NOTE

Testing Bread Slices in Tension Mode[1]

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Compressed bread specimens rarely exhibit gross failure, even when they are subjected to very large strain, on the order of 75–85%. This behavior, which is typical of many spongy foods (e.g., cakes, marshmallow) and nonfood materials, is due to the ability of the cell's walls to collapse inward, increasing the sponge density and consequently its strength. The cell walls themselves, however, particularly if thin, can either be fractured or buckle. This special characteristic of sponges results in a unique kind of sigmoid compressive stress-strain relationship whose regions can be explained in terms of the collapse mechanisms at the cell wall level (Ashby 1983, Gibson and Ashby 1988, Attenburrow et al 1989). Recently, the shape of such curves was characterized by a simple mathematical model (Peleg et al 1989), and it was shown that the model's constants could be used as quantitative parameters to characterize the compressive behavior of breads and other spongy baked goods.

Since most breads are relatively soft, the forces or stresses that are involved in their compression are relatively small. In contrast, the forces that are needed to tear them apart, such as during chewing, can be much higher.

The use of methods to characterize bread crumb texture is reported by many investigators (e.g., Hibberd and Parker 1985; Dahle and Sambucci 1987; Kamel 1987; Walker et al 1987; Joensson and Toernaes 1987; Baker et al 1987, 1988). Destructive methods, based on the Kramer shear press or its numerous versions and modifications, suffer from the introduction of arbitrary elements into the test (e.g., number of blades, shape, dimensions, spacing, etc.). Consequently, the results have a strong dependency on the test conditions, and it is difficult, if not utterly impossible, to relate the results of such tests to the fundamental mechanical properties of the tested material. From a mechanical point of view, the simplest test to interpret is tension, which is widely used in engineering materials, especially metals and polymers.

Reports on the application of tensile tests to food materials are very scarce in the food literature (Bourne 1982). This is mainly due to the grip problem and the difficulty of preparing appropriate specimens for testing. Breads and bakery products are no exception (Platt and Kratz 1933), but these two problems can be overcome, at least to some extent. The objectives of this work were to develop a practical procedure for testing breads in tension using commonly available universal testing machines and to evaluate the test performance and potential use.

MATERIALS AND METHODS

Materials

Sliced breads of various commercial types were bought in a local supermarket and tested no later than one day after purchase.

Specimen Preparation and Testing Procedure

Bread slices of known thickness, measured with a caliper, were sealed in Ziploc bags to minimize dehydration before the test. They were then placed under 5 kg of weight for 30 min. They were subsequently removed and their thickness determined again. Bone-shaped specimens were cut from the slices using a sharp edged stainless steel template. Its shape and dimension are described in Figure 1.

The edges of the specimen were taped with an adhesive tape (masking tape) as shown in Figure 1. In this form it could be mounted on the Instron universal testing machine (UTM) using the standard grips as the lower jaw. A crocodile grip was used as an upper jaw. The specimen so prepared will be referred to as compressed. Some specimens were subjected to compression of the edges only (an 8-mm region at each end) under 2.5-kg weights for 2 sec. This was done in order to enable proper grip after taping. The specimens so prepared will be referred to as uncompressed. The apparent density of the specimens was calculated by dividing their mass by their volume, which had been determined from the measured dimensions and thickness of each specimen. (The volume of the uncompressed specimens was determined before the edge compression)

The specimens were tested in tension with a UTM, model 1000, at two constant crosshead speeds, 10 and 50 mm/min. The breaking force and deformation at failure were read directly from the force deformation files of the computer interfaced with the UTM machine. Each specimen was visually inspected during the test, and if failure developed at or in the neighborhood of the grips, the test was aborted and its data discarded.

RESULTS AND DISCUSSION

The experimental tensile parameters of five commercial breads, namely pumpernickel, rye, white, oatmeal, and whole wheat, are summarized in Table I. Also listed in the table are the apparent density of these breads before and after compression. Since the procedure used to determine these densities was very crude, the figures should be considered only as a rough approximation of the true values. They do, however, reflect the large differences in density and compressibility between the various bread types. Because the breads were tested at different densities, and because the test geometry did not enable accurate calculation of the stresses and strains, the tensile data in Table I are reported in terms

