

# Sensory characteristics and sterilization value of unpeeled whole tomato in juice

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**Abstract:** The sensory quality of unpeeled whole tomato (*Lycopersicon esculentum* var. Roma VF) packed in tomato juice with or without calcium chloride (CaCl<sub>2</sub>) was investigated. Thermal process lethality for unpeeled whole tomato in CaCl<sub>2</sub> juice was also determined. Hermetically packaged tomatoes in tomato juice containing CaCl<sub>2</sub> were preferred ( $P < 0.05$ ) in terms of aroma and appearance. Results revealed that D-value of *Bacillus coagulans* at 100°C in jars of whole tomato in juice was 2.8 min and a lethal treatment equivalent to  $IS^{11.5}_{100} = 12.7$  min was safe from a spoilage standpoint for the unpeeled whole tomatoes in CaCl<sub>2</sub> tomato juice (with a pH of 4.1 or less) in the ratio of 7:9. Converted to experimental times, this lethality was achieved with a 22 minutes thermal processing in steam at 100°C for a 370 mL jar used in this investigation.

**Keywords:** unpeeled whole tomato, sensory quality, calcium chloride, thermal process lethality, integrated sterilization value

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## 1 Introduction

The commercial process applied to tomato is very important due to its perishable nature - in order to reduce wastage. The trend in the processing techniques adopted for tomato treatment has focused on how to maintain its nutritional wealth, consistency, organoleptic properties and shelf life (Tressler and Joslyn, 1996). Tomatoes used for canning are usually peeled. The removal of peels from tomatoes leads to substantial losses of carotenoid and ascorbic acid (Sharma and Le Maguer, 1996; Ihekoronye and Ngoddy, 1985). Thus, the canning of unpeeled tomatoes should therefore be encouraged rather than peeled tomatoes to minimize its nutritional losses especially in Nigeria where the tomatoes already are consumed unpeeled.

Canning of whole tomatoes is limited by the severity of the respective thermal process that consequently

promotes softening of tissue (Porretta, Poli and Palmieri, 1995), but the use of calcium chloride can reduce the softening of canned whole tomato (Gould, 1992; FAO, 1981). Evaluation of thermal process is quite pertinent in commercial sterilization to prevent under-processing or over-processing of foods, which may result in unsafe and poor quality foods, respectively, and its lethality can be determined in terms of integrated sterilizing values (IS) (Leonard et al., 1978). The IS value of a process accounts only for spores that were completely destroyed throughout the can without considering injured microorganisms capable of growth when subcultured, but are not able to grow into the product. Classical methods for evaluating process lethality are based on the heating nature of the coldest point within the food and accurate heat penetration data is very essential. In particulate foods, heat is propagated by convection of the brine or syrup and by conduction of the particulates, making it difficult to obtain accurate heat penetration data, i.e., at the center of the half peach or whole tomato. In this

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situation it is more convenient to use a direct microbiological approach (Leonard et al., 1975).

Integrated sterilizing (IS) value has been used by various investigators to determine process lethality (Rodriguez et al., 1996; Berry and Bradshaw., 1986; Leonard et al., 1978). Integrated sterilizing values are the application of inoculated pack technique for process lethality evaluation. Thus, it is biological rather than physical technique and measures the lethal heat received by the canned product in terms of its lethal effect on bacteria spores. Fruits present a problem in determining heating rates in non-agitating cookers, because the pieces of fruit tend to rise and pack together during the process (NCA, 1968). Tomatoes packed in juice are also observed to behave this way, thus the use of direct microbiological approach appears to be the best method for evaluating the heat process.

Typical thermophilic flat sour spoilage in low-acid foods, like tomatoes, is caused by the growth of *Bacillus coagulans*. This organism characteristically ferments carbohydrates with the production of short-chain fatty acids that "sour" the product with no gas. Its spores show resistance to destruction by heat and chemicals; hence, they are difficult to destroy in a product or in the plant (APHA, 2001).

## 2 Materials and methods

### 2.1 Tomato juice preparation

Fresh, mature and ripe tomatoes (*Lycopersicon esculentum* var. Roma VF) were purchased from a local market in Ile-Ife, Nigeria. The fresh tomatoes were sorted for wholesomeness and intense red color, and washed in tap water.

Tomato juice was obtained using the method of Rodriguez et al., (1996). Tomatoes (Roma VF) were pulped and screened with Langsenkamp pulping machine (model 18 SER. L 295, Indianapolis). The pulp was passed through a 1 mm sieve to obtain the juice. The juice was heated to boil for three minutes to inactivate enzymes before freezing for subsequent use.

