EFFECT OF PROCESSING CONDITIONS ON DRY-HEAT EXPANSION OF BULGUR WHEAT[1]

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ABSTRACT

Dry-heat expansion of bulgur wheat alters its structure from a hard, vitreous particle to a crisp, friable particle containing many small voids. Processing conditions leading to maximum expansion are 500° to 600°F. air temperature, 400 to 600 f.p.m. linear air velocity, 7 to 10% moisture content in the grain, and bran removal to achieve approximately a 50% reduction in crude fiber content of the grain. A fifth parameter, residence time in the air stream, is dependent on air temperature and velocity, and varies inversely to these factors. Rate of moisture imbibition by the expanded bulgur increases with bran removal to approximately a 60% reduction in crude fiber content. These studies were carried out on whole-kernel bulgurs prepared from both soft white and hard red winter wheat.

This process makes possible the relatively inexpensive production of dry, quick-cooking bulgur products for domestic and export markets. Desired end-use characteristics will determine to some extent the processing conditions used.

Bulgur, a traditional food of the Middle East, until recently was produced and distributed in this country only in limited quantities. Increased production facilities and wider distribution have now made the product available to large numbers of consumers (3). In order to hasten acceptance of the product and to promote its use, development of modified forms was undertaken.

A canning process for bulgur or whole-kernel wheat, and numerous ready-to-serve formulations prepared from them, was recently developed (2). Although these products offer many advantages for domestic distribution, production costs and shipping weights limit their suitability for export.

Some time ago, Roberts *et al.* (6,7) demonstrated that parboiled rice, a product similar to bulgur, could be expanded to a crisp, porous structure in either hot air or hot oil. The hot-air process, when applied to bulgur, also changes its structure from a hard, vitreous particle to a crisp, friable structure containing many small voids. The product differs markedly in texture and flavor from the long-familiar puffed wheat breakfast cereal. The resultant fully-cooked, puffed bulgur is usable directly as food in the dry form, or it can be hydrated

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much more rapidly than the conventional form to reduce markedly both heat and preparation time necessary for many bulgur dishes. These characteristics were found useful in developing a cereal-based, fallout-shelter ration (5). They also make the product promising as a quick-cooking convenience item for domestic markets, or for export to the many chronically fuel-short areas of the world.

Since degree of expansion directly affects end-use characteristics, this study was undertaken to determine the influence of process conditions on properties of heat-expanded commercial bulgurs.

Materials and Methods

Sample Preparation. The red bulgur was prepared commercially from hard red winter wheat of unknown history by a high-pressure, short-time cooking process. White bulgur was a commercial product prepared by an atmospheric process from soft white common wheats of the type generally available in California. In both cases materials were obtained from the manufacturer in whole-kernel form prior to removal of bran. Samples were stored in tightly sealed containers at 34°F. until used.

Except where otherwise stated, samples were used as received with moisture contents of 9.0% for white and 10.8% for red bulgur. Moisture was adjusted when desired either by drying with air at 130°F. and ambient humidity, moving at 100 f.p.m. through the grain, or by spraying the calculated amount of water on the rapidly stirred grain. Samples were stored in tightly closed jars to equilibrate for at least one week before use.

Debranning was accomplished in a No. 3 McGill rice mill. This equipment operates by stirring the grain under fixed pressure, and bran is removed by the friction of the kernels against one another. Standard procedure was 60 seconds' milling with a 12-lb. load followed by 30 seconds' milling with no load. Different degrees of bran removal were obtained by varying the milling time and by adding moisture (1–3%) to the grain 5–15 minutes before milling to increase the frictional effects.

Expansion. Grain was expanded by passing the kernels on a continuous wire mesh belt through a current of hot air. A schematic diagram of the equipment is shown in Fig. 1. The equipment is enclosed in an insulated box designed so that 80 to 85% of the hot air can be recirculated. By means of appropriate controls, air temperature can be varied from 375° to 675°F., air velocity, from 150 to 700 f.p.m. measured through the unloaded belt, and belt speed, from a grain retention time in the air stream of 7 seconds to 160 seconds. Stan-

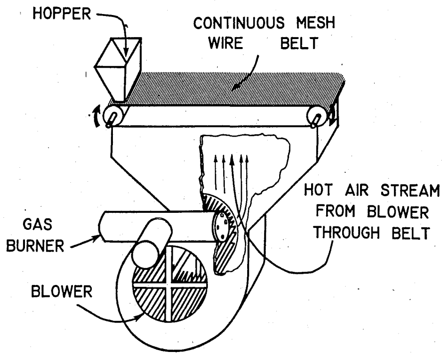

Fig. 1. Schematic diagram of equipment used for dry-heat expansion of bulgur.

dard operating conditions were 500°F., 525 f.p.m. and 25 seconds retention time.

