# Optimal Composition and Heat Processing Requirements for Canning of Eggplant Dip (Motabbal Al-bathinjan)

Sharaf S. OMAR[1], Ziad A. ABDULLAH[2], Mohammad A. HUMEID[2] and Mohammad I. YAMANI[2]

[1]Department of Nutrition and Food Processing, Al-Balqa Applied University, Salt, Jordan;
[2]Department of Nutrition and Food Technology, University of Jordan, Amman, Jordan

**Abstract**

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Twenty formulas of eggplant dip, motabbal al-bathinjan in Arabic (MB), using different percentages of grilled eggplant, tahina (sesame pulp), and yogurt with constant levels of salt and citric acid were prepared and evaluated for the overall acceptability. The formula composed of 84.2% pulp of peeled grilled eggplant and 14% tahina without the addition of yogurt was found the most acceptable. The cold point of the canned MB was found to be in the geometric centre of the can. Canning of MB was conducted using three time/temperature combinations at the centre (80°C/5 min, 85°C/4 min, and 90°C/3 min). It was found that all heat-processes applied resulted in a commercially sterile canned MB with a high sensorial quality, as evidenced by the results of microbiological examinations, incubation tests, and sensory evaluation. Based on *Bacillus coagulans*, that may grow and cause flat sour spoilage of canned MB, the sterilisation value ($F_{100}$) was estimated of the whole heat-process from the filling till cooling to about 70°C.

**Keywords**: *Solanum melongena* L.; eggplant dip; thermal processing; microbial quality; sensory evaluation

Eggplant, *Solanum melongena* L. (Bathinjan in Arabic) is consumed in the Middle East as an ingredient in many dishes. Eggplant dip (motabbal al-bathinjan – MB), which will be referred to as MB in this study, is considered as one of the most desired traditional local appetising dishes. It is prepared at homes and restaurants as an appetising nutritive meal by grilling whole eggplant fruits that are then peeled and the resulting flesh is cut and blended with tahina (sesame pulp), lemon juice (or citric acid), and salt. The overheating of eggplant peel during grilling of eggplant fruits (that is traditionally done on opened fire) gives the pulp and consequently MB its desirable smoky flavour. The added tahina improves the taste and nutritional value and acts as a binder for the mixture. Yogurt and garlic may be added to the mixture according to consumer preference. The resulting dip is spread into dishes and olive oil is added onto the surface with some parsley before serving with bread.

When produced in restaurants, MB is manufactured without controlling its pH value that mostly exceeds 4.6, which is classified as a low acid food in that case. Moreover, it is not always kept under refrigeration but sometimes it is held at room temperature for several hours. During this period and due to the production under low hygienic conditions, high numbers of microorganisms are expected to be present in the product. Yamani (1998) found that the average lactic acid bacteria count of MB was $2.6 \times 10^6$ CFU/g. Such a high number can play a role in the spoilage of the product. In countries other than Jordan, MB has been produced and preserved commercially in

plastic containers without heat processing and is sold refrigerated, however, this method requires the addition of some chemical preservatives. Canning is another method for preservation, which is already applied in some neighbouring countries.

Several studies were conducted to determine heat-processing requirements for a number of canned foods. However, no studies have been published that were carried out in view of optimal composition and heat processing requirements for MB canning. This research is aimed at developing a highly acceptable formula of MB with a pH value lower than 4.5 and studying heat-processing requirements needed for commercial sterility and their effects on the sensory properties of the product.

## MATERIAL AND METHODS

### Testing the suitable level of salt and citric acid in MB

MB recipes were followed according to Rayess (1982), but using different levels of salt/citric acid (0.8/0.4%, 1.2/0.6%, and 1.6/0.8%) to find out their suitable concentrations in the product, and to rule out extreme saltiness and sourness that might affect the judgment of panelists in the planned formulas. The prepared samples were tasted and evaluated organoleptically for saltiness and sourness by five expert panelists. The acceptable levels of both salt and citric acid were selected to be used in all formulas that would be prepared later.

pH was measured at room temperature (AOAC 1995) using a pH-meter (WTW, Weilheim, Germany) by suspending 10 g of the product with 7 ml of distilled water, then immersing the electrode of the pH-meter into the suspension, and reading pH value after a minute.