### 2.2 Average initial number of spores (flat sour) per ml of tomato product

The unprocessed tomato products were sub-sampled

aseptically to determine the average numbers of spores per mL. Serial dilutions were made in sterile distilled water. The dilutions were heated at 80°C for 5 min to destroy the vegetative cells before pour plating with glucose tryptone agar (DIFCO) containing 0.04% bromocresol purple. Plates were incubated at 37°C for 48 hours and counts obtained were reported as initial number of flat sour spores in the unprocessed tomato product.

### 2.3 Packing of unpeeled whole tomato in tomato juice

Whole tomatoes (Roma VF) in tomato juice were packed in glass jars. Two types of tomato juice were used:

- 1) Tomato juice without CaCl<sub>2</sub> and
- 2) Tomato juice containing CaCl<sub>2</sub> (0.96 g/100 mL juice (w/v))

Unpeeled whole tomato (140 g) was filled into 370 mL cylindrical glass jars. 180 mL of one of the two tomato juices were added to each jar, leaving a 12 mm head space.

The jars were covered with metal lids with rubber lining. The jars were then sterilized at 100°C for 35 min in a still retort and were cooled immediately under running water at 26°C for ten minutes before storage in a clean, cool, dark and dry place for 30 days at room temperature (28°C) for sensory evaluation.

### 2.4 Cultivation of *Bacillus coagulans* spores

A pure culture agar slant of *Bacillus coagulans* spores (previously grown on nutrient agar) was prepared in cotton-plugged fermentation bottles. The spores were grown on nutrient agar containing 5 ppm manganese sulphate (Pacheco and Massaguer, 2004). The pure cultures were incubated at 40°C and stained smear of the culture was examined to ensure that sporulation has occurred. The spores were washed from the agar surface with a sterile glass rod - after 10 days when sporulation reached 90%–95% (York et al., 1975). The suspension was transferred into a sterile bottle containing glass bead and agitated for several minutes to break up clumps before filtering aseptically with a sterile double layer cheese cloth to remove the remaining clumps. The spores were centrifuged at 7,000×g for 10 min in sterile distilled water; resuspended in sterile distilled water, and stored at 4°C prior to use (Isiam et al., 2003).

The suspension was cultured on glucose tryptone agar (DIFCO) containing 0.04% bromocresol purple, to determine its concentration. Serial dilutions of the spore suspension were carried through in sterile distilled water. Dilutions were heated to 80°C for five minutes to kill vegetative cells before plating (York et al., 1975). Incubation was performed for 48 hours at 37°C and typical colonies producing yellow halo characteristics of flat sour organism were counted. Plates showing standard plate counts (30–300 colonies) were counted and recorded.

### 2.5 Thermal death rates for *Bacillus coagulans* spores

One hundred and five grams of tomatoes (tomatoes of similar dimensions were used) were packed in 270 mL glass jars and 135 mL of the tomato juice containing calcium chloride was added to cover. The dimensions of the tomato used were 5.0 ( $\pm$  0.2) cm  $\times$  3.0 ( $\pm$  0.2) cm. The pH of the tomato juice was at 4.05 to 4.1 during the determination of the death rates. Equal volume (2 mL) of the spore suspension was added into each jar before covering with the lids. The jars were submerged in an oil bath and timing was started when the cold point reached the desired temperatures of 95, 100 and 105°C. The jars were removed at different time intervals and cooled immediately under running water at 26°C for 10 min. The experiment was double replicated for each temperature. Decimal reduction time was determined at 95, 100 and 105°C which fell within the temperature range used by different investigators when determining heat resistance of *Bacillus coagulans* (Pacheco and Massaguer, 2004; Sandoval, Barreiro and Mendoza, 1992; Fernandez Coll and Silva, 1991). The jars were later opened aseptically after vigorous shaking and serial dilutions were made in sterile water. Dilutions were heated at 80°C for five minutes to kill vegetative cells before pour plating with glucose tryptone agar (DIFCO) containing 0.04% bromocresol purple. The plates were incubated at 37°C for 24 hours (York et al 1975)

### 2.6 Determination of required IS value for tomato in jars

Tomato juice and whole unpeeled tomatoes are acid foods; therefore 100°C as the references temperature is adequate

