Glass and Metal Pans for Use with Microwave- and Conventionally Heated Cakes[1]

B. A. BAKER, E. A. DAVIS, and J. GORDON[2]

ABSTRACT

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Temperature profiles and quality characteristics (batter specific gravity, weight loss, cross-sectional area, and symmetry) were evaluated in a lean cake formulation heated by microwave and conventional energy in metal and glass baking pans for the purpose of choosing one pan type for future studies. The statistical results showed that cakes baked in glass pans in microwave and conventional ovens had more similar cross-sectional areas and weight losses than their metal pan counterparts. Also, temperature profiles showed hottest edges and coolest centers for cakes baked in glass pans in both oven types.

Cake quality is influenced by pan size and shape and by pan materials (Charley 1950, 1952, 1956; Toledo 1980.) For example, a shallow cake often results in a better quality layer cake (Charley 1952). Cake volume was higher when dark, dull pans composed of steel, japanned iron, or anodized aluminum were used, and it was lower in shiny aluminum, tinned iron, stainless steel, and copper pans (Charley 1950, 1952). Also, the heat transfer characteristics were different in glass than in metal pans. Glass pans were highly emissive and less efficient in heat transfer than metal pans (Charley 1950). The lower efficiency of glass was attributed to the lower thermal conductivity of glass relative to metal (Toledo 1980).

Microwave heating of batters results in different pan requirements for optimizing final cake quality. Lorenz et al (1973) found that metal pans resulted in nonuniform heating of batters due to the reflectivity of the microwave energy off the metal surface. Stinson (1986) compared cakes baked in shiny and dull aluminum pans and in dull thermoset polyester pans using a microwave-convection oven. The cakes baked in dull thermoset polyester pans were highest in symmetry.

Another consideration is whether a single pan type can be used in comparative studies of batters heated by conventional and microwave heating. A special consideration would be to use a pan type that resulted in temperature profiles that were the same across heating methods for a particular thermal probe location (e.g., edge, midpoint, and center positions).

The purpose of this study was to evaluate batters heated in glass or metal pans by microwave or thermal heating modes for similarities in batter temperature profile patterns for edge, midpoint, and center positions, as well as for similarities in cake quality characteristics.

MATERIALS AND METHODS

Batter Preparation and Heating Conditions

A modified lean cake formulation (Gordon et al 1979) was used in this study. Batter (400 g) was weighed into aluminum pans (20.5 cm in diameter and 3.0 cm deep) or glass pans (20.3 cm in diameter and 4.4 cm deep).

Cakes were baked in a conventional-microwave heat source oven (Litton Micro-Browner oven, model 1285), using either thermal or microwave energy sources (both were not on at the same time). The average microwave power (P) at 2,450 MHz was found to be 700 W at 118 volts alternating current when measured by the following method. The absorbed power was calculated using the equation:

$$P = (M\ C_p\ \Delta T)\ /\ kt,$$

where M is the weight of water in grams; C_p is the specific heat in cal/g·°C; ΔT is the change in temperature (in °C) before and after heating; t is the time heated, in minutes; and k is 14.335 cal/min·W (1 W = 14.335 cal/min). Care was taken to use a bowl that did not absorb microwaves. Two resistant heating elements, one at the top and one at the bottom of the oven, supplied 2,000 W of thermal heat for the thermally heated batters. Microwave cakes were baked at 70% power for 8 min; thermal cakes were baked at 177°C for 30 min. These times resulted in temperature profiles that indicated the same degrees of doneness for each cake.

Cake Quality Characteristics

Batter specific gravity. The specific gravity of the cake batter was measured immediately after preparation in a 15-ml Fisher Grease pycnometer, which was later used as a check for differences in replications before baking.

Time-temperature profile curves during baking. Temperature profiles were recorded for each of three positions. The temperature probes were placed at 101, 52, and 20 mm for the center, midpoint, and edge positions, respectively.

A fiber optic temperature probe system (Luxtron, model 1000A) was used to measure temperatures throughout baking in the thermal-microwave oven.

Final weight loss of cakes. The baked cakes were removed immediately from the oven and weighed. A percent weight loss was also calculated and analyzed by analysis of variance (ANOVA).

Cake cross-sectional area. The baked cakes were cooled for 1 hr, removed from the pans, and cut vertically into two equal halves. The cross-sectional area (in square millimeters) of the left half of the face of each cross-sectioned cake was traced and averaged over three tracings with a digitizer (Hipad, Houston Instruction). The area was analyzed by ANOVA.

Cake symmetry. The symmetry (in millimeters) of the cake was determined from the cross-sectional tracing by AACC Method 10-91 (AACC, 1976). The cake symmetry index was analyzed by ANOVA.