### Selection of optimal formula

***Formulas of MB***. Twenty formulas of MB were proposed (Table 1). The formulas differed in the percentages (w/w) of peeled grilled eggplant, tahina, and yogurt, while the percentages of the other two ingredients (salt and citric acid) remained constant in all formulas, being 1.2% and 0.6%, respectively. For the sensory evaluation purposes with the use of the nine-point hedonic scale test, the twenty formulas were randomly distributed into five groups, each consisting of four formulas prepared within two hours and evaluated as fresh on the same day (Table 2).

Table 1. Proposed formulas of MB with constant salt and citric acid percentage of 1.2% and 0.6%, respectively

| Formula No. | Percentage (w/w) | | |
|---|---|---|---|
| | peeled grilled eggplant | tahina | yogurt |
| 1 | 88.2 | 10 | 0 |
| 2 | 84.2 | 10 | 4 |
| 3 | 82.2 | 10 | 6 |
| 4 | 80.2 | 10 | 8 |
| 5 | 86.2 | 12 | 0 |
| 6 | 82.2 | 12 | 4 |
| 7 | 80.2 | 12 | 6 |
| 8 | 78.2 | 12 | 8 |
| 9 | 84.2 | 14 | 0 |
| 10 | 80.2 | 14 | 4 |
| 11 | 78.2 | 14 | 6 |
| 12 | 76.2 | 14 | 8 |
| 13 | 82.2 | 16 | 0 |
| 14 | 78.2 | 16 | 4 |
| 15 | 76.2 | 16 | 6 |
| 16 | 74.2 | 16 | 8 |
| 17 | 80.2 | 18 | 0 |
| 18 | 76.2 | 18 | 4 |
| 19 | 74.2 | 18 | 6 |
| 20 | 72.2 | 18 | 8 |

***Preparation of MB***. Known weights of eggplant fruits were grilled in a gas oven at 250°C for 30 min after making slits in the fruits to prevent the explosion and to facilitate evaporation. Eggplant fruits were turned over inside the oven after 15 min of grilling. The grilled eggplant fruits were left to cool and then peeled manually under the practical hygienic conditions. The flesh was weighed and the yield percentage was calculated as follows:

$$\text{Yield (\%)} = \frac{\text{Flesh weight (g)}}{\text{Raw eggplant fruits eight (g)}} \times 100$$

One-kg portions of MB were prepared by blending the ingredients in a multi-speed blender for 3–4 min at a medium speed, which resulted in a pasty mixture. The preparations were tested for pH and cooled to 15°C in refrigerator before they were introduced to panelists for sensory evaluation.

***Sensory evaluation of freshly-prepared MB***. MB preparations were introduced to untrained panelists from the staff and master students of Nutrition and Food Technology Department at the University of Jordan. The sample temperature was around 15°C when introduced to the panelists who were asked to evaluate the overall acceptability of each sample using a nine-point hedonic scale test (Patterson *et al*. 2004).

***Statistical analysis***. The results of the sensory tests were analysed by conducting the analysis of variance (Bower 1995) using a randomised complete block design (RCBD). The differences between the means were tested using Duncan's Multiple Range test at a level of significance $P \leq 0.05$.

## Cold point determination

Cans (73 mm × 103 mm) made from tinplate enameled with a double layer of aluminum pigmented epoxyphenolic enamel were used for the canning experiments. The cold point inside the cans filled with MB at room temperature was determined by placing a type K probe in the geometric center, and 19 mm above the center of the can bottom (Lopez 1987; Rangana 2001). Heating was conducted in a still vertical steam retort (Dixie Steam Retort No. 3, Athens, USA). The probe was fitted to the can body and connected by thermocouple wire to a digital temperature recorder (CIE 305, Italy) from which the temperature of each point was read and recorded every minute. Each selected point was tested for cold point separately from the others. The point of the slowest heating rate was considered the cold point.

