Microwave Energy for Bread Baking and its Effect on the Nutritive Value of Bread: A Review

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ABSTRACT

Microwave energy offers savings in labor, processing time, and space in bread baking. Two constraints, however, limit its application: microwave-baked bread lacks the characteristic brown crust, and baking pans inexpensive and suitable, are still to be developed for microwave baking of sandwich-type breads. To provide the brown crust, a combined microwave and thermal heating process was recommended to prepare brown-and-serve rolls and white bread. By such a process, a flour with low protein content and high alpha-amylase could be used to prepare acceptable bread. Combined microwave and thermal heating also was suggested to proof dough and bake it to reduce processing time and energy required for bread making. Microwave energy also was found practical to bake relatively dark breads such as whole-wheat and rye breads where brown crusts were less important. Nutritively, microwave baking does not produce browning reactions to reduce the availability of lysine so it minimizes nutritive losses during baking.

Microwave energy with its unique heating ability offers many advantages to the baking industries; savings in labor, processing time, and space. A number of applications have been considered, including proofing, baking, defrosting and pasteurizing certain baked products (3,30).

One of the first applications of microwave heating was in 1947 when Cathcart et al. (1) suggested its use at 14 to 17 MHz to pasteurize packaged bread. More recently their results were confirmed at 2450 MHz (14).

Producing doughnuts is one of the most successful applications of microwave energy (21,24), and microwave proofing of yeast-raised doughnuts reduces production costs and proofing time from approximately 35 to 4 min (20,22,23). Microwave energy also is used as an adjunct heat source to fry chemically leavened doughnuts to produce an improved product in shorter frying time (22). Another successful commercial application is drying pasta products with a combination of microwave energy and hot air (12,21,24). Food products, like microwave pancakes, are being formulated and packaged exclusively for microwave cooking (5,29).

Limited work has been reported on baking cakes with microwave energy. Neuzil and Baldwin (13) found that plain white and devil's food cakes cooked by microwaves were less tender and less moist than conventional cakes, though cell structure and flavor did not differ significantly. Street and Surratt (31), after studying effects of liquid level, container shape, and browning time on cakes prepared from a yellow cake mix, reported that microwave-baked cakes were more tender and less moist than conventionally baked ones. Increasing liquid produced a cake similar in cell distribution, moisture content and volume to a conventionally baked cake.

Effects of microwave energy on lipid changes in egg yolks and cakes studied by Schiller et al. (26) were in accord with the review by Rosen (17) that microwave energy does not interact strongly with lipid molecules to initiate hydrolysis or oxidation in such a food system.

Because bread is the most popular of all bakery foods, microwave energy could find its greatest potential in bread-baking. But customers prefer the characteristic brown crust, which bread baked by microwave energy lacks. Inexpensive pans still are not available for commercial microwave-baking of sandwich-type breads. Those two constraints limit the commercial application of microwave energy to bread-baking.

BROWNING BY CONVENTIONAL BAKING

In conventional baking, oven heat is gradually transferred into the interior of the loaf by conduction. The gradual heat transfer sets up a temperature gradient within the dough. The internal portion of the dough will not reach a temperature of about 100 C so long as free water is available to vaporize (15). However, the surface of the dough does dehydrate and reaches a temperature higher than 100 C, allowing browning and crust formation to occur.

Browning involves two reactions: the Maillard reaction and caramelization. The reactants for caramelizations are mostly sugars; for the Maillard reaction they are free amino acids (such as lysine) and reducing sugar groups that form a variety of colored products (16). The reactions produce the characteristic brown crust and flavors associated with the conventionally baked bread. But the reactions also reduce the nutritive value of bread, particularly when essential amino acids are involved in the Maillard reaction. Proper microwave baking does not give the browning reactions and thus minimizes nutritive losses from bread, as Tsen et al. (22) have reported.

As shown in Table 1, conventional baking results in a much darker crust and a slightly darker crumb than...
microwave baking or steaming. The browning during conventional baking increased feed conversion ratios measured by growth of experimental rats (Table 2) or decreases the protein efficiency of conventionally baked bread (Table 3) (32). That lysine is involved in the browning reaction has been well established (18). Others have reported nutritive losses of lysine by conventional baking of regular and fortified breads (8,9,10,18,19).

**COMBINED MICROWAVE AND THERMAL BAKING**

One way to provide a brown crust for microwave-baked bread is simply by conventional baking; i.e., combined microwave and thermal baking. Fetty (6) reported that doughs could be baked partially by microwave energy and then browned in a conventional oven. Decareau (3) also produced partially baked bread by baking as little as 3 min in a microwave oven. The finished product's volume and texture were equal to those of a conventionally produced, partially baked product.

Collins (4) and Chamberlain (2) reported that microwave energy can be advantageously used to bake bread from wheat flour with low protein content and high amylase activity. Wheat flour with low protein content gives doughs permeable to gas during the early stage of baking and thus produces loaves of low final volume and poor internal crumb structure. High alpha-amylase activity in flour leads to extensive breakdown of starch during baking so the bread crumb lacks resilience, loses water-holding capacity and sticky end-products that gum up slicer blades accumulate. But dough, baked with both microwave (896 MHz) and thermal (320 C) heating, made acceptable bread from all-English biscuit flour of 8-9% protein and with high amylase activity (2,4). As shown in Table 4, the specific volume of such combined microwave- and thermal-baked bread compared favorably with the bread baked conventionally from bread flour of 11.3% protein and with low amylase activity, an accomplishment stemming largely from the fast, heating capability of microwave to produce carbon dioxide and steam and to inactivate the amylase. Shute (28) recommended microwave energy at 900 MHz for baking standard- and larger-sized products because the frequency at 2450 MHz does not penetrate well.

**DARK BREAD BAKED BY MICROWAVE ENERGY**

The other way to apply microwave energy is to bake relatively dark breads like whole-wheat and rye whose brown crust formation is less important. Lorenz et al. (11) found that microwave baking was feasible for relatively dark breads that required little, if any, additional heating in a convection oven. No change in formulation of breads was necessary, but fermentation and proofing time had to be reduced. They also showed that the baking time was greatly reduced; the moisture content was higher in their microwave-baked whole-wheat and rye breads than in conventionally baked ones. The higher moisture content was thought to be the reason breads baked in the microwave oven were softer than those baked in a convection oven. The microwave-baked whole-wheat breads' flavor ratings were inferior to those of conventionally baked breads. But no difference in flavor was detected between rye breads baked by microwave and those baked conventionally (Table 5).

**SOME NEW DEVELOPMENTS**

Instead of thermal heating to produce bread's brown crust, infrared could be used, as Seiler reported (27). Infrared heating is most rapid on the outside so it produces external browning with little internal penetration. A combination of high frequency and infrared heating permits one to bake bread in a much shorter time than in conventional, steam-heated ovens. Schiff-
manner et al. (25) recently reported that bread proofing and baking can be carried out in metal baking pans with both microwave and thermal heatings, with proofing and baking times and energy requirements reduced. They used microwave heating to complete the thermal proof. Ingram et al. have developed an apparatus to proof and bake bread with microwave energy in conjunction with thermal heating (7).

REFERENCES