GUN-PUFFING WHEAT AND BULGUR[1]

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ABSTRACT

Properties of gun-puffed wheat and bulgur varied with grain moisture (10–25%) and with firing pressure (100–180 p.s.i.g.). The degree of expansion of wheat depended primarily on firing pressure; moisture exerted a smaller influence. The degree of expansion of bulgur depended primarily on moisture; firing pressure was influential only at higher moistures. Texture of both products was a function of degree of expansion. In wheat, grain moisture also influenced texture. Wheat samples with 10 to 16% moisture gave more tender products for comparable degree of expansion than samples with 19 to 25%. In both wheat and bulgur, soluble-starch values increased linearly with expansion. No change in starch solubilized because of moisture occurred in wheat products up to 16%; but above this point more moisture caused increases in starch solubilized at comparable degrees of expansion. Moisture had the opposite effect on bulgur products; the starch was most soluble in material starting at 10% moisture and was less soluble with more moisture up to 22%, at comparable degrees of expansion. Color of the final products was unaffected by moisture content and only slightly by firing pressure. Expansion varied from about 1.2-fold to 7-fold. The materials are promising for new wheat food products.

Some years ago a hot-air-puffing process for bulgur, a parboiled dry whole-wheat product, was developed at this laboratory (1). The bulgur kernel expands approximately twofold during the treatment and takes

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on a crisp, friable structure. The product was the main ingredient in a fallout shelter ration (2,3) and in preliminary development of several convenience foods and snack items. Continued interest in modifying and improving the flavor and texture of existing items and in developing new uses for wheat led to the present investigation of explosive puffing.

Although the art of gun-puffing cereal grains and dough products is nearly as old as the breakfast-food industry in this country, details of operation are poorly documented (4). Workers at the Eastern Utilization Research and Development Division, U.S. Department of Agriculture (5–9), have recently investigated explosive puffing of fruits and vegetables to improve final drying and rehydration. They have generally operated in the pressure range of 30–65 p.s.i.g. to increase the porosity of the pieces with minimum expansion. On the other hand, breakfast-food manufacturers are usually interested in maximum expansion consistent with product identity. With wheat this means as much as sixteenfold expansion. Our interest centers primarily in two- to fourfold expansion for ingredients in convenience products. These studies were extended far enough, however, to establish trends applicable to the full practical range of conditions.

Studies were carried out, first, on wheat because it is the simplest and least expensive starting material. They were extended to bulgur, because of possible differences in flavor and texture and because it is fully gelatinized and should provide insight into the puffing of cooked dough pieces.

Materials and Methods

Sample Preparation. A single, well-blended lot of hard red winter (HRW) varieties that had been partly debranned commercially to a crude-fiber content of 1.7% was used. Debranning was by a single pass through an Engelberg rice mill after the outer bran coats had been softened and loosened with a spray of water. The bulgur was a single, well-mixed lot prepared commercially from HRW wheat by an atmospheric cooking process and partially debranned to a crude-fiber content of 1.7%.

Moisture was adjusted either by drying to a calculated weight loss with through-flow air at 140°F., ambient humidity, and 80 f.p.m., or by spraying the calculated amount of water on the rapidly stirred grain. For higher moisture levels, water was added two or more times with tempering periods between. The grains were adjusted to each moisture level in several consecutive batches and the batches were thoroughly blended. All samples were stored in tightly closed cans to allow moisture equilibration. Those above 13% moisture were held at 34°F., the others at ambient temperature.

Puffing. The gun used was a commercial gas-fired model designed for batch operation. Ten pounds of grain was used for each shot. The charge was loaded into the preheated gun, the door quickly closed and latched, the gun tipped to the horizontal, rotation started, and the burner lit. This series of steps was completed in 30 sec. to prevent sticking and scorching of grain in the hot barrel. Pressure was allowed to rise to 10 p.s.i.g. below that desired, the burner was turned off, and, when the desired pressure was reached, the gun contents were fired into a receiving hopper. With experience the desired pressure could be consistently achieved within ± 2 p.s.i.g. Time in the gun varied only between 10 and 12 min. over the range of pressures and moistures investigated.