$IS_{100}^c$  is defined as:

$$IS_{100}^c = D_{100} (\log a - \log b) \quad (1)$$

The required  $IS_{100}^c$  of the unpeeled whole tomato in juice packed in glass jars was determined as described by York et al. (1975), which assumed a tolerance level of 0.01% spoilage in any commercial pack of canned whole peeled tomatoes. Thus for the glass jar used in this investigation, the initial number of spores,  $a$ , was

$$a = (\text{Average initial number of spores in tomato product mL}^{-1}) \times (\text{jar capacity, 270 mL jar}^{-1}) \times (\text{total number of jars, 10000 jars}) \quad (2)$$

York et al. (1975) found that the concentration of spores required causing spoilage in unprocessed tomato product with pH level 4.46 or less was 640 spores/ml tomato product. It was observed that when the pH level of tomato juice was adjusted to be 4.46 or less, growth of *Bacillus coagulans* spores did not occur at a concentration of 640 spores/ml; however at a higher pH growth of *Bacillus coagulans* spores occurred at the same spore concentration. Then the allowable final concentration or surviving spores,  $b$ , was:

$$\begin{aligned} b &= (\text{concentration of spores to cause spoilage}) \times \\ &(\text{jar capacity, mL jar}^{-1}) \times (1 \text{ jar}) \quad (3) \\ b &= 640 \text{ spores mL}^{-1} \times 270 \text{ mL jar}^{-1} \times 1 \text{ jar} \\ &= 1.73 \times 10^5 \text{ spores} \end{aligned}$$

### 2.7 Validating the required IS value in a 370 mL jar

The jars were filled with 140 g of unpeeled whole tomatoes and covered with 180 mL of the tomato juice containing calcium chloride – to obtain a ‘whole tomato’ to ‘juice’ proportion of 7:9 as obtained in the sample used for thermal death rates evaluation. The tomato juice was poured into the jars at 50°C (Rodriguez et al., 1996) to reduce the lag time. The jars were inoculated with the calibrated spore suspension before covering with the lids. The jars were heated in a still retort at 100°C and were removed after 12 min, 22 min and 40 min, followed by rapid cooling under running water at 26°C for 10 min.

Survival spores concentration were obtained at different time intervals by pour plate in glucose tryptone agar containing 0.04% bromocresol purple and incubating at 37°C for 48 hours. Initial number of spores ( $a$ ) and spores surviving a heat treatment ( $b$ ) were enumerated

and the  $IS$  value was determined as:  $IS = D_{100} (\log a - \log b)$ .

## 2.8 Sensory evaluation

A 12 member sensory panel did sensory evaluation. The processed tomatoes were rated for aroma, appearance, colour, taste and overall acceptability. Appearance was rated visually as tomato integrity – whether the fruit is whole or disintegrated. A 9-point hedonic scale was used with 9 being extremely acceptable, 5 being moderately acceptable and 1 being not acceptable (Enujiugha, 2006).

## 2.9 Statistical analysis

Analysis of variance was calculated for sensory and objective data as described by Spiegel and Stephens (2008) and least square differences test (LSD) as described by Akindele (1996) at 95% confidence interval. Correlation coefficients were calculated using SPSS version 11 (SPSS Inc., Chicago).

## 3 Results and discussion

The results presented here are the sensory attributes and process lethality for unpeeled whole tomato in juice obtained during the study.

### 3.1 Sensory quality of whole tomato in juice

Sensory evaluation showed that unpeeled whole tomatoes in juice containing calcium chloride were superior with respect to aroma and appearance (Table 1). Addition of calcium chloride to the juice improved the texture of the unpeeled whole tomatoes, as whole tomatoes canned in juice without calcium chloride appeared a little bit shrunk. Calcium has been reported by many investigators to improve the texture of fruits and vegetables. The divalent calcium salts increase the rigidity of the middle lamella and cell wall by binding PME-demethoxylated pectate chains to form calcium pectate or pectinate (Sato, Sanjinez-Argandona and Cunha, 2006; McCurdy et al., 1983; Nath and Ranganna, 1983).

The calcium chloride treated and the untreated tomatoes have no significant difference ( $P>0.05$ ) when assessed for color, taste and overall acceptability by the sensory panel as showed in Table 1. Tomatoes packed

in the  $\text{CaCl}_2$  juice were lighter than tomatoes packed in the ordinary juice; though it did not affect the acceptability of the product. This lightening effect of calcium was also reported by Sato, Sanjinez-Argandona and Cunha, (2006). They observed that color of guavas in syrup packed in glass jars became lighter with increasing  $\text{CaCl}_2$  concentration in the cooking syrup, after 15 days storage. The formation of calcium pectate was probably responsible for the lightening in the color of the fruits (Rodrigues, Cunha and Hubinger., 2003). The lightening effect of calcium chloride was also reported by Lu and Chang (1996).

