

Evaluation of a Two-Step Baking Procedure for Convenience Sponge Cakes

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ABSTRACT

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Typical examples of convenience foods in the bakery section include partially baked bread, rolls, croissants, and crumpets. The effects of processing variables on sponge cake characteristics were studied in a two-step baking procedure. A fractional two-factorial design was applied to describe the effects of the predictor variables on product properties. Flour type, oven type, and baking time in each baking phase were selected as categorical predictor variables on the basis of preliminary baking tests. The perform-

ance of a microwave oven was compared with that of a conventional oven. The properties of the new twice-baked products were characterized and compared with those of a standard product by using the results derived from baking tests, color measurements, and texture analyses. Correlation analysis was used to detect relationships between the response variables. Significant relationships between baking test values and texture analysis values closely related to aspects of microwave cooking were found.

A recent survey showed that executives considered the most promising direction for the food industry in the year 2000 and beyond to be product customization (Sloan 1995). Consequently, the industry reacted to these findings by developing convenience foods. These products require only minimum preparation time and effort by the consumers. They show no or only marginal loss of quality compared with their traditional counterparts. The baking industry offers various convenience products such as ready mixes and frozen doughs (Brümmer and Neumann 1994). A trend in this area is partially baked breads and rolls (Oesterwind and Pagenstedt 1982, Reineke 1993).

The partial-baking process consists of three stages: a baking phase, a storage period and shipment of the products, and a reheating or rebaking step performed by the consumer prior to consumption. During the baking step, the products are baked until a structure forms that makes the products suitable for storage and shipment. During storage and shipment, the products are packed in airtight containers or occasionally in containers with a modified atmosphere. The reheating or rebaking step reverses certain product properties typically developed during storage, generating the characteristics of a freshly baked product. To make the product convenient for the consumer, this step should not take much time.

Microwave cooking offers some positive aspects related to convenience: an increase in process speed, uniform heating throughout the product, a very fast up-heating rate, efficient energy conversion, and possibly good product quality (Schiffmann 1995, Mullin 1995). Microwaving is therefore preferred by consumers.

Several successful applications of hybrid or microwave oven cooking in the area of baking and reheating of bread, cake, and pastry have been reported (Decareau 1992, Buffler 1993b, Schiffmann 1995). Recently, microwave cooking was successfully used in combination with conventional baking to produce hot dog buns with product properties superior to those of their conventional counterpart (Willyard 1998). However, cooking in a microwave oven results in a lack of color development, and there are also some negative aspects in connection with the shape of the product. Edge-heating effects in slab or flat shapes and focusing in spherical or cylindrical shapes results in burned or tough products (Buffler 1993a). Both represent typical shapes used in sponge cake baking.

The effects of raw materials and processing variables on the final properties of traditional baked products were intensively

investigated by using standardized baking tests. Experimental designs were used to improve understanding of the complexity of the baking process. An experimental design comprises a group of statistical techniques for empirical model building and model exploitation. It seeks to relate a response variable to the levels of a number of predictor variables (Box and Draper 1987). The designs were adapted to minimize the number of baking trials without losing any information related to all possible experimental combinations. They provided not only the opportunity to quantify main effects of the process variables but also to identify and describe interactions between them.

Information about the effects of process variables and ingredients on final product properties of partially baked sponge cakes as representatives of sweet bakery products has not been available to date. In this study, a two-step baking procedure for these sponge cakes was developed. The new products were compared with their conventionally baked counterparts. Relationships between different product properties were found by using correlation analysis, and optimal processing steps were identified by an experimental design. Special attention was given to use of the microwave oven throughout the second baking step.

MATERIALS AND METHODS

Sponge Cake Recipe

The sponge cake batter was produced by a standard all-in procedure (Arbeitsgemeinschaft Getreideforschung e.V. 1994). The formula and suppliers of the ingredients are listed in Table I.

