SENSORY EVALUATION OF MICROWAVE TREATED MACARONI AND CHEESE

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Accepted for Publication May 6, 2002

ABSTRACT

A pilot-scale 915 MHz Microwave-Circulation Water Combination (MCWC) sterilization system was used to treat macaroni and cheese entrées prepared according to recipes selected to minimize treatment effects on sensory quality. Modifications to the traditional commercial boxed macaroni and cheese recipe included the selection of a noodle better suited for applications requiring prolonged heat treatments and the addition of twice the amount of cheese sauce to optimize heating uniformity. The MCWC system provided desired sterility (with a F_0 value of 7 min) within one fourth of the time required by conventional retort methods to produce shelf-stable products. Descriptive analysis was used to identify the quality attributes most significantly affected by MCWC processing. Formulation changes, such as noodle type and amount of cheese sauce present, affected the overall quality of MCWC treated macaroni and cheese entrées. Durum semolina noodles were superior to box-type noodles (a blend of durum and common wheat) in applications involving heat treatment. A consumer panel rated microwave treated macaroni and cheese as being acceptable when compared to freshly cooked controls.

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Journal of Food Processing and Preservation **26** (2002) 307-322.

INTRODUCTION

Intensive research has been conducted on the use of microwave energy in food processing applications since the Second World War (Meredith 1998). The unique electrical volumetric heating obtained through the interaction between dielectric materials and microwave radiation has been efficiently used in the food industry for thawing, continuous baking, and vacuum drying. It is also used for pasteurizing and, to a lesser extent, sterilizing prepackaged foods. A major challenge for food processors to effectively use microwave technology in food sterilization continues to be the nonuniform distribution of the microwave energy within the food products (Ayoub 1974; Ruello 1987; Schiffmann 1990; Stanford 1990; Keefer and Ball 1992). Discontinuous dielectric properties between food and the surrounding air cause reflection and refraction phenomena of the microwaves at the interface, resulting in nonuniform electric field distribution within the food and severe corner and edge heating (Ohlsson 1990).

Water immersion techniques (Stenstrom 1972; Ohlsson 1992; Lau 1998) and 915 MHz microwaves (Lau 1998) have been explored to reduce nonuniform heating. Studies using a chemical marker method have revealed that a 915 MHz Microwave-Circulation Water Combination (MCWC) heating system, designed to study the concept of microwave sterilization, provides a relatively uniform heat distribution within food products packaged both in pouches and trays (Lau 2000). Our earlier experiments with macaroni and cheese and scrambled eggs suggested that MCWC treatment reduced color degradation in those products through a relatively brief heat exposure compared with conventional retort treatments (Lau 2000).

The objectives of this study were to select macaroni and cheese formulations suitable for treatment by MCWC heating and to compare the sensory quality of products processed by MCWC with freshly cooked macaroni and cheese.

MATERIALS AND METHODS

Preparation of Macaroni and Cheese for Processing

Whole milk, margarine, and elbow-shaped 100% durum semolina noodles were purchased from a local grocery store. Box-type noodles (made from a combination of common and durum wheat) and cheese powder mix were supplied by Kraft Foods (Glenview, IL). The cheese powder mix contained some of the following ingredients: dairy product solids, flour, whey, salt, Cheddar cheese, butter, buttermilk, modified food starch, sodium phosphate, lactic acid, natural flavor, color (Yellow 5 and 6) and disodium phosphate. To prepare the macaroni and cheese, 166.1 g of dry noodles were placed in 1.5 L of boiling water and stirred occasionally during the selected cooking times. The box-type noodles were boiled