Preliminary experiments showed that raising the gas pressure to the burner above 0.6 in. of water had little effect on gun operation. One (1.0) inch was used in these studies. Moisture content of the grain had little effect on come-up time; therefore, the gun was operated in the same way for grains of any moisture. To achieve a steady state, two warm-up shots were fired at the beginning of each day. For standardization, 20 min. was always allowed to elapse between firing one shot and the beginning of loading the next. This time was ample to empty and clean up the receiving hopper, take samples, and prepare the next charge. Samples were dried to between 6 and 7% moisture by tumbling in a stream of air at 145°F. and then were stored for evaluation.

Evaluation and Analysis. Expansion is expressed in this work as puff index, which is the ratio of the bulk density of the unpuffed grain at 13% moisture to bulk density of the puffed material.

Texture was measured in the hardness tester attachment for the Brabender Farinograph. Samples were dried overnight in forced-draft air at 145°F. to 2.5 ± 0.5% moisture to avoid fluctuations in results caused by moistures above 3.5%. Results given are the average of duplicate determinations.

Soluble starch was determined by soaking 0.5000 ± 0.0002 g. of sample, ground to 30-mesh, in 100 ml. water for 1 hr. at 50°C. The mixture was cooled in tap water, transferred to 250-ml. volumetric flasks, made to volume with water, and filtered through S&S No. 597 filter paper.

A 10-ml. aliquot was placed in a 100-ml. volumetric flask and diluted to between 60 and 70 ml. with water. Concentrated hydrochloric acid, 1 ml., and 1 ml. of iodine solution (20 g. iodine and 20 g. potassium iodide per liter) were added, and the solution was made to volume with water. After 30 min., color was read in a spectrophotometer at 590 mμ against a reagent blank to set the instrument at 100% transmittance.

A standard curve was prepared from the untreated starting material following the same procedure, except that extraction was in a boiling-water bath. Aliquots of 1 to 10 ml. in 1-ml. increments were taken as standards for color development. These represented from 10 to 100% of the starch available in the starting material.

Color changes were measured on the Gardner-Hunter Color Difference Meter on both whole-kernel forms of the materials and materials ground to 20-mesh.

Moisture determinations were made by the official two-stage, air-oven procedure for wheat and other grains (10) or with an infrared moisture analyzer calibrated by the official 130°C. air-oven method (10).

Results and Discussion

The controlled variables in these studies were grain moisture and firing pressure. Their interaction with expansion is shown in Figs. 1 and 2. For wheat (Fig. 1), the principal factor controlling expansion appears to be firing pressure. Moisture had a smaller effect, with a

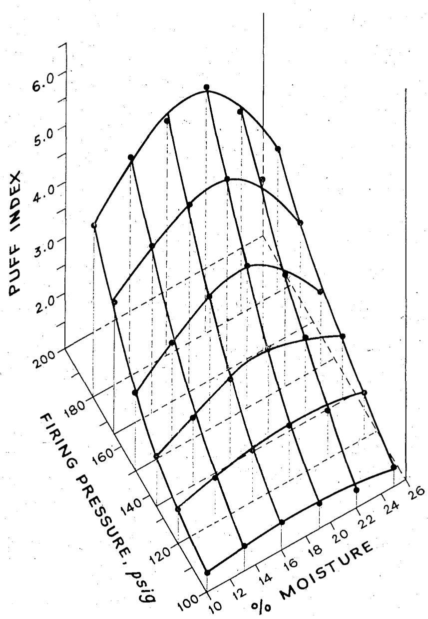

Fig. 1. Effect of moisture and firing pressure on expansion of gun-puffed wheat.

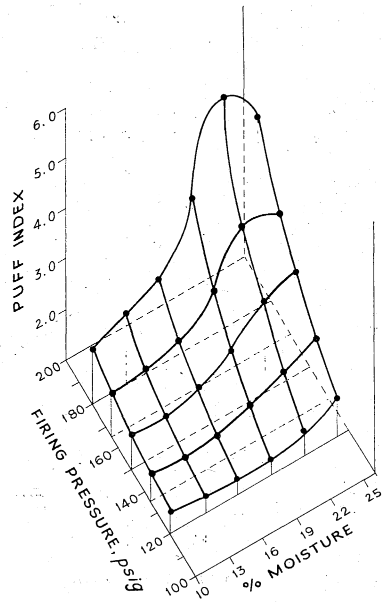

Fig. 2. Effect of moisture and firing pressure on expansion of gun-puffed bulgur.

maximum at about 19%, over the full range of pressures. Conversely, with bulgur (Fig. 2), firing pressure had relatively little effect on degree of expansion until moisture content reached about 19%. Moisture optimum was apparently 25% or above at lower firing pressures, but the optimum moved downward to 22% as firing pressure increased to 180 p.s.i.g. The moist, plastic, expanded bulgur was visibly deformed and recompressed when it hit the hopper walls. This compression may account in part for the lower curve at high moisture and pressure. Data on soluble starch (see below), however, seem to substantiate the conclusion that at least part of this reversal is from other causes.