## Canning of the most acceptable formula

Batches of the most acceptable formula of MB were prepared as mentioned earlier, heated in a boiling water bath to 70 ± 1°C, promptly manually filled into warmed cans, leaving a net head space of 10 mm, and hermetically double seamed (Dixie Can Seamer 23; Athens, USA). The cans were heat-processed in a vertical position in a still vertical steam retort. The retort cover was not hermetically closed and the steam inlet was controlled manually to keep the retort temperature at 97°C. Heat processing was conducted sufficiently enough for the cold point temperature of the canned product to reach 80°C, 85°C, and 90°C for 5, 4, and 3 min, respectively. The cans were then immediately cooled in water bath to about 40°C. The temperature in the cold point was monitored and recorded during processing and cooling.

A fresh MB sample and three canned processed samples of the most acceptable formula were introduced to 15 untrained panelists to evaluate the flavour, colour, and overall acceptability as mentioned earlier. pH values of the MB samples were measured before the processing and directly after cooling, and subsequently after one month storage at room temperature.

***Incubation test***. The cans were stored at room temperature (24 ± 3°C) for 5 months, at 35°C for 15 days, and at 45°C for 7 days. The cans were tested for swelling, and the product was tested organoleptically for undesirable changes, and also pH was measured. As a control, fresh MB samples without any heat treatment were filled in cans, hermetically sealed, stored at room temperature, and monitored for swelling.

***Microbiological examinations***. MB samples were examined microbiologically before processing and directly after cooling, and after one-month storage at room temperature. Following the procedures of FDA (1992), direct microscopic examinations of freshly prepared samples of MB and of swollen control cans were conducted. For aerobic plate count, pour plate technique was applied using aerobic plate count agar. Duplicate plates were incubated at 32°C for 48 hours. For yeasts and molds counts, pour plate technique was applied using aerobic plate count agar containing 100 mg/l each of chloramphenicol and chlortetracycline. The duplicate plates were incubated at 25°C for 3–5 days. For coliforms count, pour plate technique was applied using violet red bile agar (VRBA). The duplicate plates were incubated at 32°C for 24 hours.

***Sensory evaluation***. After one and five-month storage at room temperature, the canned MB samples were introduced to 15 untrained panelists to evaluate the flavour, colour, and overall acceptability as mentioned earlier.

***Measurement of viscosity***. The viscosity (in centipoises) of fresh and processed samples of MB was determined at 25°C (Brookfield DV-I++ viscometer; Middleboro, USA) using LV spindle No. 4 at 30 rpm. The viscosity results were analysed statistically and the differences means were

tested as mentioned earlier but using Complete Randomised Block design (CRD).

***Proximate analysis***. The canned samples of the most acceptable formula of MB were analysed in duplicates for their proximate composition following AOAC (1995).

### Canning of commercial MB samples prepared by a local restaurant

Samples of MB prepared locally by four restaurants were collected and tested microbiologically (aerobic plate count, yeast and moulds count, and coliforms count). One of these samples was canned and heat-processed as mentioned earlier after adjusting its pH to 4.1 by adding citric acid. The sample was tested microbiologically before and directly after the processing, and after one-month storage at room temperature. The cans were also incubated at 35°C for 15 days and at 45°C for 7 days.

### Calculation of lethal rates for canned MB

The temperature of cold point from the filling until the first stages of cooling was recorded each minute. For each recorded temperature, the lethal rate ($L$), which is also referred to as $F_o/t$, or the sterilisation value effective in one minute ($F_{100}$), was calculated for *Bacillus coagulans* using the following equation:

$$L = \frac{\log^{-1}[T - T_{ref}]}{Z}$$

where:

$T$ – any center temperature

$T_{ref}$ – reference temperature (Rees & Bettison 1991). The reference temperature used in the calculations was 100°C since the processing temperature did not exceed 100°C

$Z$ – Z-value (15°C) for *B. coagulans* obtained by York *et al*. (1975)

Using the total effective lethal rates or the simplified summation procedure (Patashnik 1953), sterilisation value $F_{100}$ of the whole process including the cooling period was estimated by adding up lethal rates ($L$) of each minute. The number of decimal destructions in the survival population (#D) of *B. coagulans* was then obtained by dividing the resulting $F_{100}$ value by 0.53, which represents the minutes required to kill 90% (one log cycle, 1D) of *B. coagulans* at 100°C ($D_{100}$ = 0.53) as obtained by York *et al*. (1975).

