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# ESTABLISHING A SCHEDULE TO DETERMINE THE OPTIMAL THERMAL PROCESS TIME FOR SOME CANNED FRUIT PRODUCTS

BY

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## ABSTRACT

Apricot juice, papaya puree, apricot nectar, papaya nectar and 2 nectar blends of apricot and papaya were canned in cans (Ø 65x110 mm) and thermally processed at retort temperatures 90, 95 and 100°C for 35, 25 and 15 minutes, respectively. Thermal parameters $f_{ch}$, $J_{ch}$, $f_{cc}$ and $J_{cc}$ during the heating and the cooling phases were estimated using the laboratory obtained heat penetration data. The obtained heat penetration data at laboratory were used to predict other heat penetration data at other initial temperatures (40, 45, 50, 55, 60, 65, 70 and 75°C) by applying equation of Schultz and Olson. A process schedule is very important that it helps to minimize the required energy to the thermal process, to keep the nutrition value for the products and to obtain safe product with high quality. So thermal process schedule for these canned products was calculated by using the reviewed resistance thermal parameters of pectin methylestrase enzyme (E.C. 3.1.1.11). The two nectar blends were selected as a result of sensory evaluation which was carried out to compare between sensory properties of 10 different apricot (A) and papaya (P) nectar blends. The higher score in all sensory attributes were for papaya and apricot nectars {(P50 %+A50 %)[blend 6]} and {(P60%+A 40 %)[blend 7]}.

**Key words:** Papaya, Apricot, Heating, Canning, heat penetration, Pectin methylestrase heat inactivation, Stumbo's mathematical method, Thermal process schedule.

## INTRODUCTION

Papaya fruit is one of the best sources of vitamins and contain a lot of vitamins A and C and is considered to act as mild laxative. It has a neutral taste that can considerably improved by the addition of passion fruits to make soft drink, jam and various preserves. Papaya fruits are harvested during several months of the year. Papaya is one of the bland tropical fruits that may require acidification to ensure a safe product when processed by normal methods, Rutledge (1996). Papaya is one of the largest in size of the tropical fruits; it has a pulpy flesh yellow or orange colored with shades of yellow and red, depending on the fruit var.. The fruit can be easily converted into a thick puree and preserved by common methods and later employed to manufacture papaya nectars, (Carmen *et al.*, 1978). Papaya is nutritive and presents good organoleptic characteristics. In view of the high pH, papaya puree is either frozen or acidified with citric acid or blended with acid juices prior to pasteurization. Papaya fruit is spreaded now in Egypt. It is cultivated in old Governorates (Sharkeya, Quliobia and Giza "Gezeret El Shaier"). Beside new reclaimed land at Noubareia. Egypt exported 148 ton of papaya fruits during the year 2004 (MALR, 2005).

Apricot is of paramount importance to both local markets and exportation. Its juice is considered as excellent source of vitamins particularly vitamin C, E and also considered as an important source of mineral elements necessary for human nutrition. Apricot fruits can be used fresh, dried or processed. Apricot is important for Egypt because of its export potential. Apricot is widely cultivated in Egypt, but of a short harvesting season. There are many varieties such as Amar, Hamawy and Fayoumy.

Blending of fruit drinks could be an economic requisite and also needed to improve the appearance, nutrition and flavor. Some workers have described the effect of blending of fruit drinks and nectars on chemical and sensory characteristics, but scarce information is available on the thermal process time of nectar and nectar blends.

Thermal processing is an important method of food preservation in the manufacture of shelf stable canned foods, and has been the cornerstone of the food processing in industry for more than a century, Simpson, *et al.* (2007). However, over-processing must be avoided because thermal processes also have a detrimental effect on the quality (nutritional and sensorial factors) of foods. Therefore, the accuracy of the methods used for this purpose is of importance to food science and engineering professionals working in this field.

The thermal process is one of the main food preservation techniques, which intends to guarantee the product's final quality in terms of the consumer's health. The thermal sterilization of canned foods using retort equipment has been one of the most utilized preservation techniques for the last 200 years (Teixeira and Tucker, 1997).