Cake cross section photographs. Cake cross sections were photographed to show the general appearance of the cake's crumb, texture, height, and volume. Qualitative observations by the authors were recorded for crust color, shininess of crust, and presence of capillary pores.

Statistical Design

A 2 × 2 randomized block design was used to study the main effects of heat treatment (microwave and thermal) and pan type (metal and glass). The center, midpoint, and edge positions were randomized within a given formulation. Thus, 12 observations were made per replication and three replications were used, for a total of 36 cakes. Each block of four treatments was tested each day to control the day by day variation.

An ANOVA was performed by the Statistical Analysis System (Cary, NC) at the Saint Paul Computing Center, University of Minnesota. The means for the main effects and interactions were

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[2]Department of Food Science and Nutrition, University of Minnesota, 1334 Eckles Ave., St. Paul, MN 55108; present address of first author, Quali Tech, 318 Lake Hazeltine Dr., Chaska, MN 55318.

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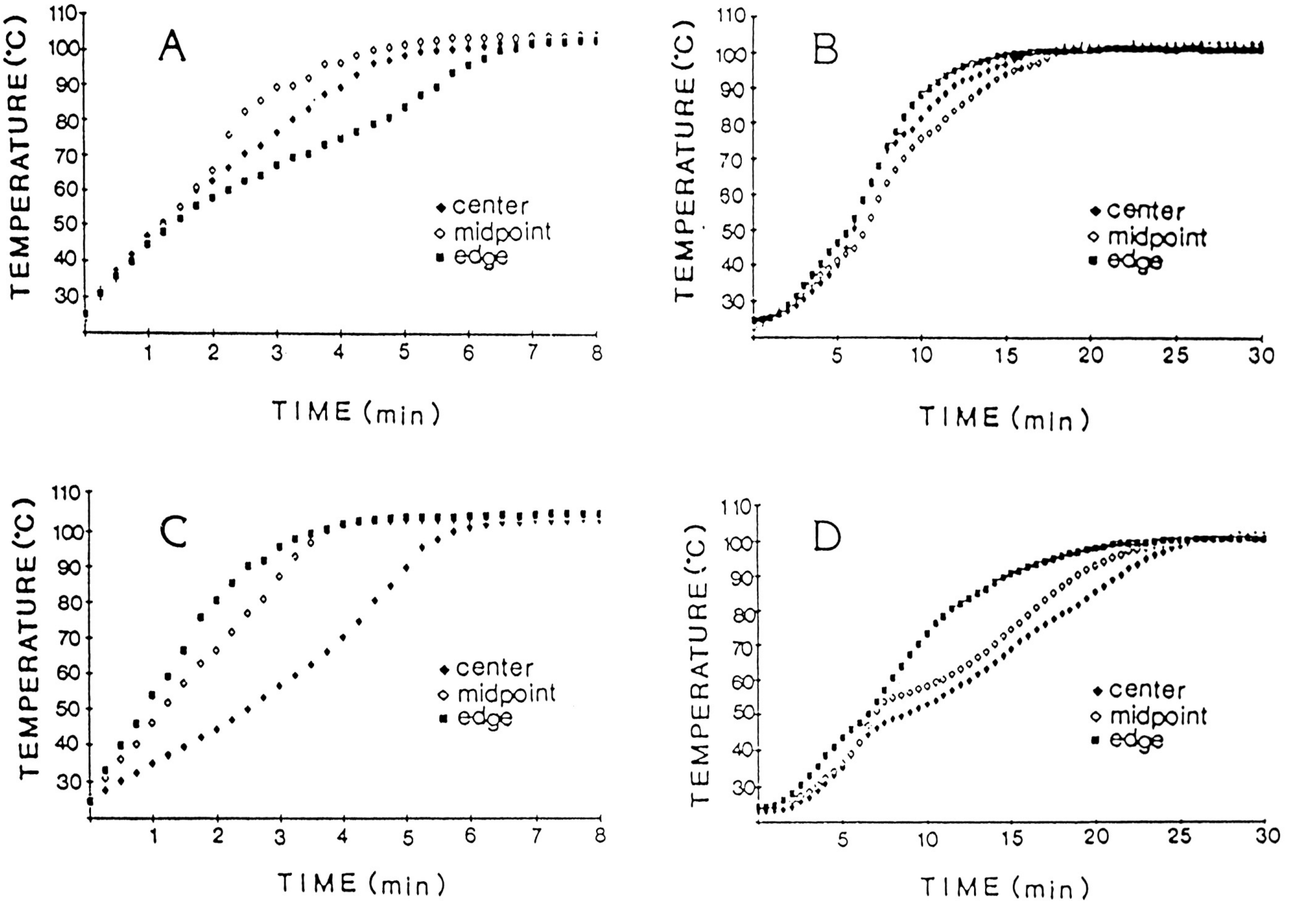

Fig. 1. Representative time-temperature profile for cakes: **A,** heated by the microwave in metal pan; **B,** heated thermally in metal pan; **C,** heated by the microwave in glass pan; **D,** heated thermally in glass pan.

further analyzed by Tukey's test (Montgomery 1984), if *F* significance at the 5% level was found.