## RESULTS AND DISCUSSION

### Suitable levels of salt and citric acid

The levels of 1.2% salt and of 0.6% citric acid in MB were found as the most suitable. With these levels and regardless of the formula used, pH value ranged from 4.0 to 4.2, indicating that MB is considered an acid food product (Lopez 1987) and may be processed safely at 100°C or less (FDA 1998). This narrow pH range is indicative of the buffering characteristic of the product, which included proteins stemming mainly from tahina.

### Selection of the most acceptable formula

Yield percentage of flesh after grilling and peeling of eggplant fruits ranged from 35% to 41% with an average of 37.8%. This low yield percentage was due to the evaporation of large amounts of moisture during grilling in the oven and to the removal of peels of eggplant fruits after grilling. pH values of the twenty prepared formulas of MB shown in Table 2 were close to one another with a difference of 0.09 between the highest and lowest pH values.

Table 2 shows the mean scores of the overall acceptability of the twenty freshly prepared formulas of MB. It can be noticed in the table that formula No. 9 had the highest score (7.86), which is significantly different from all other formulas. According to the nine-point hedonic scale, all formulas were considered acceptable since each score fell between "like slightly" and "like moderately". Formula No. 9 was chosen for the next canning experiment. It can be also noticed that there were no significant differences between the formulas with or without yogurt with the same percentage of tahina except for formula No. 9, which was superior to all other formulas and was prepared without yogurt. This indicates that the addition of yogurt did not positively affect the overall acceptability of MB. However, the use of yogurt would cause an improvement in the protein quality of

Table 2. Means* of overall acceptability scores and pH values of twenty fresh formulas of MB

| Formula No. | Group | PH value | Overall acceptability |
|---|---|---|---|
| 1 | A | 4.08 | 6.66$^{bc}$ |
| 2 | B | 4.07 | 7.00$^{bc}$ |
| 3 | C | 4.07 | 7.13$^{b}$ |
| 4 | D | 4.09 | 7.06$^{b}$ |
| 5 | E | 4.10 | 7.13$^{b}$ |
| 6 | A | 4.10 | 7.26$^{b}$ |
| 7 | B | 4.09 | 7.20$^{b}$ |
| 8 | C | 4.10 | 7.13$^{b}$ |
| 9 | D | 4.10 | 7.86$^{a}$ |
| 10 | E | 4.12 | 7.13$^{b}$ |
| 11 | A | 4.09 | 6.73$^{bc}$ |
| 12 | B | 4.10 | 6.86$^{bc}$ |
| 13 | C | 4.10 | 7.13$^{b}$ |
| 14 | D | 4.12 | 7.20$^{b}$ |
| 15 | E | 4.11 | 7.00$^{bc}$ |
| 16 | A | 4.12 | 6.66$^{bc}$ |
| 17 | B | 4.16 | 6.66$^{bc}$ |
| 18 | C | 4.13 | 6.60$^{bc}$ |
| 19 | D | 4.15 | 6.53$^{bc}$ |
| 20 | E | 4.15 | 6.33$^{c}$ |

*means of $n$ = 15, where score 1 refers to dislike extremely and 9 to like extremely in the nine-point hedonic scale

$^{a–c}$means followed by the same letter do not differ significantly (Duncan's Multiple Range test at $P \leq 0.05$)

the product as a result of complementing milk and sesame proteins.

### Cold point of MB cans

Figure 1 shows that the point of the slowest heating rate is the geometric center of the can, which means that heat is transferred through the container and its contents by conduction.

### Sensory evaluation of the canned most acceptable formula

As shown in Table 3, all tested samples were considered acceptable since all scores fell between "like moderately" and "like very much" (i.e. 7 and 8 in the nine-point hedonic scale, respectively).