Degree of expansion, as used in this report, is the ratio of the specific volume of expanded grain to that of the starting material. The apparatus used to make the measurements was a 250-ml. graduate cut off level at the 200-ml. mark, with a broad-necked funnel centered over it 1 in. above the lip, and a 500-ml. graduate with a second broad-necked funnel similarly placed. The 200-ml. graduate was filled to overflowing with untreated grain and leveled off to the lip with a broad-bladed spatula. The 200 ml. of grain were weighed, expanded, reweighed, and then transferred to the 500-ml. graduate, and the volume was read. Volumetric fills were made by free fall with no shaking or packing. Reported values are averages of triplicate determinations.

Moisture Absorption Rate. The effect of process variables on the rate of moisture imbibition of the expanded material was determined by soaking 20-g. portions of the material for 8 and 16 minutes at 195°F. Samples were drained, blotted free of excess water between paper towels, and reweighed. Moisture contents were calculated from original moisture content, and initial and final weights. Values reported are averages of duplicate determinations.

Moisture determinations were made by the official two-stage air-oven procedure for wheat and other grains (1).

Results and Discussion

The effect of changes in grain moisture, between 6 and 14%, on expansion is shown in Fig. 2. The red wheat bulgur tested shows an optimum between 7 and 9%, and has a much sharper response to changes in moisture content than does the white wheat bulgur, whose

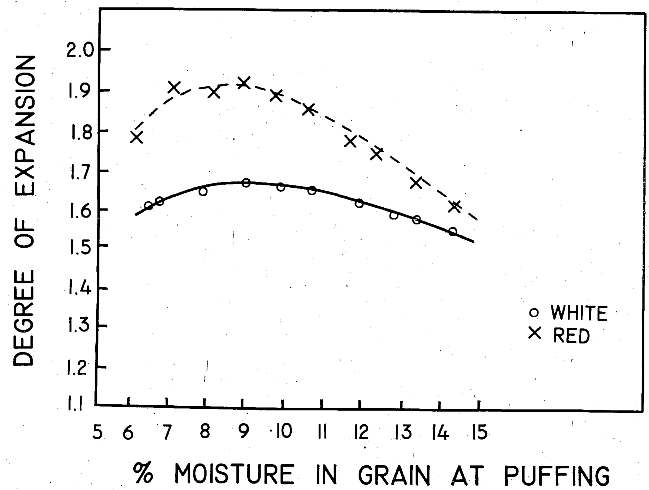

Fig. 2. Effect of moisture content of whole-kernel bulgur on degree of expansion.

maximum expansion is obtained between 7 and 11% moisture. Since moisture content of 13% and below is considered a safe storage level for most grains, extra drying would probably be required for bulgur intended for dry-heat expansion. Figure 3 illustrates the extent to which changes in air temperature alter the degree of expansion. Responses for both types of bulgur are of the same magnitude, and maximum expansion was obtained in the same range of approximately 500°–600°F.

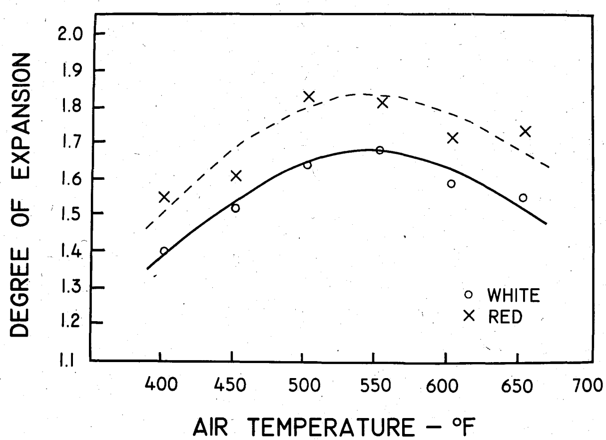

Fig. 3. Effect of air temperature on degree of expansion of whole-kernel bulgur.