Procedure

All ingredients were blended in a mixer (Kenwood KM250, Kenwood Ltd., New Hampshire, England) at low speed for 30 sec and at high speed for 240 sec. The batter (35 ± 1 g) was poured into muffin cases, which were then placed into ramekins. The standard sponge cakes were baked in one step in a deck oven at 180°C (top heat) and 160°C (bottom heat) for 35 min. Hi Ratio flour was used in the formula. The partially baked products were baked in two steps according to the baking parameters listed in Table II and stored between the first and second baking steps as described below.

Storage

Thirty minutes after baking, the sponge cakes were placed individually into small, airtight plastic containers and stored for up to seven days at 20°C in an incubator (Memmert, Schwabach, Germany).

Design of Experiments

Flour type (Extra Strong, 14.4% protein, or Hi Ratio, 12.6% protein, chlorinated) (Daniel 1978), baking time in baking phase 1, and oven type and baking or heating duration in baking phase 2 were chosen as predictor variables on the basis of preliminary baking

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tests. A fractional two-factorial design (Design Expert, StatEase Inc., Minneapolis, MN) was applied to select the necessary number of experiments to be conducted without any or only a minimal loss of information in relation to all experiments. Validation tests were performed to confirm the results obtained by the experimental design.

Selection of the Baking Parameters

Ovens with different baking behaviors were chosen. Traditional baking took place in a deck oven, which combined a grill function on top of the internal baking chamber and a hot stone plate at the bottom. Temperature settings for the grill and stone plate were regulated independently. The heat transfer to the product was based on the principles of radiation and conduction. A microwave oven (Hotpoint, Peterborough, UK) was selected as the second oven. Microwaves are forms of energy that are manifested only as heat through interaction with materials. The heat transfer to the product was based primarily on ionic induction and dipolar rotation. The choice of microwave cooking in the second baking step was based on convenience: only a short reheating time is necessary to finish the product. Baking time, temperature, and power settings were chosen after preliminary baking tests. The shortest baking time in the first baking step was established as the time at which structure setting of the crumb throughout the product had just taken place. The upper limit in this baking step was the time at which the product was almost entirely baked. The lower limit in the second baking step was chosen as the time needed to heat the product to a core temperature of 60°C, the minimum temperature required to reverse staling effects and resolubilize crystalline amylose molecules (Hoseney 1994).

Analysis of Sponge Cakes

The volume of the sponge cakes was measured by the rapeseed displacement method. The batter weight and product weight of every sponge cake baked were determined. The values for bake loss (g/100 g) and specific volume (mL/g) were calculated.

Crust color was measured with a Chromameter (model CR-300, Minolta, Osaka, Japan). The CIE L* values (brightness), a* values (redness), and b* values (yellowness) were recorded.

Texture was assessed with a texture analyzer (model TA-XT2i, Stable Micro Systems, Surrey, UK). A modified texture profile analysis (compression rate 40%, 20-mm diameter aluminum probe,

test speed 2 mm/sec) was conducted on the sponge cake crumb. Values for hardness and gumminess were calculated by using data evaluation software (Texture Expert V1.17, Stable Micro Systems). Values for slope ratio were calculated as:

$$R = \frac{\text{Force}_{(t=1.4 \text{ sec})} (\text{g}) - \text{Force}_{(t=0.8 \text{ sec})} (\text{g})}{\text{Force}_{(t=2.0 \text{ sec})} (\text{g}) - \text{Force}_{(t=1.4 \text{ sec})} (\text{g})}$$

Elastic products are characterized by values close to 1. This indicates a uniform increase of the force with increasing distance. The slopes of the two time intervals chosen are similar. A slower increase of the force between 1.4 and 2.0 sec is observed when the crumb is damaged and results in slope ratios >1.

RESULTS AND DISCUSSION

Sensory Evaluation

Once-baked sponge cake, tested 1 hr after baking, had the typical product characteristics desired by the consumer and that are the goals of experienced bakers. The surface was even and had a light brown color. The crumb was soft, smooth, and elastic. The taste of the product was neutral to bland, as was expected from the plain recipe used. After one week of storage, the outer appearance of the products was unchanged. However, the textural characteristics had changed completely. The cakes were hard and brittle and not suitable for consumption.