Texture is primarily a function of expansion in both wheat and bulgur, gun-puffed. With wheat (Fig. 3) there are apparently two distinct curves of interaction between expansion and texture for puff indices below about 4: one for grains puffed at moisture contents of 16% and below, and a second for those fired at 19% and above. The lower-moisture samples have the tenderer texture. The break between 16 and 19% conforms to the approximately 19% moisture optimum observed for degree of expansion. The interaction of tenderness and puff index of puffed bulgur, on the other hand (Fig. 4), lies on one curve over the full moisture range studied. Except at the lowest puff

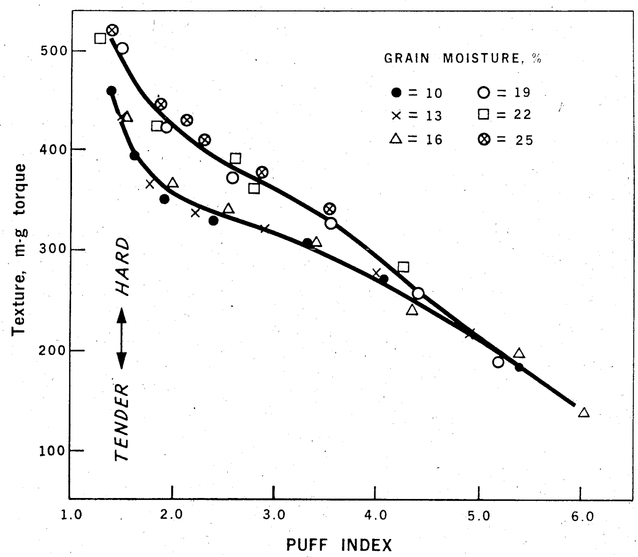

Fig. 3. Moisture, degree of expansion, and texture in gun-puffed wheat.

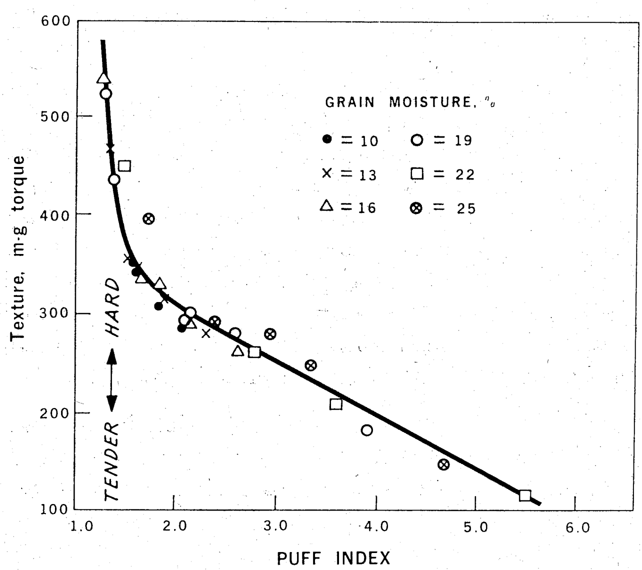

Fig. 4. Moisture, degree of expansion, and texture in gun-puffed bulgur.

index, puffed bulgur is somewhat more tender than puffed wheat of comparable expansion.