for either 8.5 min (fully cooked) or 4 min (precooking time prior to MCWC treatment) and the durum semolina noodles were either fully cooked for 12 min or precooked for 6 min. The noodles to be processed by MCWC were undercooked to reduce the adverse effect of overheating on product quality, especially texture, during the thermal treatment. After completion of the selected cooking time, the noodles were drained and immediately cooled with tap water. The cheese sauces were prepared separately by blending melted margarine, milk, and cheese powder mix together. Preliminary testing enabled formulations and sauce quantities for subsequent tests to be established. Three levels of cheese sauce, which led to minimal edge burning and appropriate hydration, were selected for MCWC treatment and sensory tests. The recipes used to prepare macaroni and cheese for sensory evaluation testing are shown in Table 1. To prepare the product for the thermal process, the cheese sauce and the boiled noodles were mixed into a tray and vacuum packed with nitrogen flushing. The dimensions and thickness of the tray (Polypropylene and EVOH, Rexam™, Union, MO) used for packaging were 10.0 cm x 14.0 cm x 2.5 cm and 0.3 mm, respectively.

Samples Evaluated

A popular commercial macaroni and cheese product was selected for analysis (Table 1). The boxed product (sample 4) was freshly prepared according to packaging instructions. Preliminary experiments indicated that the boxed product noodle integrity did not hold up (i.e., original cylindrical shape became flattened and deformed) under MCWC sterilization conditions, so an elbow-shaped 100% durum semolina noodle was selected for the remaining treatments (samples 1, 2, and 3). Sample 1 was also freshly prepared and identical to sample 4 except for noodle type. Samples 2 and 3 (labeled *2X*) contained twice as much cheese mix and milk as samples 1 and 4 (labeled *1X*). Sample 3 differed from sample 2 in that it contained additional hydration water and was MCWC treated.

MCWC Sterilization System

The 915 MHz MCWC sterilization system consisted of three major components: (1) a multiple-mode pressurized microwave heating vessel; (2) a 5 kW 915 MHz microwave generating system (Microdry Model IV-5 Industrial Microwave Generator, Microdry Inc., Crestwood, KY); and (3) a circulation water heating and cooling system (Fig. 1). The pressurized microwave heating vessel allowed treatment of a single meal tray at a time under certain pressure. The side wall of the pressurized microwave heating vessel was made of a section of cylindrical aluminum tube (23 cm in diameter and 5 cm tall). The top and bottom plates were made of Tempalux materials (Ultem Polyetherimide Resin, Lenni, PA). The two plates had a high melting temperature (above 150C) and were transparent

TABLE 1.
RECIPES FOR MACARONI AND CHEESE ENTRÉES PREPARED FOR SENSORY EVALUATION

Sample No.	Treatment	Preparation Method	Recipe[a]	Boiling Time
1	1X Semolina	Freshly prepared	62.0 g milk 39.5 g cheese mix	12 min[b]
2	2X Semolina	Freshly prepared	124.0 g milk 79.0 g cheese mix	12 min[b]
3	2X-MW Semolina	Microwave treated and heated in tray[d]	124.0 g milk 79.0 g cheese mix 88.0 g hydration water	6 min[c]
4	1X Boxed	Freshly prepared	62.0 g milk 39.5 g cheese mix	8.5 min[b]

[a]All macaroni and cheese products contain 166.1 g of noodles (either semolina or box-type) and 36.9 g of margarine.
[b]Boiling time required to cook noodles thoroughly.
[c]Noodle boiling time prior to MCWC treatment (precooking time).
[d]Tray was heated to 60C in a water bath.