The rebaked products were divided into three groups. Products with long rebaking times in the microwave oven were unpalatable, mainly because the product core was firm. Products with short first baking time and a second baking phase in the microwave oven had very poor color but showed good textural characteristics. The remaining cakes showed improved product characteristics compared with the stored products and were similar to the standard product.

Standard Product

Products obtained in the two-step baking procedure were compared with those obtained by the standard sponge cake procedure involving only one baking step. The product properties of the standard product are shown in Table III.

Like most bakery products, sponge cakes deteriorate in quality during storage. Although shape, volume, weight, and color did not change significantly under the chosen storage conditions, textural characteristics changed notably. Results of texture profile analyses conducted after one to seven days of storage are shown in Table IV. After one week, hardness values were five times higher than those of fresh products. The increase in crumb firmness was an expres-

TABLE I
Sponge Cake Recipe

Ingredient	Supplier	FlourBase %	g/100 g of Batter
Flour	Odlum Group, Dublin, Ireland	100.0	18.5
Cornstarch	Shamrock Foods Ltd., Blackrock, Ireland	75.0	13.9
Whole eggs	KVI Brands, Dublin, Ireland	162.5	30.1
Sugar	Siucra, Irish Sugar plc, Carlow, Ireland	130.0	24.0
Water		55.0	10.2
Emulsifier	Crestawhip 200, Croda Food Services, Oldham, UK	9.2	1.7
Leavening agent	Royal Baking Powder, Homepride Foods, Harborough, UK	8.0	1.5
Table salt	Salt Union, Runcorn, UK	0.85	0.16

TABLE II
Partial-Baking and Rebaking Parameters

Baking Step	Oven Type	Temperature (top/bottom) or Power	Bake Time (min:sec)	
			Short	Long
1st	Deck	180°C/160°C	20:00	30:00
2nd	Deck	200°C/160°C	7:00	11:00
	Microwave	665 W	1:00	1:40

TABLE III
Standard Sponge Cake Properties^a

Analytical Method	Average	Standard Deviation
Bake loss (g/100 g)	20.3	0.9
Volume yield (ml/100 g of flour)	988	56.8
Specific volume (ml/g)	4.2	0.27
L* value	78.9	0.6
a* value	5.1	0.2
b* value	27.7	1.7

^a Values are the means of three separate analyses.

TABLE IV
Texture Profile Analyses of Fresh Sponge Cakes and After Various Storage Times^a

Characteristic	Fresh	1 Day	3 Days	7 Days
Hardness (g)	523 (25)	892 (35)	1,537 (132)	2,522 (220)
Cohesiveness	0.48 (0.02)	0.41 (0.01)	0.31 (0.01)	0.27 (0.01)
Gumminess	251 (8)	363 (8)	483 (52)	675 (43)

^a Values are averages. Numbers in parentheses are standard deviations.

sion of the staling process during which modifications in the starch molecule took place. This behavior is well described in bread crumb (Hoseney 1994). The measurements proved that products rich in sugar and egg also undergo dramatic changes in crumb characteristics during storage. An increase in gumminess values and a decrease in cohesiveness revealed changes in texture in addition to hardening of the crumb.

Results for Twice-Baked Products

Bake loss. The bake loss of all twice-baked sponge cakes was greater than that of the once-baked standard product (Fig. 1). Baking time or type of reheating caused only small variations in bake loss for the products made with chlorinated flour. Variations in bake loss between 20 and 35% were achieved in products made with Extra Strong flour. Duration and type of oven used in the second baking step had a significant effect on bake loss. The process involving a short reheating time in a microwave oven achieved values similar to those of the standard product. Long bake times during the second baking phase led to the highest values for bake loss. Correlation analysis revealed a negative correlation between bake loss and brightness of the product (Table V). No significant correlations were found among any of the texture parameters.