The food sterilization modeling is very important to any study about the process optimization and the operation of its equipments. Also, it is quite relevant for correcting processing failures, such as a decrease in the retort's temperature and a variation of the product's initial temperature, Sablani and Shayya (2001).

Time–temperature data are employed to evaluate the heat penetration parameters, $f_h$, $j_{ch}$, $f_c$ and $j_{cc}$, as well as to compute the lethality and the process time. The Ball's, Stumbo's and Pham's methods are also utilize for calculating the process times and lethality, Afaghi *et al.* (2001).

The phrase "minimal thermal process" was introduced by US Food and Drug Administration in 1977 and defined as the application of heat to food, either before or after sealing in a hermetically sealed container, for a period of time and at a temperature scientifically determined to be adequate to ensure the destruction of microorganism of public health concern (Lopez, 1987).

Three types of data are required to determine a process time for a new canned food, such as low acid: (i) thermal resistance of the most heat resistant organism, including those affecting public health and those which are able to grow in such a food; (ii) initial contamination (number and kind) in the raw product, in order to establish an accurate decimal reduction factor; and (iii) heat penetration rate at the cold point in the canned food (Rodrigo and Safon, 1982). In order to determine the extent of heat treatment, several factors must be known (Fellows, 1988) which are type and heat resistance of the target microorganism, spore or enzyme present in the food, pH of the food, heating conditions, thermophysical properties of the food and the container shape and size and storage conditions following the process.

The basic ideas of thermal process calculations are well presented in several published articles and textbooks (Ball and Olson, 1957; Stumbo, 1973; Hayakawa, 1978; Merson *et al.*, 1978; Ramaswamy *et al.*, 1992; Yang and Rao, 1998; Toledo, 1997 and Ramaswamy and Marcotte 2006). It is important to note that there is a large amount of published informations available on the formula method calculations and modification to suit a variety of processing equipments, techniques and conditions especially in relation to the estimation of the thermal lags (Ball, 1923, Hayakawa, 1970, 1978; Vinters *et al.*, 1975, Steele and Board, 1979; Steele *et al.*, 1979; Cleland and Robertson, 1985; Larkin, 1989; Larkin and Berry, 1991 and Hasahallis *et al.*, 1997).

Previous studies identified a heat resistant portion of pectinesterase and pectic enzymes in acidified pulp from papaya, which displayed greater thermal resistance than *Clostridium pasteurianum* in thermal destruction studies, Fayyaz *et al.*, 1995 and Magalhaes *et al.*, 1996, 1999. Also, Dastur *et al.* (1968) found that in high acid foods the heat resistance of *lactobacilli*, yeasts and molds were lower than that of heat resistant enzyme systems such as peroxidase, pectin esterase and polyphenol oxidase present in food and lead to undesirable changes unless inactivated. Pectinesterase (E.C. 3.1.1.11) is of prime importance to the food industry. It has a great impact on fruit and vegetable processing technology because of its potential effect on the quality of the finished products. It also plays a central role in the process of fruit softening during ripening; the control of its activity, through knowledge of dependence on such parameters as the temperature and pH, is of great practical importance in the food industry for protecting and improving the texture and firmness of several processed fruits and vegetables (Castaldo *et al.* (1989) and Fayyaz *et al.* (1995).

Heat penetration trials were carried out by Magalhaes *et al.*, 1999, on canned Formosa papaya pulp in order to study the kinetics of heat-resistant pectinesterase and to provide recommendations for commercial processing. Processing duration for the canned papaya (acidified to pH 3.8) was calculated using Shiga's method for estimating thermal process times for a given F value. A heating time of 12.9 min in a water bath at 97°C was established which was equivalent to a 1.7 decimal reduction of the activity of heat-resistant pectinesterase (98% inactivation).

Hasahallis *et al.* (1997) mentioned that the purpose of the thermal process calculation is to arrive at an appropriate process under a given set of heating conditions to result in a given process lethality, or alternately to estimate the process lethality of a given process. The method used must accurately integrate the lethal effects of the transient temperature response for the food undergoing the thermal processes with respect to test microorganism of both public health and spoilage concern. The desired degree of lethality in terms of equivalent time at a reference temperature ($F_o$) is generally prestablished and process are desired to deliver a minimum of this preset value at the thermal center. The process calculation methods are broadly divided into two classes, general methods and formula methods.

