Modification of the Processing Method for Home-Preservation of Tomato Juice

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ABSTRACT

A modification (low water level bath, LWL) of the recommended water bath (high water level bath, HWL) procedure was used to process tomato juice in quart jars. The LWL bath contained one-fifth the amount of water recommended for the HWL bath. Use of the HWL bath required 59 min and 1838 watt-hours of electricity to heat the bath and process hot packed (92°C) juice for 15 min. In comparison, 34 min and 1065 watt-hours of electricity were required when the LWL bath was used. Samples of juice were inoculated with log 3.0 Bacillus coagulans per ml, processed in each of the two baths, and stored up to 12 weeks at 27°C. Aerobic mesophiles were found only in juice processed in the HWL bath and stored 4 weeks and in juice processed in the LWL bath and stored 0 weeks. The aerobic mesophile count (log_{10}) of juice processed in the HWL bath and stored 4 weeks was a mean log 1.4 per ml. Similar juice processed in the LWL bath had a mean log 1.3 aerobic mesophiles per ml. Juice processed in both water baths and stored for 8 and 12 weeks exhibited mesophile counts of <1 log per ml. None of the inoculated, processed samples had a mean count greater than 1 log per ml of juice for aerobic, acid forming mesophiles; aerobic thermophiles; anaerobic mesophiles and thermophiles; and mold. Using temperature values and microbiological measurements, one may conclude that the LWL bath was as effective as the HWL bath for processing tomato juice while allowing for a substantial saving of time and electricity.

Home canning of foods is practiced by a large number of American families (1,4,7), the practice being partially due to belief that such foods are less expensive than commercial foods. This may be a fact, but the cost of materials and processing in home canning should be considered. Canning at home can be expensive, one specific item being the cost of providing heat. Pressure cookers are recommended for canning low acid foods (e.g., vegetables, meats, poultry, fish) and water bath canners are recommended for canning acid foods (e.g., fruits, tomatoes, jellies, pickles) (3,5,6,10). The choice of processing vessel is dictated by the type of food being processed. Consequently, the most apparent option available to control costs is the judicious application of heat to process the canned food product.

Home canning recommendations specify that the water in the bath cover the jars 2.54 to 10.16 cm (3,6,10). Reducing the amount of water could lower the cost of providing heat. Harris and Davis (4), using different levels of water, reported that tomato juice processed in a covered water bath heated as rapidly with only 6.35 cm of water on the lower section of the jar as it heated with 2.54 cm over the jars. The lower levels of water reduced the amount of time and energy required to heat the water. They based the study on data for thermodynamic properties of water and steam which indicate that products in a closed vessel (9) will heat as well with a low level of boiling water as with a high level.

The purpose of this study was to investigate a method of improving energy use in processing tomato juice.

MATERIALS AND METHODS

Tomato juice was used to determine the effect of a modification of the water bath process on temperature changes and microbiological conditions of the processed juice. The juice was canned in standard canning jars of quart (0.95 L) capacity.

A 7-quart capacity water bath canner was used. The canner lid was modified by cementing a neoprene gasket under the portion which contacted the rim of the canner. Copper-constantan thermocouples were used to monitor temperature. One thermocouple was placed in the canner 4 cm from the bottom to record temperature of the water. Two thermocouples were placed in the canner 5 cm below the rim to record temperature of the water or steam, depending on the depth of water. Temperature of the juice was determined by a thermocouple inserted through a hole in the jar lid and extended to the cold spot (4 cm from bottom of jar). The hole in the lid was sealed with silicone sealant. Thermocouple leads were placed between the lid and rim of the canner and extended to the recorder. Temperature measurements were made at 1-min intervals by a Kaye Instrument (System 8000).

The bath was heated by an element supplied with 208 volts of electricity and rated at 2.6 KW. The amount of electricity consumed was recorded with a watt-hour meter.

Tomato juice was purchased from a grocery store for use in the temperature measurements. The juice was heated in a steam-jacketed kettle to approximately 95°C and filled into the jars for processing. The

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jars were filled to allow a headspace of 1.25 cm and closed with a two-piece closure (band and lid containing a thermocouple). The juice was processed in a water bath in which one of two levels of water was used. One bath contained a level of water which covered the top of the jar 3.8 cm and was referred to as "high water level" (HWL). The other bath was filled with an amount of water such that the depth was 5.1 cm from the bottom of the canner with the jars in place. This bath was referred to as "low water level" (LWL). The HWL bath contained 10 kg of water; the LWL bath, 2 kg.