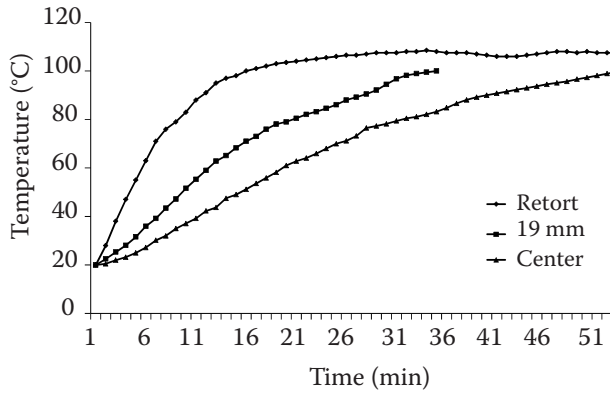


Figure 1. Temperature rise in two points inside 73 mm × 103 mm cans filled with motabbal al-bathinjan during processing in still steam retort

Table 3. Means* of sensory attributes for formula No. 9 of MB before and directly after heat processing

| Senzory atributes | Fresh | Processed | | |
|---|---|---|---|---|
| | | 80°C/5 min | 85°C/4 min | 90°C/3 min |
| Colour | 7.73$^{a}$ | 7.60$^{a}$ | 7.46$^{a}$ | 7.40$^{a}$ |
| Flavour | 8.33$^{a}$ | 8.00$^{a}$ | 8.13$^{a}$ | 8.26$^{a}$ |
| Overall acceptability | 7.93$^{a}$ | 7.73$^{a}$ | 7.66$^{a}$ | 7.73$^{a}$ |

*means of $n$ = 15, where score 1 refers to dislike extremely and 9 to like extremely in the nine-point hedonic scale

$^{a}$means within the same row followed by the same letter do not differ significantly (Duncan's Multiple Range Test at $P \leq 0.05$)

There were no significant differences between the mean scores of sensory attributes (colour, flavour, and overall acceptability) for the formula No. 9 either fresh or heat-processed with any of the three heat treatments applied. This indicates a high tolerance of the product to the selected heat treatments.

Table 4. Results of microbial examinations and pH values of fresh MB samples collected from four local restaurants

| Rest. No. | pH | Count (CFU/g) | | |
|---|---|---|---|---|
| | | standard plate | yeasts & molds | coliform |
| 1 | 4.4 | $2.5 \times 10^{6}$ | $3.2 \times 10^{4}$ | $8.5 \times 10^{2}$ |
| 2 | 5.0 | $1.1 \times 10^{9}$ | $1.5 \times 10^{4}$ | $1.4 \times 10^{7}$ |
| 3 | 4.72 | $1.16 \times 10^{8}$ | $2.7 \times 10^{3}$ | $1.7 \times 10^{7}$ |
| 4 | 4.46 | $4.5 \times 10^{8}$ | $1.7 \times 10^{5}$ | $6.4 \times 10^{4}$ |

Table 5. Results (CFU/g) of microbial examinations and pH values of fresh and canned heat-processed MB

| Run | Test | Before processing | Directly after processing | | | After 1-month storage at room temperature | | |
|---|---|---|---|---|---|---|---|---|
| | | | 8°C/5 min | 85°C/4 min | 90°C/3 min | 80°C/5 min | 85°C/4 min | 90°C/3 min |
| MB prepared in laboratory | aerobic plate count | $1 \times 10^3$ | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| | yeasts & molds | $3.5 \times 10^2$ | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| | coliform count | < 10 | < 10 | < 10 | < 10 | – | – | – |
| | pH | 4.11 | 4.12 | 4.12 | 4.11 | 4.11 | 4.11 | 4.1 |
| MB purchased from a restaurant | aerobic plate count | $4.5 \times 10^8$ | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| | yeasts & molds | $1.7 \times 10^5$ | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| | coliform count | $6.4 \times 10^4$ | < 10 | < 10 | < 10 | – | – | – |
| | pH | 4.1 | 4.13 | 4.12 | 4.12 | 4.12 | 4.13 | 4.12 |

### Microbial examinations of MB

***Microbial examination of MB samples purchased from local restaurants***. Table 4 shows microbial counts and pH values of fresh MB samples collected from local restaurants. Two samples had a pH value above 4.6, which indicated a safety hazard that might arise from the possible growth of several pathogens. The high coliform counts in all samples were indicative of microbial contamination and of the possibility of the presence of pathogens, while total count might play an important role in the spoilage of MB.