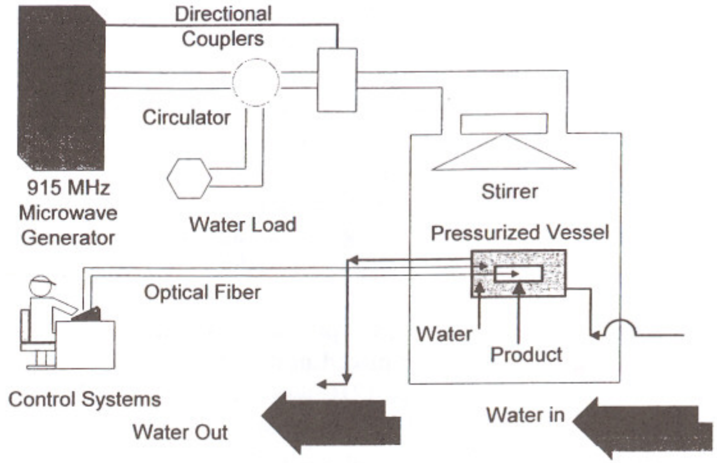

FIG. 1. SCHEMATIC DIAGRAM OF THE MICROWAVE AND CIRCULATION-WATER CONTROL SYSTEMS

to microwaves. An appropriate pressure (30~35 psig) was maintained within the vessel to ensure the integrity of the food during the thermal process. Fittings were provided to allow for continuous pressure and temperature measurements and for concurrent circulation of water for heating and cooling. The 915 MHz microwave system was equipped with a circulator to protect the microwave generator from heating damage caused by reflected power, and a directional coupler with appropriate sensors to measure forward and reflected power. The output microwave power could be adjusted between 0.2 and 5 kW by regulating anode current to the magnetron. The temperature of the circulating water for in-line heating or cooling of the food package was measured with a computer program (Think & Do™, Cumming, GA). This program controlled modulating valves for two plate heat exchangers heated and cooled with steam and tap water, respectively.

MCWC and Conventional Sterilization Procedures

The major advantage of microwave energy is its fast heating due to the direct coupling of microwave energy into dielectric materials to generate heat. But in many cases, adequate processing time is needed to reduce target microorganism load, to obtain a desired F_0 value, or to allow certain chemical reactions such as browning to occur (Schiffmann 1986, 1997). Product heating can be controlled by the appropriate selection of microwave power. In this study, 1.0 kW microwave power was used to allow a relatively short process time (5 min) and a certain degree of thermal conduction to reduce possible uneven heating.

Since smaller temperature differences between the starting and the desired temperature (127C) resulted in lower consumption of microwave energy, all products were preheated with circulation water from ambient temperature to 75C prior to starting the microwave generator. After the product reached the desired temperature, the microwave system was turned off, followed by a 30 s holding period. Tap water at 20C was circulated to cool the product until the center of the sample reached 80C, at which point the product could be reintroduced to atmospheric pressure without damaging the package. The product was removed from the pressurized microwave heating vessel and immediately placed into an ice-water bath.

For conventional retort heating, the product was packaged in the same trays used for the MWCW process and placed in the pressurized microwave heating vessel, but only circulating water at 121C was used to treat the sample under the same over-pressure used for the MWCW process. The processing time was about 40 min to provide a F_0 value of 7.

Both the circulation water temperature and the cold spot temperature of the product were measured using optical fiber sensors (Fiso Technologies, Sainte-Foy, Canada). For the MCWC treatment, the location of the cold spot, 2.3 cm off the geometric center of the tray, was determined by a chemical marker technique used in preliminary experiments (Lau 2000), while the cold spot during conventional retort heating is located at the geometric center of the tray (Lopez 1987). By monitoring the product temperature through the data acquisition program, an integrated sterilizing value (F_0) using the General Method was calculated (Lopez 1987):

$$F_0 = \int_0^t 10^{(T-T_r)/z}\, dt \ , \qquad (1)$$

where F_0 is the sterilizing value (min), T is the actual temperature of the product (°C), T_r is the reference temperature 121.1C, the z-value is 10C, and t is heating time (min).

Sensory Evaluation

MCWC treated macaroni and cheeses were evaluated and compared to freshly made product by both a trained panel (n=10) and an acceptance panel (n=115) within two days of being processed. Participation in this study was voluntary and judges were compensated for their time. All panelists signed a Washington State University (WSU) human subject approval form prior to the evaluation and completed a questionnaire regarding frequency of consumption, buying interests and demographic information. Four different treatments (one MCWC treated and three freshly made controls, Table 1) were evaluated by both panels in duplicate. Tasting sessions were spread over three different days to prevent errors due to sensory fatigue. Consumer panelists were encouraged but not required to participate in each of the sessions; trained panelists attended all three sessions. The macaroni and cheeses were placed in clear glass containers that were held for no more than 30 min in a 65C water bath. Freshly prepared macaroni and cheese was cooked approximately every 30 min and placed in identical jars for serving. All evaluations took place in individual booths equipped with incandescent lighting. Panelists were encouraged to drink water in between samples to cleanse their palates. The samples were labeled with randomly generated three-digit codes and presented one at a time using a randomized complete block design with repeated measures. Some imbalance may have occurred due to the fact that not all samples were tested on each day by every person.