Because of differences in grain dimensions, a given air velocity exerts a greater buoyancy on the short, plump, white bulgur than on the slimmer red bulgur. This may account for the slightly different response of these materials to changes in air velocity as depicted in Fig. 4. As velocities increase, changes in degree of expansion for

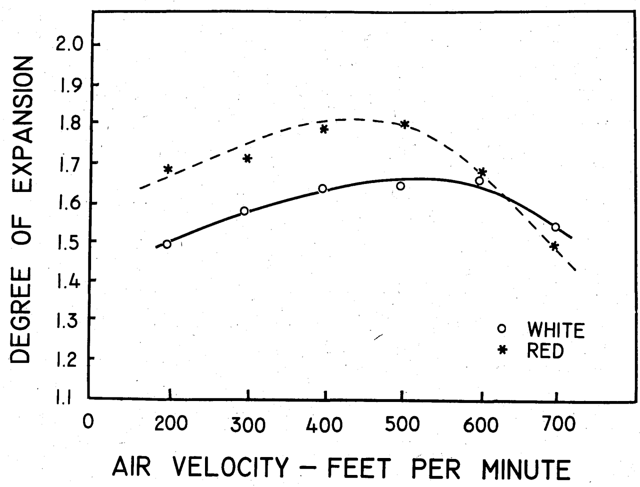

Fig. 4. Effect of air velocity on degree of expansion of whole-kernel bulgur.

both materials are of similar magnitude; however, red bulgur reaches a maximum degree of expansion at a slightly lower velocity and undergoes a more rapid decline with increasing velocity than does white bulgur.

Residence time in the air stream was found to be dependent on both air temperature and velocity and to vary inversely to them. No particular effect on degree of expansion was detected. If the time is too short, all kernels do not expand; if it is too long, the material becomes scorched.

The tough, fibrous outer layers of bran contribute little to the nutritive value of wheat products and are generally undesirable from the standpoint of textural characteristics. They are normally partially removed in bulgur processing. The effect of their removal on expansion characteristics of bulgur is demonstrated in Fig. 5. A general increase in degree of expansion is apparent as increasing amounts of bran are removed, as measured by reduction in crude fiber content of the residual kernel. Responses appear to be slightly different in the two materials. In this connection it should be noted that bran is much more easily removed from white bulgur than from red. For

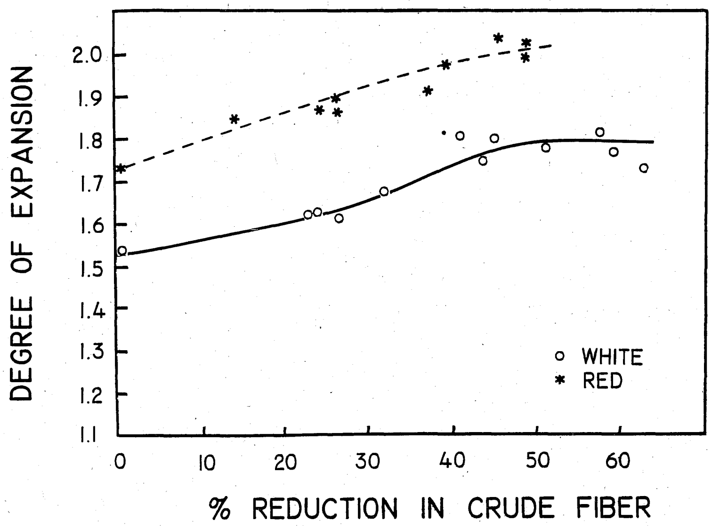

Fig. 5. Effect of bran removal on degree of expansion of whole-kernel bulgur.

example, conditions that remove 32% of the crude fiber from white bulgur remove only 14% from red.