***Microbial examination of fresh and heat processed MB***. As shown in Table 5, microbial counts of the fresh MB investigated were very low compared to those of MB collected from local restaurants discussed above. The absence of coliforms from the samples prepared in the lab compared to those collected from local restaurants indicates that it is possible to produce microbiologically high quality dip if good manufacturing and hygienic practices are followed. The results of direct microscopic examination of fresh MB samples prepared in the lab revealed the presence of yeasts and lactic acid bacteria and the absence of spore formers including *Bacillus coagulans*, which is the most expected spore former that is able to grow in such products with a pH value of 4.1. The results of microbial counts in the canned dip, directly and one month after heat processing, indicated the efficiency of all heat treatments applied.

Table 6. Incubation results of canned heat-processed MB prepared in lab and purchased from a restaurant

| Test | Heat treatment (process)[a] | MB purchased from a restaurant | | | MB prepared in laboratory | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 month at room temp. | 35°C/ 15 days | 45°C/ 7 days | months after storage at room temperature | | | | | 35°C/ 15 days | 45°C/ 7 days |
| | | | | | 1 | 2 | 3 | 4 | 5 | | |
| pH[a] | 80°C/5 min | 4.11 | 4.11 | 4.11 | 4.11 | 4.11 | 4.11 | 4.12 | 4.12 | 4.11 | 4.11 |
| | 85°C/4 min | 4.12 | 4.11 | 4.12 | 4.11 | 4.1 | 4.11 | 4.12 | 4.11 | 4.12 | 4.11. |
| | 90°C/3 min | 4.12 | 4.11 | 4.11 | 4.1 | 4.11 | 4.11 | 4.11 | 4.11 | 4.11 | 4.11 |
| Swelling | 80°C/5 min<br>85°C/4 min<br>90°C/3 min | no signs of swelling | | | | | | | | | |
| Organoleptic (colour & odour) | 80°C/5 min<br>85°C/4 min<br>90°C/3 min | colour and odour of the product were not negatively altered | | | | | | | | | |

[a]before processing, pH was 4.11 for fresh MB prepared in laboratory and 4.1 for fresh MB purchased from a restaurant

Table 7. Means* of sensory attributes for canned heat-processed MB after one and five months of storage at room temperature

| Sensory attributes | After one month storage at room temperature | | | After five months storage at room temperature | | |
|---|---|---|---|---|---|---|
| | 80°C/5 min | 85°C/4 min | 90°C/3 min | 80°C/5 min | 85°C/4 min | 90°C/3 min |
| Colour | 7.53[a]** | 7.40[a] | 7.33[a] | 7.40[a] | 7.33[a] | 7.26[a] |
| Flavour | 7.73[a] | 7.66[a] | 7.73[a] | 7.66[a] | 7.66[a] | 7.60[a] |
| Overall acceptability | 7.66 [a] | 7.60[a] | 7.66[a] | 7.60[a] | 7.66[a] | 7.60[a] |

*means of $n$ = 15, where score 1 refers to dislike extremely and 9 to like extremely in the nine-point hedonic scale

[a]means within the same row followed by the same letter do not differ significantly (Duncan's Multiple Range Test at $P \leq 0.05$)

### Incubation study

Under all incubation conditions as shown in Table 6, none of the incubated processed cans showed signs of swelling. Organoleptic test of the product proved the absence of undesirable changes with respect to colour and odour. pH values before and directly after the heat processing as shown in Table 5, and under all storage and incubation conditions remained practically unchanged in all treatments. Control cans filled without any heat treatment swelled after five days of storage at room temperature. Direct microscopic examination of the contents of swollen cans showed that yeasts and lactic acid bacteria were present, leading to cans swelling.

### Sensory evaluation of stored canned MB

Table 7 shows the scores of colour, flavour, and overall acceptability of the stored canned heat-processed samples. It is clear that there were no significant differences between the scores of the three attributes after storage at room temperature for one and five months. This indicates that there were no changes in sensory properties during storage, which confirms that the heat treatments applied were also suitable and efficient with respect to the products sensory properties during five-month storage at room temperature.