Descriptive analysis (Stone and Sidel 1992) was used to describe the qualitative and quantitative characteristics of the selected macaroni and cheese treatments. Judges with previous experience in sensory evaluation were chosen among WSU employees and students. They were trained in six sessions to discuss and select a list of descriptors to characterize the appearance, aroma, flavor and texture attributes of the macaroni and cheese samples. They also defined a standard evaluation procedure using a 9-point scale. Performance evaluation was initiated after the first three training sessions had been completed to identify problems among individual panelists or misunderstandings in the use of the descriptive terminology.

Faculty, staff and student volunteers with or without previous experience in sensory evaluation participated in one or more of three consumer-panel sessions. Panelists were asked to indicate their perception of appearance, aroma, flavor, texture and overall acceptance for each of the samples tested using a 9-point hedonic scale. Space for comments was provided on the evaluation ballots.

Statistical Analysis

Mean scores were analyzed with an analysis of variance (ANOVA) based upon a randomized complete block (panelists) design with two repeated measures for each panelist. Trained and untrained panelists were the units of replication and panelists were treated as random effects. Differences were considered significant when resultant P-values were <0.05 (SAS/STAT® 1989). When the ANOVA was significant, the Least Significant Difference (LSD) method was used to separate treatment means.

RESULTS AND DISCUSSION

Effect of MCWC and Conventional Retort Heating on Processing Time

Figure 2 shows the temperature profiles of *2X*-sauce macaroni and cheese entrées during MCWC and conventional retort sterilization conditions. The corresponding integrated sterilizing values (F_0) were very close to 7 min. Under MCWC heating, the product reached 129.1C within 8 min, while it took more than 35 min for the same product to reach 119.1C under conventional retort heating. Preliminary test indicated the shorter processing time of the MCWC treatment led to considerable reductions in color degradation and loss of texture and flavor quality. The difference in quality obtained with the two heating methods was extreme. Upon visual inspection, the researchers agreed that the poor quality obtained by conventional retort method made it unnecessary to include this sample in the sensory evaluation protocol. Compared to the microwaved product, the