Dispersion of points in Fig. 5 is probably due to difficulties encountered in removing different increments of bran. In each case, different milling times, different amounts of water addition, different tempering times after water addition, or combinations of these factors were used and might be expected to lead to somewhat different effects on the kernel. For example, prolonged milling time sharply raises the temperature of the grain. In one preliminary trial, temperature increased enough to partially expand the kernel.

The porous structure of the expanded kernel enables it to absorb water much more rapidly than regular bulgur, thus markedly reducing both the time and heat required for culinary preparation. To determine effects of processing conditions on the rate of moisture imbibition, the expanded samples obtained from the study of effects of various process conditions on degree of expansion were subjected to moisture uptake tests. They were soaked 8 and 16 minutes at 195°F. and their moisture content was determined.

Degree of bran removal has a marked effect on the rate of moisture absorption (Fig. 6). The results suggest that the inner bran layers, which are reported to be more impervious to moisture penetration (4), stretch rather than rupture when the grain expands. Unless these layers are partly removed, or at least scored or scratched in spots by

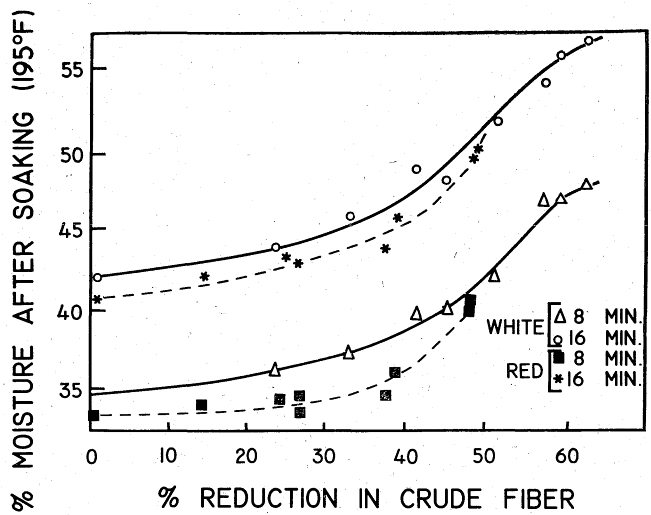

Fig. 6. Effect of bran removal on water absorption of expanded bulgur.

debranning, moisture absorption is probably not rapid enough for the product to be considered quick-cooking. For domestic "convenience" markets, which demand the shortest cooking time possible, bran removal corresponding to at least a 55% reduction in crude fiber would be desirable. For export markets, where convenience is not so important, less bran removal might be acceptable.

Comparisons between Figs. 5 and 6 show, somewhat contrary to expectation, that moisture absorption is not directly related to degree of expansion. This was also observed when moisture uptake was plotted against grain moisture, air velocity, and air temperature (data not shown); increases in degree of expansion did not cause a corresponding increase in moisture content of expanded bulgur soaked at 195°F. This suggests that, where shipping charges are based on volume, as well as weight, it might be advantageous to maintain minimum expansion consistent with desired end-use characteristics.

Because the results reported were obtained on only two lots of commercial bulgur, some variation in behavior of other lots can be expected. The trends demonstrated, however, should furnish reliable guides to the dry-heat expansion behavior of bulgur wheat in general.

Acknowledgment

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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.

Literature Cited

1. American Association of Cereal Chemists. Cereal laboratory methods (6th ed.). The Association: St. Paul, Minn. (1957).
2. Copley, M. J., Mecham, D. K., Weinstein, N. E., and Ferrel, R. E. U.S. Patent 2,929,725 (March 22, 1960).
3. Haley, W. L., and Pence, J. W. Bulgor, an ancient wheat food. Cereal Sci. Today 5: 203, 204, 206, 207, 214 (1960).
4. Hinton, J. J. C. Resistance of the testa to entry of water into the wheat kernel. Cereal Chem. 32: 296–306 (1955).
5. Olson, R. L., Ferrel, R. E., Juilly, M. E., Kaufman, V. F., and Taylor, E. C. Food supply for fallout shelters. Western Utilization Research and Development Division, Albany 10, California (Nov. 1960).
6. Roberts, R. L. U.S. Patent 2,616,808 (January 24, 1950).
7. Roberts, R. L., Houston, D. F., and Kester, E. B. Expanded rice product. A new use for parboiled rice. Food Technol. 5: 361–363 (1951).