The objectives of the present work were:

(1) Formulating of different blends of apricot and papaya fruits to produce a new and lower cost nectars in Egypt.
(2) To study the profile of heat penetration of canned juice, puree and nectars to calculate the parameters of heating and cooling curves.
(3) To obtain a thermal process schedule indicating the optimum thermal process time (min.) at different retort and initial temperatures for canned apricot and papaya nectars blending. This schedule is very important that it helps to minimize the required energy to the thermal process, to keep the nutrition value for the products and to obtain safe product with high quality.

## MATERIALS AND METHODS

**Materials:**

- Apricot fruits (*Prunus armeniaca*) variety Amar were picked at the ripe stage from Amar village, Quliobia Governorate, Egypt, during season of 2006.
- Papaya fruits (*Carica papaya* L.cv. Sunrise Solo) are usually collected green mature from the farm of Moshtohor Faculty of Agric. Banha Univ., Egypt. The fruits, weighing between 750 to 1750g. The fruit surface was treated by $H_2O_2$ 5 % as disinfectant. It ripened under storage at room temperature for 3-4 days.

**Processing:**

**Apricot juice:** ripe apricot fruits were washed with running water, cut into halves and the kernels were removed. The juice was mechanically extracted by using Moulinex blender (Blender Mixer, type: 741). The juice was strained by a stainless steel strainer to remove stone cells, to avoid coarse pulp particles and to have only fine particles of almost colloidal consistency.

**Papaya puree:** ripe papaya fruits were washed, dried in air, hand peeled, seeds carefully removed and cut into small parts. The papaya puree was extracted by Moulinex blender (Blender Mixer, type: 741). It took five minutes blending to get papaya puree. The puree was strained by a stainless steel strainer, then strained again by a clean muslin cloth to get rid of seeds and peels for obtaining papaya puree.

Apricot and papaya puree were divided into two parts:

The first part was used to determine the chemical composition, thermal measurements and sensory evaluation.

The second part was used in preparation of nectar and different blends.

**Apricot nectar:** nectar was prepared "as recommended method described by Tressler and Joslyn (1971)" from 25% apricot juice + 75% (sugar and water) to get: total soluble solids 17%; pH 3.5. The pH was adjusted to 3.5 by adding citric acid as 50% (w/v) solution.

**Papaya nectar:** nectar was prepared "as recommended method described by Tressler and Joslyn (1971) and Brekke *et al.*, 1976)" from 25% papaya puree + 75 % (sugar and water) to get total soluble solids 17%; pH 3.5. The pH was adjusted to 3.5 by adding citric acid as 50% (w/v) solution.

**Papaya and apricot nectar blends:** the papaya puree and apricot juice were blended together as follows: blend (1) [0% papaya puree +100% apricot juice]; blend (2) [10% papaya puree + 90% apricot juice]; blend (3) [20% papaya puree + 80% apricot juice]; blend (4) [30% papaya puree +70% apricot juice]; blend (5) [40% papaya puree + 60% apricot juice]; blend (6) [50% papaya puree + 50% apricot juice]; blend (7) [60% papaya puree + 40% apricot juice]; blend (8) [70% papaya puree + 30% apricot juice]; blend (9) [80% papaya puree+ 20% apricot juice] and blend (10) [90% papaya puree + 10% apricot juice].

Nectars of 17% total solids were obtained by mixing 25% blend + 75% (sugar and water). Nectars pH was adjusted to 3.5 by adding citric acid as 50% (w/v) solution.

**Canning process:**

Apricot juice, papaya puree, apricot nectar, papaya nectar and the two most scores nectar blendes, from the standpoint of sensory evaluation, were packed in Ø 65x110 *mm* cans. Sterilization was carried out at different retort temperatures (90, 95 and 100°C) for different times (35, 25 and 15 min.), respectively. The cans were suddenly cooled using tap water of 24 ° C.