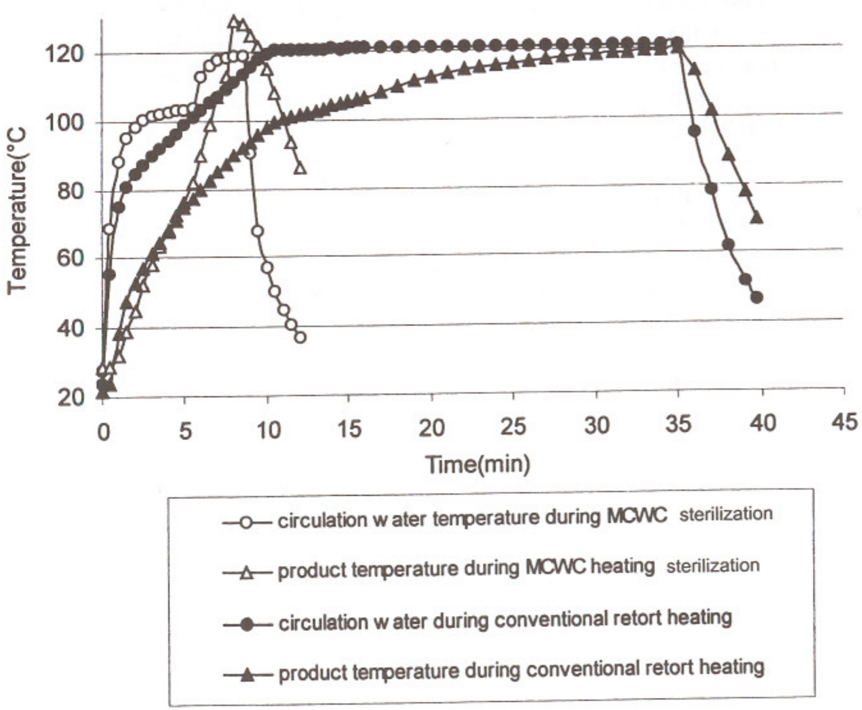

FIG. 2. TYPICAL TEMPERATURE HISTORY OF MACARONI AND CHEESE AND CIRCULATED WATER DURING MCWC AND CONVENTIONAL RETORT HEATING

retorted macaroni and cheese was darker throughout the tray, had severely burnt edges and appeared extremely dry. For this reason, only MCWC treated samples were tested and compared with freshly cooked macaroni and cheese controls.

Effect of Product Formulation on Heating History

Figure 3 shows representative temperature profiles of two macaroni and cheese entrées treated by MCWC heating at a fixed microwave power of 0.5 kW. During preliminary experiments, additional cheese sauce or cheese powder mix and thickeners or stabilizers, such as instant starches and gums, were added to the macaroni and cheese formula for MCWC treatment. In microwave sterilization, the ability of materials to absorb electromagnetic energy depends to a great extent on the dielectric properties of the product being heated (Buffler and Stanford 1991; Thostenson and Chou 1999), which mainly depend on moisture and salt contents (Mudget 1986). The change in formulation did affect the moisture and salt content of the product, however, due to the relatively small size of the tray, the change in dielectric properties was compensated for by the heating provided by the circulation water. As shown in Fig. 3, the change of formulation had no significant effect on the MCWC heating history at similar F_0 levels, but its impact on the sensory quality of the final product was considerable (Table 2).

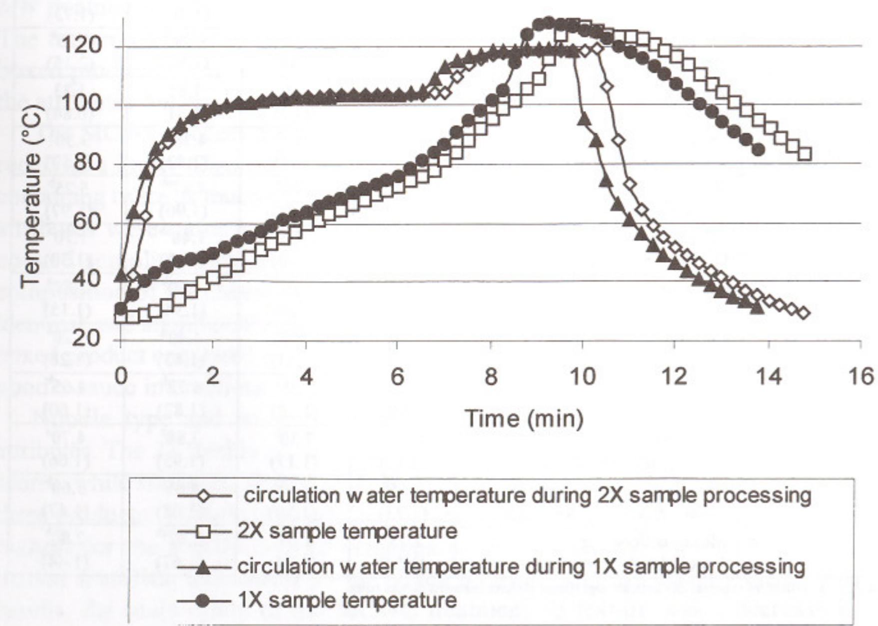

FIG. 3. REPRESENTATIVE TEMPERATURE PROFILES OF TWO MACARONI AND CHEESE ENTRÉES DURING MCWC TREATMENT

TABLE 2.
MEAN SCORES OF SELECTED MACARONI AND CHEESE QUALITY ATTRIBUTES JUDGED BY A TRAINED PANEL (N=10)