RESULTS AND DISCUSSION

Time-Temperature Profile Curves

Representative curves for center, midpoint, and edge positions for each combination of pan type and heating mode are shown in Fig. 1A–D.

For batters heated by microwave energy in the metal pans, the temperatures at the three positions were initially similar, but after 2 min of heating, the temperature at the midpoint positions increased more rapidly than temperatures at other positions (Fig. 1A). As a result, a temperature gradient developed within the batter, with the temperature at the midpoint position being the highest and that at the edge, the lowest. In the later stages of heating, the temperatures at all positions converged as temperatures reached 100°C. For batters heated thermally in metal pans, the temperatures at the three positions were similar throughout the heating period (Fig. 1B). For batters heated in glass pans, temperature gradients developed early in both the microwave heating and thermal heating modes (Fig. 1C and D). Temperatures at the edge were the highest, followed by midpoint and center temperatures. The edge and midpoint positions remained considerably hotter in the first two thirds of the baking time for microwave-heated batters, and the temperature spread for those cakes was greater than for the thermally heated batters. Within the microwave heating mode, some of the differences in temperature gradients between the two pan types can be related to the difference in response of the two materials to microwave energy; the glass pan is relatively transparent to microwave energy, and absorption of microwave energy by the batter could occur at the bottom and sides as well as the top. Temperature gradients would develop, with the highest temperature being at the edge position. In the metal pan, which reflects microwave energy, absorption of microwave energy by the batter would occur primarily at the surface of the batter.

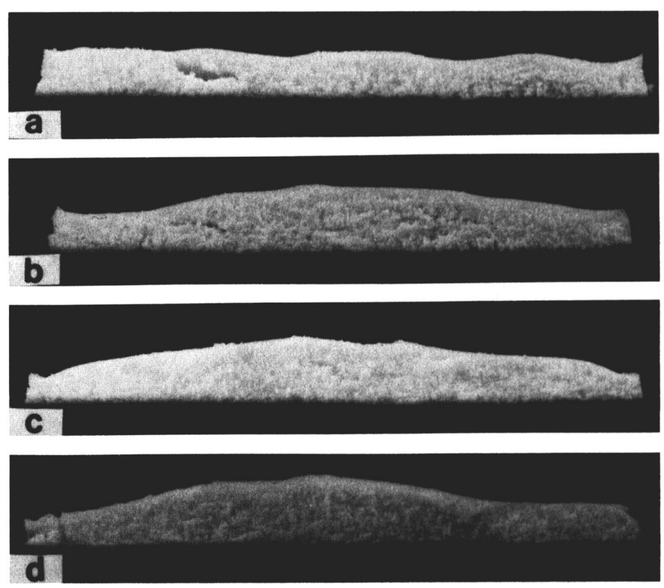

Fig. 2. Cross-sectional photographs of lean cakes: **a,** Microwave cake heated in metal pan; **b,** microwave cake heated in glass pan; **c,** thermal cake heated in metal pan; **d,** thermal cake heated in glass pan.

Therefore, glass pans gave similar temperature profile characteristics relative to the three positions for microwave- and thermally heated batters. Metals pans gave differing temperature

TABLE I
F-Values for Batter Specific Gravity and Cake Percent Final Weight Loss, Cross-Sectional Area, and Symmetry

Source	df	Specific Gravity	Percent Final Weight Loss	Cross-Sectional Area (mm^2)	Symmetry (mm)
Blocks (probe position)	2	2.33	0.29	0.68	0.061
Replicate	2	1.43	0.10	5.31*[a]	0.092
Treatments	3	0.56	332.42*	33.06*	18.01*
Heat	1	0.00	461.00*	31.66*	23.86*
Pan	1	0.39	25.96*	59.91*	30.1*
Heat × Pan	1	0.17	510.25*	7.58*	0.078
Error	28				
Total	35	Mean square = 0.000258	Mean square = 0.120	Mean square = 33019	Mean square = 15.0

[a] * = $P < 0.05$.

TABLE II
Means[a] for Final Weight Loss (%) of Cakes Heated by Microwave and Thermal Modes in Glass and Metal Pans

	Heating Method		
Pan Type	Microwave	Thermal	Average
Glass	10.9 b	10.8 b	10.9
Metal	7.7 a	12.8 c	10.3
Average	9.3	11.8	

[a] Mean differences by Tukey's test ($P < 0.05$). Standard error = 0.163 and $n = 9$.