Table 8. Viscosity in centipoises of fresh and canned heat-processed MB

| | Fresh | 80°C/5 min | 85°C/4 min | 90°C/3 min |
|---|---|---|---|---|
| Rep. 1 | 18 550 | 14 650 | 14 420 | 14 220 |
| Rep. 2 | 18 900 | 14 710 | 14 440 | 14 310 |
| Average | 18 725[a] | 14 680[b] | 14 430[bc] | 14 265[c] |

[a–c]means within the same row followed by the same letter do not differ significantly (Duncan's Multiple Range test at $P \leq 0.05$)

### Viscosity results

Viscosity values in Table 8 indicate that the heat processing resulted in a significant decrease in viscosity compared to fresh samples. The viscosity decrease might be due to the hydrolysis of

Table 9. Proximate composition of canned MB formula No. 9

| Composition | As is basis | | | Dry matter basis | | |
|---|---|---|---|---|---|---|
| | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 1 | Rep. 2 | Rep. 3 |
| Moisture (%) | 77.96 | 77.90 | 77.93 | | | |
| Ash (%) | 2.11 | 2.10 | 2.105 | 9.58 | 9.52 | 9.55 |
| Crude fibers (%) | 1.52 | 1.56 | 1.54 | 6.90 | 7.10 | 7.00 |
| Protein (%) | 4.42 | 4.54 | 4.48 | 20.10 | 20.60 | 20.35 |
| Fat (%) | 7.95 | 7.92 | 7.935 | 36.10 | 35.90 | 36.00 |
| Nitrogen free extract (%) | 6.04 | 5.98 | 6.01 | 27.27 | 27.13 | 27.20 |

macromolecules like protein, pectin, starch, and hemicellulose that are prone to break down during heat processing in the presence of acid and heat. In addition, some changes in the dispersion degree of the oil in water emulsion as well as in the gel structure may have occurred due to the heat processing, which might influence internal friction in the product. However, the apparent consistency of the product was not substantially affected. The exposure of the product to harsher heat treatments may lead to further decrease in viscosity, but this assumption should be examined.

Table 10. Center temperature changes during processing in still steam retort at 97°C and their lethal rates (*L*)

| Minutes | 80°C/5 min | | 85°C/4 min | | 90°C/3 min | |
|---|---|---|---|---|---|---|
| | center temp. (°C) | $L^a$ | center temp. (°C) | $L^a$ | center temp. (°C) | $L^a$ |
| Filling | 69.3 | – | 69.5 | – | 70.2 | – |
| 1 | 70.5 | 0.011 | 70.1 | 0.010 | 70.5 | 0.011 |
| 2 | 71.2 | 0.011 | 70.8 | 0.011 | 70.9 | 0.011 |
| 3 | 71.9 | 0.013 | 71.5 | 0.012 | 71.7 | 0.013 |
| 4 | 72.7 | 0.015 | 72.8 | 0.015 | 71.9[b] | 0.013 |
| 5 | 73.6[b] | 0.017 | 73.7[b] | 0.018 | 73.9 | 0.018 |
| 6 | 74.9 | 0.021 | 74.5 | 0.020 | 74.8 | 0.021 |
| 7 | 76.1 | 0.026 | 75.9 | 0.025 | 76.1 | 0.025 |
| 8 | 77.9 | 0.034 | 77.2 | 0.030 | 77.1 | 0.030 |
| 9 | 79.2 | 0.041 | 78.2 | 0.035 | 78.0 | 0.034 |
| 10 | 80.1 | 0.047 | 79.3 | 0.042 | 79.1 | 0.040 |
| 11 | 80.7 | 0.052 | 80.2 | 0.048 | 80.2 | 0.048 |
| 12 | 81.3 | 0.057 | 81.1 | 0.055 | 81.4 | 0.058 |
| 13 | 81.2 | 0.056 | 81.9 | 0.062 | 82.2 | 0.071 |
| 14 | 80.9 | 0.053 | 83.0 | 0.073 | 83.2 | 0.076 |
| 15 | 80.7[c] | 0.052 | 84.1 | 0.087 | 84.1 | 0.087 |
| 16 | 78.1 | 0.037 | 85.0 | 0.100 | 85.2 | 0.103 |
| 17 | 72.7 | 0.015 | 85.3 | 0.105 | 85.9 | 0.115 |
| 18 | | | 85.7 | 0.111 | 86.8 | 0.132 |
| 19 | | | 85.9 | 0.115 | 88.0 | 0.158 |
| 20 | | | 85.8[c] | 0.113 | 89.1 | 0.188 |
| 21 | | | 84.1 | 0.087 | 90.0 | 0.215 |
| 22 | | | 80.3 | 0.049 | 90.5 | 0.233 |
| 23 | | | 75.8 | 0.024 | 91.0[c] | 0.251 |
| 24 | | | 71.3 | 0.012 | 89.5 | 0.200 |
| 25 | | | | | 84.3 | 0.090 |
| 26 | | | | | 78.5 | 0.037 |
| 27 | | | | | 73.6 | 0.017 |
| 28 | | | | | 68.3 | – |
| Total (min) | | $F_{100}$ = 0.56 | | $F_{100}$ = 1.26 | | $F_{100}$ = 2.3 |
| #D[d] | | 1.1D | | 2.38D | | 4.34D |