Category	Attribute	1X Semolina	2X Semolina	2X-MW Semolina	1X Boxed
Appearance	Noodle Integrity 1=deformed/flat, 9=round	6.20^{bc} (1.64)	6.60^{c} (1.57)	5.69^{b} (1.90)	4.15^{a} (1.98)
	Adhesiveness 1=loose, 9=solid/gelatinous	2.90^{a} (1.33)	2.60^{a} (1.31)	4.62^{b} (1.93)	4.20^{b} (1.64)
	Shine 1=dull, 9=shiny	5.55^{c} (1.82)	6.80^{d} (1.51)	3.17^{a} (1.12)	4.30^{b} (1.53)
	Color 1=yellow, 9=brownish	4.47^{b} (1.22)	4.50^{b} (0.83)	5.20^{c} (0.83)	3.30^{a} (0.98)
	Amt. ofSauce 1=none/lacking, 9=excess	4.30^{a} (2.06)	6.40^{b} (1.35)	3.50^{a} (1.46)	3.60^{a} (1.23)
	Smoothness of Sauce 1=curdled, 9=smooth/creamy	5.75^{b} (2.10)	6.55^{c} (1.43)	1.83^{a} (0.65)	3.85^{b} (1.63)
Flavor	Cheddar Flavor 1=bland, 9=strong/sharp	3.85^{b} (1.69)	5.85^{c} (1.73)	5.15^{c} (1.70)	2.45^{a} (1.15)
	Buttery 1=slight, 9=definite	5.85 (1.76)	5.20 (1.74)	4.63 (1.80)	4.65 (1.73)
	Starchy Flavor 1=none/slight, 9=definite	4.05^{ab} (2.26)	3.05^{a} (1.60)	3.79^{ab} (1.84)	5.25^{b} (2.15)
	Off-Flavor 1=none/slight, 9=definite	1.37 (0.90)	1.50 (0.80)	1.85 (1.61)	1.33 (0.84)
Aroma	Cheddar Aroma 1=none/faint, 9=strong	5.00^{b} (1.49)	5.40^{b} (1.47)	4.38^{ab} (1.82)	3.30^{a} (1.59)
	Starch Aroma 1=none/faint, 9=strong	4.10^{ab} (1.74)	3.90^{a} (1.48)	4.87^{ab} (1.90)	5.25^{b} (1.97)
	Off-Aroma 1=none/faint, 9=strong	1.20^{ab} (0.70)	1.00^{a} (0.00)	1.48^{ab} (1.18)	1.70^{b} (1.30)
Texture	Firmness 1=soft/mushy, 9=firm/al dente	6.85^{c} (1.35)	6.10^{c} (1.25)	4.60^{b} (1.34)	2.80^{a} (1.15)
	Chewiness 1=soft, 9=chewy/rubbery	6.40^{c} (1.14)	5.60^{c} (1.43)	4.40^{b} (1.43)	3.20^{a} (1.28)
	Stickiness 1=slippery, 9=sticky	4.60^{b} (2.19)	3.25^{a} (1.52)	4.72^{b} (1.82)	4.65^{b} (1.60)
	Moistness 1=dry/none, 9=moist/juicy	4.55^{a} (2.11)	7.30^{b} (1.17)	3.88^{a} (1.95)	4.70^{a} (1.66)
	Graininess 1=smooth/creamy, 9=grainy	3.65^{b} (1.73)	2.60^{a} (1.50)	4.65^{c} (1.68)	3.60^{b} (1.47)
	Mouthfeel/coating 1=none/slight, 9=definite	2.75^{b} (1.52)	1.85^{a} (1.24)	2.67^{ab} (1.67)	2.80^{b} (1.44)

a, b, c, d: Different superscripts indicate significant differences exist across rows.

Sensory Evaluation

Trained Panel. Mean scores for selected aroma, appearance, flavor and texture attributes given by a trained panel are presented in Table 2. The scores were significantly different for most of the attributes evaluated.