TABLE III
Means[a] for Cross-Sectional Area (mm^2) of Cakes Heated by Microwave and Thermal Modes

	Heating Method		
Pan Type	Microwave	Thermal	Average
Glass	4,311 b	4,163 b	4,247
Metal	3,676 a	4,485 c	4,080
Average	3,993	4,334	

[a] Mean differences by Tukey's test ($P < 0.05$). Standard error = 0.163 and $n = 9$.

TABLE IV
Means[a] for Index to Symmetry (mm) of Cakes Heated by Microwave and Thermal Modes in Glass and Metal Pans

	Heating Method		
Pan Type	Microwave	Thermal	Average
Glass	9.7	16.4	13.1 d
Metal	3.0	8.9	6.0 a
Average	6.4 b	12.7 c	

[a] Mean differences of averages by Tukey's test ($P < 0.05$) for heat means and pan means only, because the heat × pan interaction was not significantly different. Standard error = 1.291 and $n = 18$.

profile characteristics depending on the mode of heat and pan type used.

Quality Characteristics

Various properties before and after baking were evaluated for batters heated by microwave and thermal radiation in metal and glass pans. In photographs of cross sections of the baked cakes (Fig. 2), differences in cross-sectional area and contour are evident. All cakes were peaked, except for the cake baked by microwave radiation in a metal pan (the flat cake). Cake crumb structures for microwave- and thermally heated cakes in glass pans and for thermally heated batters in metal pans were more open than those for the microwave-heated batters in metal pans. For the cakes with open crumb structure (Fig. 2b–d), temperatures from edge to center either had almost the same profile (Fig. 1B) or were highest at the edge and lowest at the center (Fig. 1C and D). The cake with the more compact crumb structure (Fig. 2a) took longer to reach 100°C regardless of probe location, with the midpoint having the highest and the edge the lowest temperature after 2 min of baking (Fig. 1A).

Cake surfaces were not browned, as expected, for the microwave-heated cakes, but browning was present for the thermally heated cakes. The cakes baked thermally in a metal pan had a darker crust than cakes heated thermally in a glass pan. This was attributed to the lower thermal conductivity of the glass pan (Toledo 1980).

The results of the ANOVA for specific gravity of batters, cross-sectional area, total weight loss, and index to symmetry are summarized in Table I.

None of the *F*-values were significant at the 5% level of significance for specific gravity. The mean specific gravity was 1.0, which indicated that no batter differences existed for cakes evaluated between treatments and replications. *F*-values for blocks were not significant for any of the quality characteristics.

The statistical results showed a significant difference ($P < 0.05$) for heating-mode pan-type interactions for percent final weight loss and cross-sectional area (Table I). The means in Table II showed the greatest weight loss for cakes prepared in metal pans heated by thermal heat and the smallest weight loss for cakes baked in metal pans heated by microwave energy. Cakes baked in glass pans, whether heated by thermal or microwave energy, showed no differences in weight loss. This same trend was noted for the cross-sectional area of cakes (Table III).

Even though no statistical difference was found in the interaction term heating mode × pan type for symmetry (Table IV), differences were seen between microwave- and thermally heated cakes in glass and metal pans. Cakes were flatter when microwave heated than when thermally heated. Also, they were flatter when heated in metal pans rather than in glass pans.

From the time-temperature profiles, cakes with higher temperatures for a longer time at all locations throughout the baking process (Fig. 1B) had greater final weight losses and cross-sectional areas. In contrast, cakes that took longer to reach maximum temperatures at all locations (Fig. 1A) had lower final weight losses. Cakes with a greater spread between the three temperature locations (Fig. 1C and D) showed intermediate final weight losses and cross-sectional areas.

From these results, the decision was made that even though heat transfer was best for metal pans during thermal heating, as found by Charley (1950), the similarity in heating profiles for batters heated in glass pans made the use of glass pans more attractive for future studies.

CONCLUSIONS

Cakes baked by microwave and thermal heat in glass pans appeared more similar in their temperature gradients, cross-sectional areas, and final weight losses than cakes baked in metal pans by the same heating methods. These results, combined with the bigger differences in flat tops for cakes baked in metal pans, resulted in glass pans being chosen for future studies in this oven system. For example, within the microwave mode, weight losses and the tendency to peak were greater in glass pans than in metal pans, but cross-sectional areas were larger in glass pans. Within the thermal mode, weight losses were smaller in glass pans than in metal pans, but cross-sectional areas were smaller and the tendency to peak was greater than in metal pans.

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