Specific volume. Specific volumes for twice-baked products were lower than those of the standard product (Fig. 2). Products prepared with Hi Ratio flour had improved volume compared with products containing Extra Strong flour. For both flour types, volumes of products reheated in the deck oven were higher than those of products reheated in the microwave oven. Whereas long bake times during the first baking phase increased the volume, no effects of duration of the second baking phase were determined. During the first baking phase, the development of CO₂ by the baking

powder, the expansion of incorporated air during heating, and the build-up of water vapor led to an increase in volume. When the final temperature of ≈100°C was reached in the core of the product, the volume remained constant. The ability of the crumb and crust to maintain the volume reached after baking was determined by the product's stability. This stability was increased during the last minutes of baking. The shorter the first baking phase, the more the volume was reduced during storage. During the second baking phase, the increase in temperature led again to an expansion of gas and the development of water vapor. Because of the porosity of sponge cake, little gas was retained within the structure, and the volume reached was not the same as that before the storage period. During reheating in the microwave, the rapid increase in temperature and development of vapor led to a short-term softening of the structure. During cooling of the product prior to volume determination, shrinkage of the sponge cakes led to further volume loss.

Color development. The surface brightness values of products made with Hi Ratio flour were higher but not significantly different from those obtained with Extra Strong flour when the same baking parameters were applied (results not shown). This fulfilled the intention of selecting baking and rebaking parameters that ensured tolerable crust colors on either side of the experimental design in accordance with consumer expectations. Within one type of flour, products reheated in the deck oven were darker. Surface brightness is a combined effect of color and surface reflection. The smoother surface observed when Hi Ratio flour was used contributed to this effect.

Duration of the first baking time and type of oven chosen for reheating influenced the a* value of sponge cakes (Fig. 3). The a* values increased with increasing first baking time, and using the microwave resulted in significantly lower a* values. Positive a*

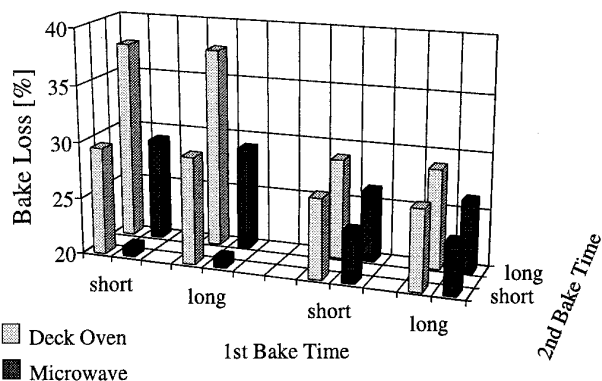


Fig. 1. Bake loss of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

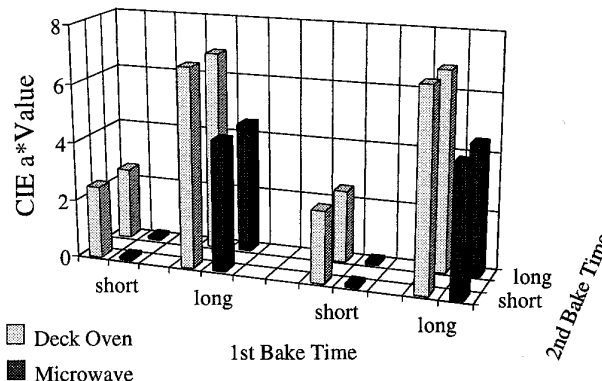


Fig. 3. Redness (a* value) of the crust of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