[a]lethal rate $L = 10^{(T - 100)/15}$

[b]at this minute, retort temperature reached 97°C (come-up time)

[c]end of the process, cans were removed from the retort and transferred directly to tab-water bath

[d]#D – number of decimal reductions or the number of log cycles traversed in survivor curve of *B. coagulans* as a result of that process

### Proximate composition

The proximate composition of the canned MB formula No. 9 is shown in Table 9. Pellett and Shadarevian (1970) reported moisture, protein, and fat contents of MB to be 78.1%, 3.5%, and 3.7%, respectively (as is basis). Our results were higher than those obtained by Pellett and Shadrevian (1970) and this might be due to the difference in the amounts of the ingredients added. The results showed that MB had a medium nutritional value, which was lower than that of chickpea dip reported by Yaseen (1992). However, the values calculated on dry matter basis showed a good balance between protein, fat, and carbohydrate (20:36:27).

### Lethal rates for canned MB

The temperatures recorded in the centre of MB cans during processing and their lethal rates are presented in Table 10. Total sterilisation value ($F_{100}$) of the heat-processes used (80°C/5 min, 85°C/4 min, and 90°C/3 min in the can centre), considering come-up time and cooling down period to about 70°C, were 0.56, 1.26, and 2.3 min, respectively. $F_{100}$ designates the equivalent in minutes at 100°C of the combined lethality of all temperatures in the center (slowest heating point) (Rees & Bettison 1991). The values of decimal reductions (#D) for the three heat-processes were 1.1, 2.38, and 4.34, respectively.

According to Nath *et al.* (1983) and Raccach and Mellatdoust (2007), who reported that a 2-D process is microbiologically safe for canned guava pulp (pH 4.0), it can be stated that the heat-processes (85°C/4 min) and (90°C/3 min) would ensure a microbiologically safe canned MB. In contrast to that and depending on York *et al.* (1975), who reported that a 3-D process was sufficient for commercial sterility of canned whole tomatoes (pH 4.3), only the third heat-process (90°C/3 min) can be considered sufficient to render a safe and stable product. It should be noted that lethal rates during heating the product before filling were not considered in the above calculations, which would add a safety factor to those processes.

## CONCLUSIONS

MB is prepared by some local restaurants under low hygienic conditions with varying pH values that may exceed 4.6, however, highly acceptable MB formulas could be prepared with pH values around 4.1, which are classified as acid foods and may be processed safely at temperatures lower than 100°C.

The cold point of MB cans was found to be in the geometric centre, which indicates consistency stability of the product during processing, and also that heat is transferred in MB by conduction.

MB withstood the heat treatment up to 90°C for 3 min without adversely affecting its consistency or its sensory properties.

Canning of hot-filled (70°C) MB in 73 × 103 mm cans at 80°C/5 min, 85°C/4 min or 90°C/3 min at the centre proved to be adequate for commercial sterility according to microbial examinations and incubation tests.

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*Corresponding author.*

Dr. Sharaf S. Omar, Al-Balqa' Applied University, Faculty of Agricultural Technology, Department of Nutrition and Food Processing, PO Box 36197, Amman, 11120 Jordan
tel. + 962 539 436 48, e-mail: sharaf@bau.edu.jo