Solubilization is a convenient measure of changes in starch usually associated with cooking. The solubility of the puffed samples in these studies was measured and expressed as percent of total starch. In both products, starch solubilization was a function of degree of expansion. Explosive puffing could be expected to disrupt granule structure roughly in proportion to expansion. Rate of solubilization, however, shows a marked moisture dependence which differs for the two materials. In explosive puffing of wheat (Fig. 5), the rate of solubilization

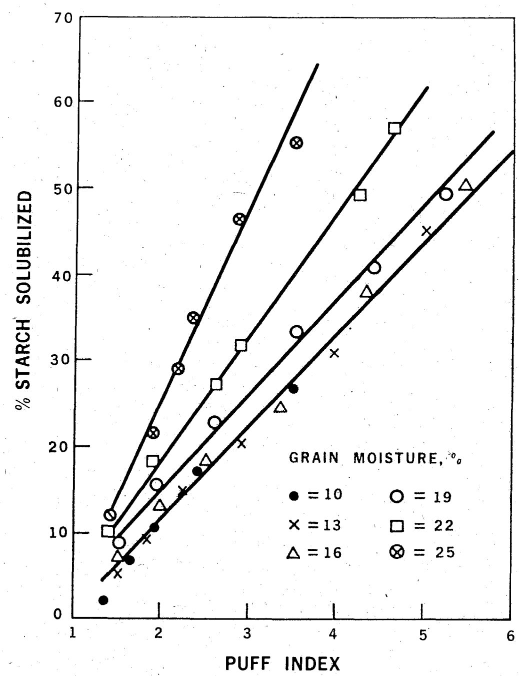

Fig. 5. Starch solubilization, moisture, and degree of expansion in gun-puffed wheat.

is constant for samples puffed at 10, 13, and 16% moisture. Above 16% moisture, however, the rate of starch solubilization increased. Apparently at 16% moisture and below, the starch was not changing significantly in the gun, and the starch was solubilized only by mechanical rupture of the starch granules. Above 16% moisture, starch appeared to gelatinize appreciably in the gun before firing. Starch may then be solubilized both by hydration and mechanical rupture, or by increasing mechanical rupture because of hydration effects.

In gun-puffiing of bulgur, the interaction between moisture content and solubilization was opposite (Fig. 6). The driest samples showed the greatest starch solubilization and a regular decrease as moisture

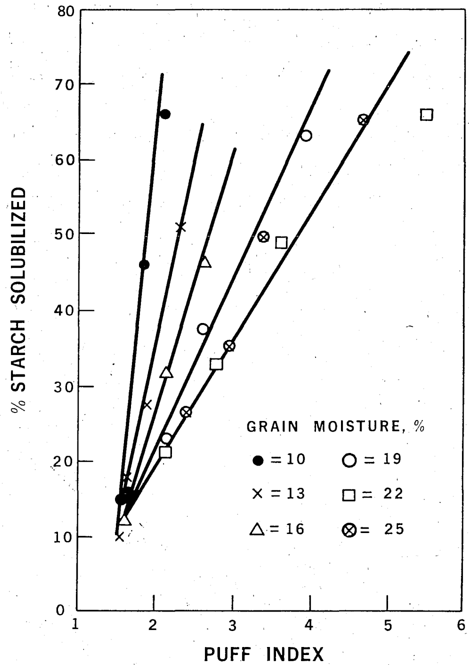

Fig. 6. Starch solubilization, moisture, and degree of expansion in gun-puffed bulgur.

content increased up to 22%. The rate for 25%-moisture samples was about the same as for 22%. This suggests that the starch in the bulgur was essentially completely gelatinized before it went into the gun. The apparent reduction in starch solubility may due to starch degradation, perhaps hydrolytic, which could increase with moisture during the pressure build-up in the gun. Less probably, the highest moisture levels might toughen the granule walls and so limit disruption on puffing. The leveling-off of the rate of solubilization at 22% moisture is slight confirmatory evidence that 22% moisture is the optimum for expansion.

Moisture content of the grain did not affect color, contrary to expectation. In whole-kernel samples of both puffed wheat and puffed bulgur, when compared on the color-difference meter (data not shown), the redness factor decreased regularly as firing pressure increased, but the lightness-darkness component did not change significantly. The opening-up of the kernel and exposure of the light endosperm by puffing apparently offset the darkening of the surface due to toasting. Under low-moisture, high-pressure conditions, where small expansion exposed little endosperm, bulgur tended slightly to be both redder and darker than wheat. When finely ground duplicate samples were compared on the instrument, both the redness and darkness increased as firing pressure increased.

The results reported here are for a single lot of HRW wheat and for bulgur prepared from HRW wheat by one commercial process. Some variation in other lots or different types of starting material may be expected. However, the information presented should furnish a reliable guide to the gun-puffiing behavior of wheat and bulgur in general, and perhaps for gelatinized dough pieces as well. The materials appear promising and are being evaluated for use in new wheat foods.

Acknowledgment

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