For each process, 7 jars of juice were placed into the water bath in which the water had been brought to a boil. The lid was placed onto the canning vessel and the water was allowed to return to a boil. The processing time of the juice was recorded from this point. The juice was processed for 15 min (4). Each process was replicated 3 times. Thus each temperature measurement was the mean of 21 readings (7 jars of juice times 3 replications).

For microbiological examination, juice was prepared from vine-ripened tomatoes consisting of several cultivars. All fruits were firm, mature red with absence of green color. A pure culture of Bacillus coagulans (Bacillus thermocatalurans, ATCC 8038) was maintained on nutrient agar (2). To produce spores, B. coagulans was grown for 72 h (37°C) in sporulation broth containing gelysate peptone (6 g), pancreatic digest of casein (4 g), yeast extract (3 g), beef extract (1.6 g), dextrose (1 g), MnSO₄ (0.3 g) and agar (15 g) per liter of distilled water. Final pH of the sporulation broth was 6.6. Dilutions were made in 0.1% peptone water to give log 3.0 spores per ml of juice. The tomato juice was heated to just below boiling. Before adding the juice, 1.0 ml of B. coagulans inoculum was added to the jar. After filling and sealing, the jars of juice were placed in a HWL or LWL water bath and processed for 15 min. All jars were cooled at ambient temperature and stored at 27°C until microbiological analysis. For each process (HWL and LWL), a replicate consisted of 7 jars. Four replicates were prepared per process. Two jars were selected at random from each process for each replicate at 0, 4, 8 and 12 weeks for examination. Since only 7 jars could be prepared per process, one of the examination periods had only 1 jar for testing. The jars were selected at random and assigned to the respective examination periods.

Additional samples of juice were prepared for microbiological examination but were not heated or processed. For each process, 2 jars of uninoculated juice and 2 jars of inoculated juice were prepared. The former pair of jars provided for determination of the natural microflora, while the latter pair of jars provided for determination of the inoculum count. These samples were examined 1 d after being prepared.

Before opening for microbiological sampling, the exterior of the jars was sanitized by holding them in a solution of 100 ppm chlorine for 15 min. Each jar was rinsed in sterile water and opened aseptically. The tomato juice was stirred with a sterile pipette and portions of juice were withdrawn and placed onto petri plates or into peptone water (0.1%) dilution blanks. Duplicate pour plates were prepared for each sample. The juice was tested for the following microorganisms using the indicated media and incubation temperatures: aerobic mesophiles using thermocatalurans agar (TAA) - 37°C; aerobic, acid forming mesophiles using dextrose tryptone bromocresol purple agar (DTBP) - 35°C; aerobic thermophiles using TAA - 55°C; anaerobic mesophiles using TAA in a BBL "Gas-Pak" Jar - 35°C; anaerobic thermophiles using TAA with an anaerobe jar - 55°C; and mold using acidified potato dextrose agar (PDA) - 32°C (2). All plates were incubated for 5 d.

The pH of the juice was measured using a Corning pH meter for each sample. Before opening, each jar was observed for swells. After opening, the juice was observed for gas bubbles and sniffed for an indication of off-odor.

RESULTS AND DISCUSSION

The heating patterns for the tomato juice are presented in Fig. 1 and 2. The water in the HWL bath required heating for 40 min before reaching a boil (Fig. 1). In the LWL bath, the water began boiling after 14 min of heating (Fig. 2). During this period of heating, the temperature of the steam in the LWL bath was lower than that of the water at any given time. However, the maximum temperature of the steam was reached 1 min after the water began to boil. Temperature of water and
TABLE 1. Amount of time and electricity used to heat the water bath and process seven quart jars of tomato juice 15 minutes.

<table>
<thead>
<tr>
<th>Filling temperature, °C</th>
<th>Water bath</th>
<th>Time, minutes</th>
<th>Electricity, watt-hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>92.3</td>
<td>HWL</td>
<td>59</td>
<td>1838</td>
</tr>
<tr>
<td>92.1</td>
<td>LWL</td>
<td>34</td>
<td>1065</td>
</tr>
</tbody>
</table>

*aEach value is a mean of 21 measurements.

*bHWL = water 3.8 cm above top of jars; LWL = water 5.1 cm from bottom of canner.

*cEach value is a mean of 3 measurements.

steam decreased when the lid was removed from the canner and jars of product were added to the bath. After the lid was replaced and the water and steam had reached their maximum temperatures, the temperature of the water was 99.6°C and that of the steam was 99.2°C.

The temperature of the juice was the same at the end of the processing period as it was at the beginning of the processing period. When the HWL bath was used, 59 min were required to heat the bath and to process the juice (Fig. 1 and Table 1). When the LWL bath was used, 34 min were required to provide the 15-min process (Fig. 2 and Table 1). The shorter period represented a 42% reduction in time. It is apparent that the difference in total processing time was due to the longer time required to bring the water to boil in the HWL bath. From the standpoint of temperature, the LWL bath was as effective for heating the juice as the HWL bath.