**Methods:**

**Analytical methods:**

Moisture content, total solids, fat, protein, ash, ascorbic acid and starch were determined according to A.O.A.C. (2000). The pH value was measured with a pH meter model Consort pH meter P107. Titratable acidity was determined by titration with NaOH 0.1 N solution using phenolphthalein as indicator according to A.O.A.C. (2000). Total and reducing sugars were determined by Shaffer and Hartman method as described in the A.O.A.C. (2000). Total pectin content and fractional pectin components were determined by the method of Robertson (1979). Crude Fiber was determined by Weende method which using VELP Scientifica extraction unit, the method is based on the solubilization of non-cellulosic compounds by sulfuric acid and hydroxide solutions as described in

A.O.A.C. (2000). Pulp content was determined according to El-Mansy *et al.* (2000). Color index was determined by the method of Meydov *et al.* (1977). Carotenoids were determined according to Harvey and Catherine (1982). Total anthocyanins were measured according to the method of Skalaki and Sistrunk (1973). Specific heat (cp) was calculated according to Alvarado (1991). Density was determined with a pyknometer at 25 °C according to A.O.A.C. (2000). Water activity ($a_w$) was measured with a (Rotronic Hygromer TM water activity meter model A2101) operated following the procedure described in detail by Rao and Tapia (1991). All the experiment was measured at room temperature. Three replications of all of these determinations were carried out.

**Sensory evaluation**

Sensory evaluation was carried out by a properly well trained panel of 12 testers. They were selected if their individual scores in 10 different tests showed a reproducibility of 90%. The 12 member internal panel evaluated the different apricot and papaya nectar blends for color, appearance, taste, flavor, mouthfeel (smoothness, consistency, spreadability) and overall acceptability. Mineral water was used by the panellists to rinse the mouth between samples. Scoring was based on a 100 point scale (10-100) where (90-100) = excellent, (70-80) = very good, (50-60) = good, (30-40) = fair and (10-20) = poor, according to Onweluzo, *et al.*, 1999.

**Estimation the slowest heating point inside the cans:**

It is important to check the slowest heating point inside the cans, for a product to obtain the actual $F_0$-value. Pre measuring can three (T.C.) of the self-made type were mounted on the central axis at different heights above bottom height ¼, $^1/_3$ and ½ height (i.e. 28, 42 and 56 mm, respectively). T.C's inside can (size Ø 65x110 mm) were fixed by the rubber stoppers.

**Evaluation of thermal processing time:**

Heat penetration data were obtained using portable hydride recorder (thermocouples) Digi-Sense Model 92800-15, Cole Parmer Company.

Heating and cooling curves were plotted according to Ramaswamy and Marcotte (2006).

Evaluation of thermal processing time was carried out using the mathematical method (Stumbo, 1973) as indicated by Ramaswamy and Marcotte (2006), which includes the following equation:

$B = f_h (\log J_h I_h - \log g)$

where:

B : Thermal process time corrected for time required to bring the retort to processing temperature.

$f_h$ : Number of minutes required to cross the straight line portion of the heating curve one log cycle.

$J_h$ : $(Tr - Tp_{ih})/I_h$

Tr : Retort or process temperature.

$T_{ih}$ : Initial food temperature when heating is started.

$Tp_{ih}$ : Pseudo-initial food temperature when heating is started. Temperature indicated by the intersection of the extension of the straight-line portion of the heating curve and a vertical-line representing beginning of heating that zero time is shifted 0.58 *l*.

$I_h$ : Tr - $T_{ih}$ (Difference between retort temperature and food temperature when heating is started.)

g : Difference in degrees Fahrenheit, between retort temperature and the maximum temperature reached by the food at the point concern. It could be obtained using Stumbo tables for the relationship $f_h/u$ : g for suitable Z and $J_{cc}$ Values.

*l* : Time, in minutes, required to bring retort to processing temperature (come up time).

**Calculation the Percent of Enzyme Activity Retained at End of Process.**

1- The following equation was used to obtain $g_c$ value
$B = f_{ch} (\log J_{ch}I_h - \text{Log } g_c)$.

2. From $f_h/U$ : $g_c$ from Stumbo tables for suitable Z and $J_{cc}$ for the product, fh/U could be obtained for the previously calculated $g_c$.
Then U could be obtained by substituting for $f_{ch}$.