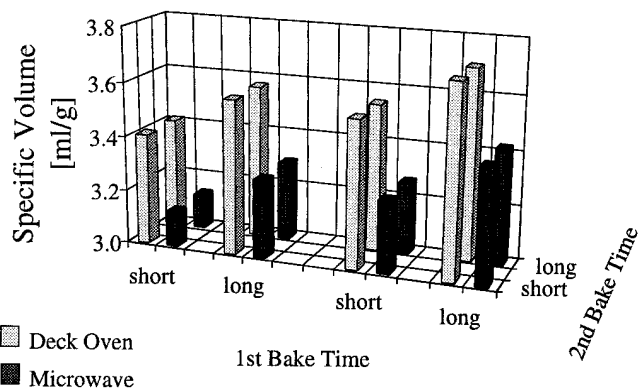


Fig. 2. Specific volume of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

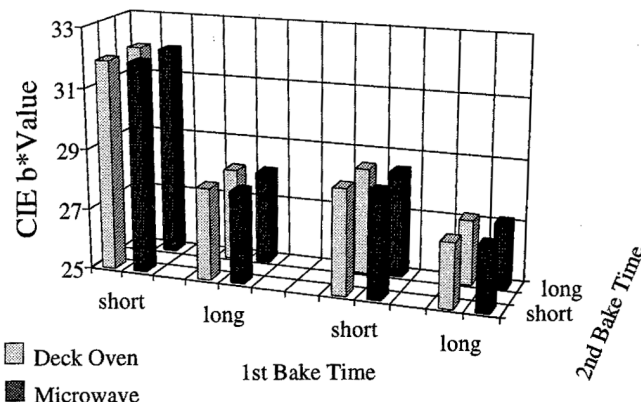


Fig. 4. Yellowness (b* value) of the crust of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

values describe the red hue of a color. The color of products that had a short first baking time and were reheated in the microwave contained no red shares, indicated by a^* values near zero. The appearance of these products was totally atypical for sponge cakes and without any coating would not be accepted by the consumer. Long first baking time and reheating in the deck oven resulted in a^* values >6 . These values were higher than those of the standard sponge cake but still represented an acceptable product.

Distribution of the yellowness (b^* value) of a product was completely different (Fig. 4). Duration of the first baking phase and flour type chosen controlled the development of yellowness. The b^* values were not affected by the oven type chosen for reheating. Products with short first baking time produced with Extra Strong flour had the highest b^* values.

Textural properties. The force necessary to compress the crumb of a sponge cake was greatly affected by the duration of both baking times and the type of oven used during reheating (Fig. 5).

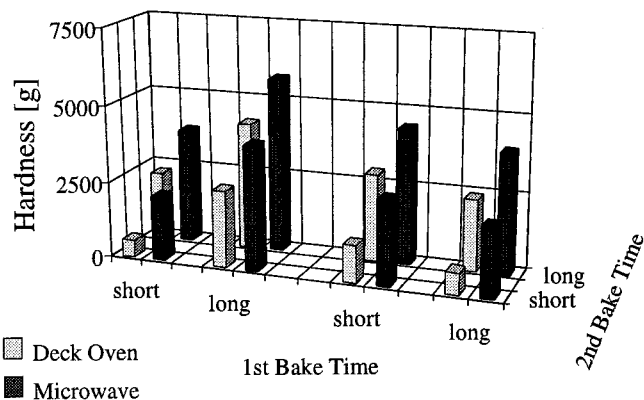


Fig. 5. Hardness of the crumb of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

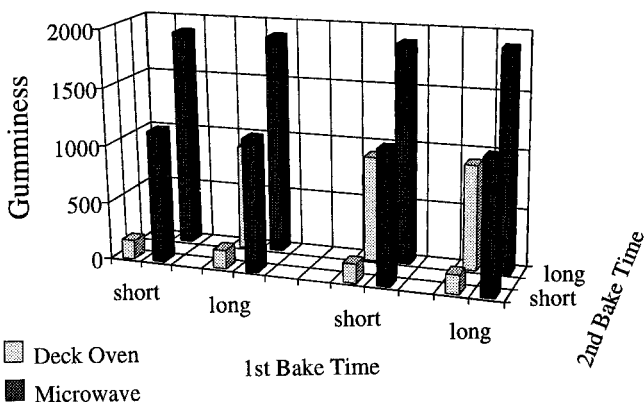


Fig. 6. Gumminess of the crumb of twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

The type of flour had no significant effect on hardness values. For the standard product, values of about 500 g of force were measured (Table IV). This value characterized a soft product with a pleasant mouth feel. In both oven types used for reheating, an increase in baking time resulted in increased hardness. Short first and second baking times in a deck oven produced sponge cakes with the lowest hardness values. Hardness values four times higher than those of the standard product were achieved in products with long first and second baking times.