**Table 1 Sensory score of whole tomato in juice**

Attributes	$\text{CaCl}_2$ treated tomatoes	Untreated tomatoes
Aroma	6.38 <sup>a</sup> ±1.22	4.00 <sup>b</sup> ±1.32
Appearance	6.50 <sup>a</sup> ±1.22	3.13 <sup>b</sup> ±1.45
Colour	6.38 <sup>a</sup> ±0.86	5.00 <sup>a</sup> ±2.05
Taste	5.13 <sup>a</sup> ±1.36	4.63 <sup>a</sup> ±1.80
Overall acceptability	6.00 <sup>a</sup> ±2.00	4.50 <sup>a</sup> ±1.58

Note: Means within a row followed by different letters are significantly different ( $P<0.05$ ).

### 3.2 Thermal resistance of *B. coagulans*.

The concentration of the spore suspension was  $2 \times 10^9$  spores  $\text{mL}^{-1}$ . The survival counts of the *B. coagulans* spores during thermal processing are shown in Tables 2, 3 and 4.  $D$  values of 9,  $2.8 \pm 0.14$  and  $1.25 \pm 0.07$  min was obtained for *B. coagulans* at 95, 100 and 105°C, respectively, and a calculated  $z$  value of 11.5°C for the whole tomatoes in juice (Figure 1). Reported  $D$  values of *B. coagulans* at 100°C by different investigators (Pacheco and Massaguer, 2004; Sandoval, Barreiro and Mendoza, 1992; Fernandez Coll and Silva, 1991) ranged from 0.31 to 13.2 min in acid foods and the  $z$  values ranged from 9.5 to 15°C.

**Table 2 Survival count of *B. coagulans* spores in thermally processed unpeeled whole tomatoes in juice at 95°C**

Process time/minutes	Total viable counts/log cfu · $\text{mL}^{-1}$
0	6.71 ± 0.00
6	6.41 ± 0.14
12	5.68 ± 0.11
18	5.15 ± 0.00
24	4.35 ± 0.07

Note: Data represents the means ± s.d of two replicate experiments.

**Table 3 Survival count of *B. coagulans* spores in thermally processed unpeeled whole tomatoes in juice at 100°C**

Process time/minutes	Total viable counts/log cfu · mL <sup>-1</sup>
0	6.71 ± 0.00
6	6.28 ± 0.40
10	4.64 ± 0.23
14	3.39 ± 0.12
18	2.00 ± 0.00

Note: Data represents the means ± s.d of two replicate experiments.

**Table 4 Survival count of *B. coagulans* spores in thermally processed unpeeled whole tomatoes in juice at 105°C**

Process time/minutes	Total viable counts/log cfu · mL <sup>-1</sup>
0	6.71 ± 0.00
4	6.48 ± 0.25
6	4.84 ± 0.25
8	3.40 ± 0.28
10	1.60 ± 0.21

Note: Data represents the means ± s.d of two replicate experiments.

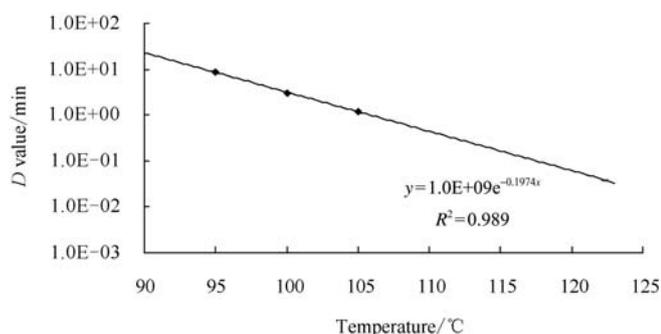


Figure 1 Thermal death time curve of spores of *B. coagulans*

Rodriguez et al. (1996) reported a  $D$  value of 2.26 min and a  $z$  value of 14°C for *B. coagulans* at 100°C in tomato concentrate (18°Brix, pH = 4.5). Sandoval, Barreiro and Mendoza (1992) reported a  $D_{100}$  value of 0.31 min and  $z$  value of 9.5°C using concentrated tomato puree (30.3°Brix, pH=4.0) while Pacheco and Massaguer (2004) obtained a  $D_{100}$  value of 1.32 min and  $z$  value of 10.14 ± 1.49°C in tomato pulp (8°Brix, pH = 4.3). The  $D_{100}$  value of 2.88 min reported for *B. coagulans* in tomato pulp by Pirone, Mannino and Vicini (1989) is closer to the value obtained in this investigation. The unpeeled tomato (particulate food) used in this investigation probably provided some protection for the spores therefore increasing its  $D$  value. The  $z$  value of 11.5°C obtained for *B. coagulans* in this work falls within the range obtained by the different investigators. The  $D$  value at 121.1°C estimated from this work (Figure 1) is