The amount of cheese sauce in each recipe had a direct impact on *shine*, *amount of sauce* and *smoothness of sauce*, as indicated by the significantly higher scores given to the freshly cooked *2X*-Semolina sample compared to the two *1X* samples for those attributes. In addition, when more free cheese sauce was present in the final product, better *noodle integrity* was noted, and vice versa. Likewise, noodle type had an effect on *noodle integrity* and on *color*. Specifically, the semolina samples scored consistently higher for *noodle integrity* and were darker than the boxed product. The appearance attributes most affected by MCWC processing were *noodle integrity* (initial cylindrical shape became flattened), *adhesiveness* (noodles tended to stick to each other), *shine* (product appeared more dull), *color* (became darker), and *smoothness of sauce* (appeared somewhat curdled). The amount of free cheese sauce present was lower in the MCWC treated sample than in the rest of the samples due to greater water absorption during the extra processing time.

As expected, *Cheddar flavor* was highest for the freshly cooked *2X* and the *2X-MW* treatments since the amount of cheese powder mix in the sauce was doubled. The trained panel also identified *starch flavor* as being more pronounced in the boxed product, but no significant differences between treatments were found for the attributes *buttery* and *off-flavor*.

The MCWC process had a negative impact on aroma, since the *2X-MW* sample received a lower *Cheddar aroma* score than the *1X*-Semolina sample in spite of containing twice as much cheese as the *1X* sample. Both the *starch* and *off-aroma* attributes were more intense in the MCWC treated sample than in the freshly cooked semolina samples, but not as high as in the boxed product. Since the composition of the cheese sauce in the boxed and the *1X-S*emolina products was identical, and significantly lower flavor and aroma scores were associated with the boxed product compared to *1X-S*emolina, either the type of noodle used or adverse noodle-sauce interactions explain the differences.

Noodle type and amount of cheese sauce present also influenced texture attributes. The *2X* freshly cooked semolina sample received the highest *moistness* scores, while *stickiness* and *graininess* were significantly lower than for the other three products. Noodle type affected *firmness* and *chewiness* scores, which were highest for the freshly cooked semolina samples, followed by the microwave treated semolina, and lowest for the boxed product. As illustrated by the texture results, the main effect of the MCWC treatment on texture was a decrease in *firmness* and *chewiness*, and an increase in *graininess* felt on the roof of the mouth while chewing.

Consumer Panel. Table 3 shows the mean acceptability scores given to the selected macaroni and cheese entrées by a consumer panel. On average, consumer responses fell within the range of 5.0 (*neither like nor dislike)* to about 7.0 (*like moderately*). Overall acceptance scores for the different macaroni and cheese treatments were *like moderately* for *2X*-Semolina, *like slightly* for *1X*-Semolina and *2X-MW* Semolina, and *neither like nor dislike* for *1X* Boxed. Highest scores were consistently given to the *2X*-Semolina sample for all attributes.

The appearance of the *1X*-Semolina and *2X-MW* Semolina samples were rated significantly higher than the boxed product, but not as high as *2X*-Semolina, suggesting a consumer preference for the elbow noodle, which was more plump than the boxed noodle, and for extra cheese sauce. The appearance attributes that might have contributed the most to higher consumer acceptability for the *2X*-Semolina sample and a lower acceptability for the boxed product are *noodle integrity* and *amount of sauce*.