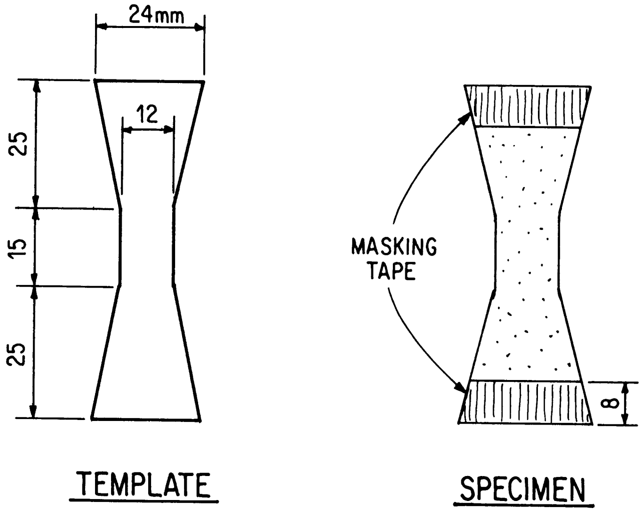

Fig. 1. The shape and dimensions of the template and bread specimens tested in tension (all measures are in millimeters).

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TABLE I
Some Tensile Characteristics of Various Breads[a]

				Compressed					Uncompressed				
	Apparent Density (g/cm^3)		Deformation Rate		Ultimate Force		Deformation at Failure			Ultimate Force		Deformation at Failure	
Bread	Initial	Compressed[b]	(mm/min)	*n*	Mean (N)	CV[c] (mm)	Mean (%)	CV[c] (%)	*n*	Mean (N)	CV[c] (%)	Mean (mm)	CV[c] (%)
Pumpernickel	0.25	0.80	10	3	0.24	10	6.5	10	4	0.19	21	7.4	17
		(3.2)	50	6	0.45	16	8.5	12	5	0.35	27	8.4	22
Rye	0.28	0.95	10	5	0.38	12	5.9	16	4	0.28	19	5.9	3
		(3.4)	50	5	0.46	9	6.4	20	5	0.47	20	7.7	19
White	0.19	0.58	10	7	0.40	15	8.5	12	4	0.31	14	9.2	8
		(3.1)	50	5	0.45	20	10.2	13	4	0.39	13	9.7	8
Oatmeal	0.13	0.77	10	8	0.39	22	7.1	40	4	0.51	20	7.9	30
		(5.9)	50	6	0.32	22	9.3	14	4	0.40	12	12.9	9
Whole wheat	0.34	0.52	10	4	0.56	13	5.3	16	4	0.50	18	6.5	9
		(1.6)	50	4	0.64	8	8.0	10	4	0.63	41	8.8	34

[a] For specimen dimensions, preparation and loading procedure see text and Fig. 1.

[b] Numbers in parentheses are the density ratios.

[c] CV is the coefficient of variation calculated as 100 $\sigma/\bar{x}$.

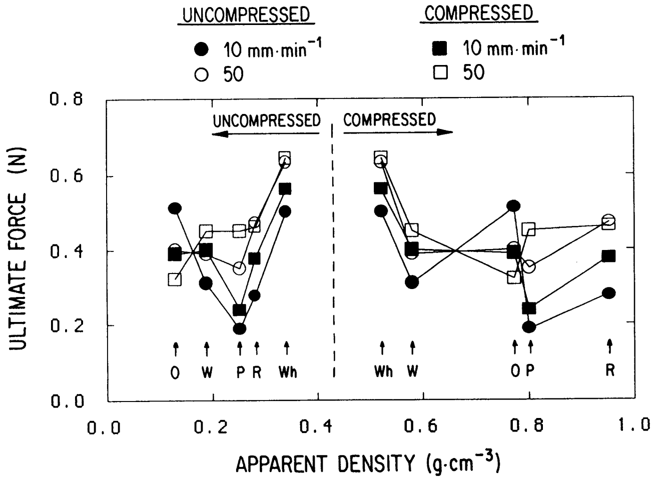

Fig. 2. Ultimate tensile force vs. apparent density plots of sliced breads. **O** = oatmeal, **P** = pumpernickel, **R** = rye, **W** = white, **Wh** = whole wheat.

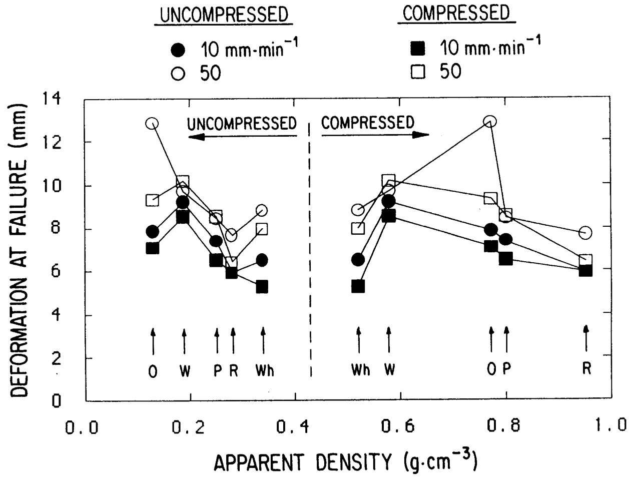

Fig. 3. Deformation at failure vs. apparent density plots of sliced breads. **O** = oatmeal, **P** = pumpernickel, **R** = rye, **W** = white, **Wh** = whole wheat.

of ultimate force and absolute deformation, that is, the force and deformation at failure. (Proper monitoring of tests with the described or similar geometry, so that the results can be expressed in stress-strain relationships, requires instrumentation and methodology probably not available to most food laboratories.)

