat starch after 6.5 hr. incubation with a malted wheat flour extract. These show that the enzyme tends to enter the granule at certain sites, often preferring an equatorial groove, degrading some of the surface layer then following a path toward the interior of the granules. Some granules are attacked at many surface sites. The enzyme then apparently follows a path of least resistance toward the interior layers of the granules. This mode of attack has been postulated by Sandstedt (16) using the light microscope.

Degradation is not as extensive on slightly sprouted wheat. However, Figure 3C gives evidence it has started. This picture shows endosperm near the germ end of a kernel of Gaines wheat that had a 2-mm. sprout. Several granules show degradation effects, especially the small granules with clearly visible laminar structure after enzyme attack. The intergranular material appears to have disintegrated also. From these results it seems reasonable to assume that the low level of amylase activity present in wheat just beginning to sprout may have caused sufficient surface alteration on several granules to modify dough properties. If protease activity caused parallel changes in protein properties, these combined physical changes could be as important as enzyme activity in noodle dough preparations.

Acknowledgments

We wish to thank James W. Pence for his helpful suggestions and advice during the progress of these studies. We also thank Felix Bloch for his help in sprouting the wheat and Albert Mossman for milling the various samples. We also wish to acknowledge the helpful information and advice we received from Gordon L. Rubenthaler, Western Wheat Quality Laboratory, Pullman, Washington, upon his return from a study trip to Japan.

Literature Cited

1. WATANABE, Y., and NAGASAWA, S. A study on rheological properties of noodle by means of relaxation test. Nippon Shokuhin Kogyo Gakkaisi 15: 466 (1968).
2. BEAN, M. M., and FULLINGTON, J. G. Suppression of excess alpha-amylase in sprout-damaged wheats. Report of Sixth National Conference on Wheat Utilization Research, U.S. Dep. Agr. ARS 74-54, p. 49 (1970).
3. BEAN, M. M., NIMMO, C. C., FULLINGTON, J. G., KEAGY, P. M., and MECHAM, D. K. Dried Japanese noodles. II. Effects of amylase, protease, salts, and pH on noodle doughs. Cereal Chem. 51: 427 (1974).
4. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC (7th ed.) The Association: St. Paul, Minn. (1962).
5. KAMINSKI, E., and BUSHUK, W. Wheat proteases. I. Separation and detection by starch-gel electrophoresis. Cereal Chem. 46: 317 (1969).
6. DUBOIS, M., GILLES, K. A., HAMILTON, J. K., REBERS, P. A., and SMITH, F. Colorimetric method for determination of sugars and related substances. Anal. Chem. 28: 350 (1956).
7. JOHNSON, J. A., and MILLER, B. S. High levels of alpha-amylase in baking. I. Evaluation of the effect of alpha-amylase from various sources. Cereal Chem. 25: 168 (1948).
8. JOHNSON, J. A., and MILLER, B. S. Studies on the role of alpha-amylase and proteinase in breadmaking. Cereal Chem. 26: 371 (1949).
9. SHIMIZU, T., FUKAWA, H., and ICHIBA, A. Physical properties of noodles. Cereal Chem. 35: 34 (1958).
10. McDONALD, C. E., and CHEN, L. L. Properties of wheat-flour proteinases. Cereal Chem. 41: 443 (1964).
11. CAWLEY, P. U., and MITCHELL, T. A. Inhibition of wheat α-amylase by bran phytic acid. J. Sci. Food Agr. 19: 106 (1968).
12. STEWART, B. A. Alpha-amylase activity of varieties of English wheat. Nature 204: 1088 (1964).

13. EVERS, A. D., and McDERMOTT, E. E. SEM of wheat starch. II. Structure of granules modified by alpha-amylolysis, preliminary report. Staerke 22: 23 (1970).
14. DRONZEK, B. L., HWANG, P., and BUSHUK, W. Scanning electron microscopy of starch from sprouted wheat. Cereal Chem. 49: 232 (1972).
15. JONES, F. T., and BEAN, M. M. A light and SEM look at enzyme-damaged wheat starch. Microscope 20: 333 (1972).
16. SANDSTEDT, R. M. Photomicrographic studies of wheat starch. III. Enzymatic digestion and granule structure. Supplement to Cereal Chem. 32: 17 (1955).

[Received June 20, 1972. Accepted September 14, 1973]