A comparison of consumer and trained data shows a direct correlation between consumer flavor acceptability scores and the trained attribute *Cheddar flavor*. Low *starch flavor* also correlated well with flavor acceptability. Consumer acceptability scores for the freshly prepared and MCWC treated products (*2X* and *2X-MW* semolina, respectively) did not differ significantly, indicating that MCWC processing did not adversely affect flavor. In terms of aroma, a correlation between amount of cheese present and consumer acceptability was not observed, since the *2X-MW* Semolina product received the lowest aroma acceptability score of the four samples studied, in spite of containing additional cheese. The effect of specific aroma attributes identified by the trained panel (*Cheddar*, *starch-* and *off-aroma*) on consumer acceptability was not clear. As shown in Table 2, the freshly cooked boxed product received the lowest *Cheddar aroma* and highest *starch-* and *off-aroma* scores. However, consumer aroma acceptability scores for the microwave treated macaroni and cheese were significantly lower than for the boxed product, suggesting there might have been a change in aroma during MCWC processing that was not detected by the trained panel. Alternatively, the consumer panelists may have detected an aroma attribute that did not fit into any of the aroma descriptors developed by the trained panel.

The higher texture scores given to the two freshly cooked semolina noodle samples (*2X* and *1X* semolina) than to the boxed product also indicate a preference for the firmer semolina noodle over the noodle typically used in boxed macaroni and cheese. Likewise, higher texture scores for the *2X* over the *1X* semolina samples further confirm a consumer preference for extra cheese sauce. The additional cooking time required for MCWC treatment had an adverse effect on texture quality, as shown by the significantly different texture scores for the *2X* and *2X-MW* semolina samples (Table 3). But in spite of the microwave treatment, the *2X-MW* and the freshly cooked boxed products received similar texture scores, demonstrating the superiority of durum wheat over common wheat for noodle

TABLE 3.
MEAN ACCEPTABILITY SCORES[a] OF MACARONI AND CHEESE BY AN UNTRAINED CONSUMER PANEL (N=115)

Attribute	1X Semolina (sample 1)	2X Semolina (sample 2)	2X-MW Semolina (sample 3)	1X Boxed (sample 4)
Appearance	5.65^c	6.73^d	5.81^c	5.08^b
Aroma	6.41^c	6.96^d	5.24^b	6.01^c
Flavor	5.03^b	5.90^c	5.74^c	4.95^b
Texture	6.67^c	7.38^d	6.22^b	6.15^b
Overall	5.86^b	6.76^c	5.69^b	5.42^b

a: 1=highly unacceptable; 9=highly acceptable
b, c, d: Different superscripts indicate significant differences exist across rows.

manufacture in applications involving severe heat treatment, such as in a ready-to-eat, shelf-stable macaroni and cheese. *Firmness* and *chewiness*, which scored significantly higher for *1X* and *2X* freshly cooked Semolina, were the predominant attributes responsible for the higher consumer acceptability scores received by the macaroni and cheese made with elbow-shaped semolina noodles.

The consumer population sampled was composed of 87-93% who consume macaroni and cheese (mainly boxed-type) at least once per month, suggesting familiarity with the product presented. Therefore, it is safe to extrapolate these data to macaroni and cheese consumers at large. No correlation between frequency of consumption and buying interest was observed. When questioned after tasting the macaroni and cheese, the majority (73%) of the respondents indicated they were at least *somewhat likely* to buy a ready-to-eat, shelf-stable macaroni and cheese, with 9% who were *very likely* to do so.

CONCLUSIONS

The MCWC system heat-treated macaroni and cheese entrées within one fourth of time required by conventional retort methods to attain the same sterility (F_0 value with 7 min). Changes in formulation, such as amount of cheese sauce and noodle type, affected the quality and acceptability of MCWC treated macaroni and cheese entrées. Although the MCWC treated product received lower mean consumer acceptability scores than freshly cooked products made with the same noodle type and cheese sauce, the MCWC entrées received higher scores than a popular boxed macaroni and cheese. Combined with consumers' indication of willingness to purchase shelf-stable macaroni and cheese, these findings show the potential for success of MCWC process.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support provided by the U.S. Army Soldier Support Center and Kraft Foods. We would also like to thank Dr. Marc Evans for statistical guidance, and Frank Younce of WSU, Evan Turek and Dr. Ming H. Lau of Kraft Foods, Glenview, IL, for their technical advice and assistance. The students and university employees, especially Dr. Lloyd Luedecke, Xiaoming Liu, and Lisa Pitka, were appreciated for their help during the tasting sessions.

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