“Gumminess” describes the potential of a material for elastic recovery between two compression cycles. High values are associated with dense, rubbery characteristics, certainly not desirable in a product such as sponge cake (Fig. 6). Gumminess values were similar for both flour types and were independent of the duration of the first baking step. During the second baking step, gumminess increased with increasing duration of the treatment. Figure 6 clearly shows that high gumminess values were associated with microwaving. Gumminess values were significantly correlated with the hardness of the products (Table V).

Slope ratio was affected mainly by the duration of the first and second bake times (Fig. 7). Shorter bake times resulted in high values, and values decreased after longer baking times. Values of 2.2 for products with a short first bake time and a short reheating period in the deck oven indicated a break of the crumb during the first compression cycle. After the cylindrical probe was removed from the product, the imprint remained clearly visible where cell walls were disrupted, even though the compressed core of the product showed elastic recovery. Long reheating times in the microwave resulted in a value of 1.2, lower than that of the standard product. The force necessary to compress the crumb by 40% of its original height increased uniformly over the whole distance. After the probe was removed, only a small imprint remained visible and most of the cell walls remained intact.

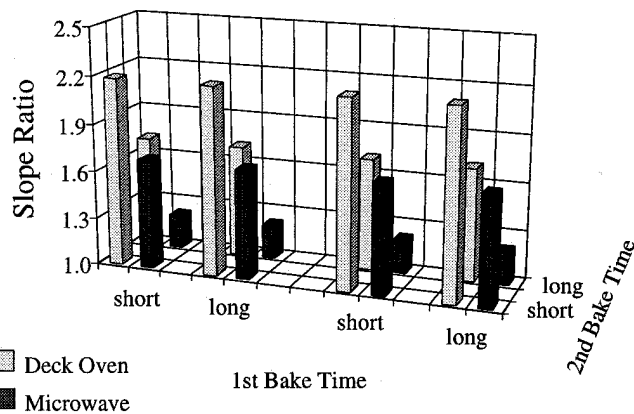


Fig. 7. Slope ratio of the crumb twice-baked sponge cakes. Left eight bars = Extra Strong flour; right eight bars = Hi Ratio flour.

TABLE V
Correlations Among Results for Twice-Baked Sponge Cakes^a

	Bake Loss	Specific Volume	L*	a*	b*	Hardness	Gumminess	Slope Ratio
Bake loss	1.00							
Specific volume	ns	1.00						
L*	-0.58**	ns	1.00					
a*	ns	0.78***	ns	1.00				
b*	ns	-0.56**	-0.77***	-0.63***	1.00			
Hardness	ns	-0.42*	n.s	ns	ns	1.00		
Gumminess	ns	-0.64***	ns	ns	ns	0.82***	1.00	
Slope ratio	ns	0.58**	ns	ns	ns	-0.83***	-0.99***	1.00

^a ns = not significant; *, **, and *** = 95, 99, and 99.9% significant, respectively.

CONCLUSIONS

The two-step baking procedure was successfully applied to products rich in egg and sugar. The optimized process reversed staling effects in these products to a large extent. Some of the products showed significantly improved characteristics compared with week-old products and achieved values similar to those of the fresh control product. The study showed that simply heating the products to a core temperature of 60°C alone was not sufficient to generate the same effect.

The first baking step should be long enough to result in an almost fully baked product. At this point, the crumb is stable enough to prevent volume loss through shrinkage after baking. Also, color development of the crust is complete. This is important because reheating in the microwave will not contribute to further color development and pale or discolored products would certainly be rejected by the consumer.

Microwave reheating of sponge cakes is a time-saving and therefore convenient alternative to rebaking in the deck oven. Characteristics commonly associated with microwave cooking, such as toughening of the crumb, necessitate a careful selection of the reheating parameter. For sponge cakes, reheating times have to be short to prevent deterioration in product quality. Advantages of microwave cooking are reduced water loss and extremely short preparation times.

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