Despite the test's crudeness, its results, as judged by the magnitude of the coefficient of variation, were fairly reproducible. The coefficient of variation was generally on the order of 10–25% for both the ultimate force and the deformation at failure, although extreme values of 41 and 3% were also observed. As far as reproducibility is concerned, it appears that compression of the specimens prior to testing improved the test's performance in some breads, e.g., pumpernickel and rye, but the effect was not drastic. In the dense and coarser whole wheat bread, compression appears to be required not only to reduce the scatter (Table I) but also to reduce the number of aborted tests.

In general, increasing the deformation rate from 10 to 50 mm/min resulted in higher ultimate force and larger deformation at failure. This was observed in both compressed and uncompressed specimens.

According to the behavior of cellular solids in compression (Ashby 1983, Attenburrow et al 1989), one would expect that the ultimate force and perhaps the deformation at failure should be related to the specimen density before or after compression. Similar trends were also expected in bread, that is, the higher the density the higher the strength (Taranto 1983, Kamel 1987).

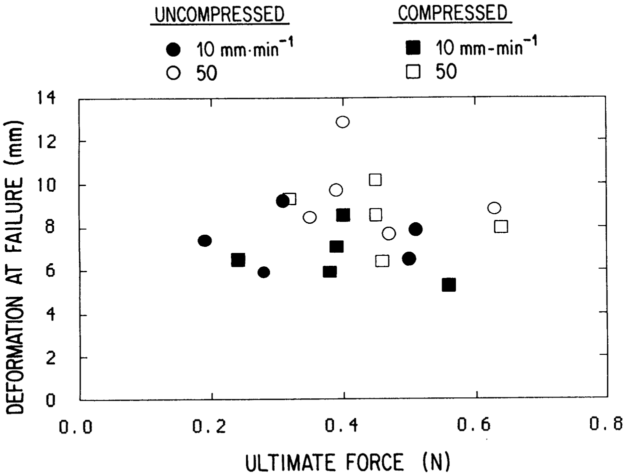

Fig. 4. Deformation at failure vs. ultimate tensile force of sliced breads.

Plots of these parameters versus the initial specimen density and its density when compressed are shown in Figures 2 and 3. The figures indicate that no such relationship emerged despite the very large differences in density and compressibility between the breads (Table I). The lack of evidence that higher density was associated with higher strength suggests that density alone cannot serve as a reliable measure of structural integrity of breads. A plot of deformation at failure versus ultimate force is shown in Figure 4. Again, no pattern emerged from the data, suggesting that at least in the tested breads, strength and deformability are independent mechanical attributes.

Implications in Textural Evaluation of Breads and Other Bakery Products

The described procedure for bread testing in tension, compressed or uncompressed, is simple to perform and does not require any special technical skills. The test itself can be performed on almost any type of UTM with standard grips or custom made inexpensive substitutes. The specimen preparation procedure is also simple and except for the template does not require any equipment not readily available in food laboratories. The reproducibility of the tests varied considerably among the tested breads (Table I) and was generally higher than that reported in compression (e.g., Baker and Ponte 1987). The scatter was most probably a reflection of the breads structural nonuniformity. Partly, however, it may also be attributed to imperfections in the procedure itself. Exactly to what extent this is so can only be learned by repeating the tests with different templates, adhesive tapes, etc. If, however, the scatter is mostly due to structural nonuniformity then the CV itself can be treated as a textural property (Finkowski and Peleg 1981).

Although the reported tests were performed under rather arbitrary conditions, they confirm a very early report that spongy baked goods can be tested in tension (Platt and Kratz 1933). This is a welcome conclusion because as previously mentioned, tension can be considered the cleanest or most direct testing mode. Whether the experimental procedure can be improved and whether the results of tensile analysis can indicate differences in breads of same type as a result of age, baking conditions, etc., is not known. Similarly, a correlation between tensile parameters and organoleptic textural attributes can only be determined on the basis of detailed studies of specific breads. This would be necessary because mastication involves shear and compressive stresses and a hard to define geometry. If such a correlation were found, the method would find wide application in the baking industry and it could be extended to the evaluation of other bakery products with minor modifications to accommodate for these products shape and size.

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