0.041 min and it falls within the range of 0.01 to 0.07 min reported by Brennan et al (1981) for *B. coagulans* at 121.11°C in acid foods.

### 3.3 Required $IS_{100}^{11.5}$ value of unpeeled whole tomato in juice

The integrated sterilizing ( $IS_{100}^{11.5}$ ) value required for the whole tomato in juice packed in the 270 ml jars used for this work was calculated from eqn. (1).

The average initial number of flat sour spores in the unprocessed sample of the tomato product in this investigation was found be  $2.2 \pm 1.1 \times 10^3$  spores per mL. The required  $IS_{100}^{11.5}$  value for the unpeeled tomato product in the 270 mL jars used in this work would be derived from Eqn. (1).

$$IS_{100}^{11.5} = 2.8 \text{ min} \times (\log 5.94 \times 10^9 - \log 1.73 \times 10^5)$$

$$IS_{100}^{11.5} = 2.8 \text{ min} \times 4.54 = 12.7 \text{ min}$$

The  $IS_{100}^{11.5}$  of 12.7 min is equivalent to 4.54 decimal reductions of *B. coagulans* spores. Early investigators found that spores of *B. coagulans* were easily rendered harmless as spoilage causing organisms in tomato product with pH 4.2 or less when given only marginal heat treatment.

### 3.4 Validation of the required IS value in a 370 mL jar

The jars were inoculated with the calibrated spore suspension ( $2 \times 10^9$  spores mL<sup>-1</sup>). The  $IS_{100}^{11.5}$  values obtained for different heating time is shown in Table 5. The data revealed that a process time of 22 min is sufficient to produce a commercially sterile (safe and stable) whole tomato in juice packed in the 370 mL glass jar used in this investigation. The 22 min process time gave an  $IS_{100}^{11.5}$  value of 13.2 min, which is a little higher than the target value of 12.7 min. The  $IS_{100}^{11.5}$  value obtained after the first 12 min of heating is lower compared to the lethality accumulated in the subsequent 10 min of heating that followed. This is as a result of heating lag that usually occurs when heating process is done under non-agitating in-container procedure. After 40 minutes of heating the number of surviving spores in the jars ranged from 0–1 spores per ml and the  $IS_{100}^{11.5}$  value obtained after the given heat treatment is quite larger than the target value of 12.7 min - required to obtain commercial sterility. Commercial sterility

addresses the ability of the spoilage organism to grow in the packed product and not the absence or presence of the spoilage organism.

**Table 5 Survival count of *Bacillus coagulans* in canned whole tomato in juice**

Processing Time/min	No. of Surviving spores			$IS^{11.5}_{100}$ value /min
	Run 2	Run 2	Run 2	
0	$1.10 \times 10^6$	$7.2 \times 10^5$	$6.6 \times 10^5$	0
12	$1.45 \times 10^5$	$1.66 \times 10^5$	$1.25 \times 10^5$	$2.07 \pm 0.29$
22	$2 \times 10^1$	$2 \times 10^1$	$1 \times 10^1$	$13.2 \pm 0.27$
40	1	1	0	$16.66 \pm 0.26$

## 4 Conclusions

The introduction of  $\text{CaCl}_2$  into unpeeled whole

tomato in juice product produced tomatoes that were preferred in terms of aroma and appearance, although there was no difference in overall acceptability when compared with the control (tomato in tomato juice not containing  $\text{CaCl}_2$ ). The  $D$  value of *B. Coagulans* in unpeeled whole tomato in tomato juice was found to be 9, 2.8 and 1.5 minutes at 95, 100 and 105°C respectively. A  $IS^{11.5}_{100} = 12.7$  min was found to be adequate to produce a commercially sterile unpeeled whole tomato in juice in the ratio of 7:9; when converted to experimental times, this lethality was achieved with a 22 minutes thermal processing in steam at 100°C for a 370 mL jar used in this investigation.

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