The amount of electricity used to heat the bath and to process the juice was dependent upon the process used (Table 1). Heating the water of the HWL bath and processing the jars of juice required use of 1838 watt-hours of electricity. When the LWL bath was used, 1065 watt-hours of electricity were used to heat the bath and process the 7 jars of juice. The shorter period of time represented a 42% reduction in the amount of electricity used.

Microbiological tests of the processed tomato juice indicated that both water baths were equally effective for processing the juice. The inoculated, unheated juice had aerobic mesophilic counts of log 2.9 per ml (HWL bath process) and log 3.0 per ml (LWL bath process) (Table 2). When inoculated juice was processed in the water bath, the counts 1 d after processing were reduced to <1 log per ml (HWL bath) and log 1.3 per ml (LWL bath). Samples held 4 weeks had log 1.4 mesophiles per ml of juice processed in the HWL bath and <1 log per ml of juice processed in the LWL bath. The mean numbers for samples stored 8 and 12 weeks and processed in both baths were <1 log per ml juice.

Tests for aerobic, acid forming mesophiles showed that the inoculated, unheated juice had a count of log 2.9 per ml of juice (HWL bath) and log 3.0 per ml of juice (LWL bath) (Table 3). All inoculated, processed samples had <1 log count per ml juice. It is not surprising that *B. coagulans* did not grow in the samples since this organism does not grow at pH below 4.2 (3).

The uninoculated, unprocessed juice had no mold. Also, mold was not detected in inoculated, unprocessed juice or in inoculated, processed juice.

The pH of the uninoculated, unheated juice was 4.08. The pH increased to 4.11 when the juice was inoculated but unheated. When the juice was inoculated and processed, the pH increased to 4.15. The pH values for juice stored 4 to 12 weeks ranged from 4.11 to 4.14. The

TABLE 2. Aerobic mesophile numbers (log 10) in tomato juice processed in a water bath at boiling for 15 minutes.

<table>
<thead>
<tr>
<th>Water bath</th>
<th>Sample</th>
<th>Storage of canned juice, weeks</th>
<th>0</th>
<th>4</th>
<th>8</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Uninoculated&lt;sup&gt;c&lt;/sup&gt;</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unheated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inoculated&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unheated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>heated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

*aHWL = water 3.8 cm above top of jars; LWL = water 5.1 cm from bottom of canner.

*bMedium for plating was thermoacidurans agar, incubated 5 d at 37°C.

*cEach value is a mean of 4 measurements.

*dEach value is a mean of 14 measurements.

*eNo data obtained after 0 week of storage.

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TABLE 3. Aerobic acid forming mesophile numbers (log_{10}) in tomato juice processed in a water bath at boiling for 15 minutes.

<table>
<thead>
<tr>
<th>Water bath(^a)</th>
<th>Sample(^b)</th>
<th>Storage of canned juice, weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWL</td>
<td>Uninoculated(^c) unheated</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Inoculated unheated(^c) unheated</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Inoculated unheated(^c) heated(^b)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>LWL</td>
<td>Uninoculated(^c) unheated</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>Inoculated unheated(^c) heated(^d)</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Inoculated unheated(^c) heated</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

\(^a\)HWL = water 3.8 cm above top of jars; LWL = water 5.1 cm from bottom of canner.
\(^b\)Medium for plating was dextrose tryptone bromcresol purple agar, incubated 5 d at 35 °C.
\(^c\)Each value is a mean of 4 measurements.
\(^d\)Each value is a mean of 14 measurements.
\(^e\)No data obtained after 0 week of storage.

initial pH of the juice was lower than that usually observed, but no explanation for the low pH is available.

Observations indicated that every jar of juice had a partial vacuum (actual values were not determined). Only one jar (HWL bath, 8-weeks storage) had what was considered to be bubbles. Since this jar of juice had a pH of 4.09 and no counts of any microorganism greater than 1 log per ml of juice, the juice was probably not spoiled.

By comparing the temperature values of the juice and the microbiological examinations of canned tomato juice, it was apparent that the LWL bath was as effective as the HWL bath for processing tomato juice. By processing the juice in the LWL bath compared to processing the juice in the HWL bath, a saving of 42% in the amount of time and electricity was realized. The counts for the different types of microorganisms were similar between samples processed in the two water baths. Mean counts for the different groups of microorganisms in samples stored 8 or 12 weeks were <1 log per ml of juice. It is concluded that juice processed in the LWL bath offered no health hazard and would not spoil when stored at ambient room temperature.

REFERENCES