3. $F_i$ value was calculated by the following equation:
$F_i = \log^{-1} (T_x - T_r/Z)$

4. From the following equation F could be calculated
$U = FF_i$

5. Using the following equation percent enzyme activity retained b could be calculated as follows:
$F = D_r (\log a - \log b)$

where:

a: Initial percent of enzyme activity.

b: Final percent of enzyme activity retained at end of process.

$g_c$: g when the point of concern is the geometrical center of the container.

F: The equivalent, in minutes at some given reference temperature, of all heating considered with respects to its capacity to destroy spores, vegetative cells of a particular organism or enzyme.

$F_i$: Time at any other temperature equivalent to 1 minute at some designated reference temperature.

$D_r$: Time required at any designated reference temperature to destroy 90% of the spores, vegetative cells of a given organism or destroy 90% of activation of a given enzyme.

$T_x$: Reference temperature.

$T_r$: Retort temperature.

U: The equivalent in minutes at retort temperature of all lethal heat received by some designated point in the container during the process.

Z: Number of centigrade degrees required for the thermal destruction curve (for pectin methylestrase enzyme) to traverse one log cycle. Mathematically

**Temperature conversion for different initial and retort temperature:**

According to Schultz and Olson (1940) mentioned by Holdsworth (1997), the equation for converting food (can) temperature when the initial temperature remained the same, the following equation was used.

$$Tc' = Tr - \frac{Tr - Ti'}{Tr - Ti}(Tr - Tc)$$

where:

Tr: retort temperature.

Ti': new initial temperature.

Ti: original initial temperature.

Tc: a can temperature of the original set.

Tc': a new can temperature corresponding to Ti'.

**Statistical analysis:**

Data for the sensory evaluation of all nectar preparations were subjected to the analysis of variance followed by multiple comparisons using [Least significant difference, (L.S.D.)] analysis, according to Gomez and Gomez (1984). L.S.D. was calculated at 0.05 level as significance.

## RESULTS AND DISCUSSION

**Physicochemical properties of apricot juice and papaya puree:**

Results recorded in Table (1) show some physicochemical properties of the obtained papaya puree and apricot juice. Numerous reports on the chemical composition of papaya puree and apricot juice have appeared in the literature but refer to old cultivars which are used less and less by industry. Hence, there is a need to characterize new varieties of papaya and apricot, which have been utilized by the food industry for some years. These results were in agreement with Voi *et al.* (1995), Guerrero and Alzamora (1998) and Rodrigues, *et al.* (2003).

**Sensory properties of apricot and papaya nectars blends:**

Sensory evaluation is generally the final guide of the quality from the consumer's point of view. Thus, it is beneficial to make a comparison between the nectars blends, which were applied. Organoleptic parameters, indicate the possibility of nectar for acceptability. Color, appearance, taste, flavor, mouthfeel and overall acceptability of different papaya (P) and apricot (A) nectar blends were organoleptically evaluated, the results are indicated in Table (2). There are significant differences among the 9 tested nectars. Regarding the mouthfeel (consistency) of papaya and apricot nectars, results in Table (2) reflect that the mouthfeel of nectars (P 50% + A 50%) and (P 60% + A 40%) [blends No. 6 and 7, respectively] had the highest scores compared with the other blends. In the same time these two blends (6, 7) have the higher scores in all other attributes. The lower scores in all attributes were for nectars (P10% + A 90%) and (P 20% + A 80%) [blends No. 2 and 3, respectively].

In conclusion, results for papaya and apricot nectar blends appear that the nectar blends containing equal percentage of papaya puree and apricot juice (blend 6) had the higher score in all attributes and most acceptable to panelists due to better consistency and flavor. This indicates that papaya, which is cheaper than apricot, could be blended with apricot in the preparation of pulp and juices.

**Table (1) : Physicochemical properties of apricot juice and papaya puree.**

| Analysed item | Mean values | |
|---|---|---|
| | Apricot Juice | Papaya Puree |
| Moisture % | 84.23±0.52 | 87.05±0.73 |
| Total solids % | 15.77±0.52 | 12.95±0.73 |
| Ash % | 0.87±0.04 | 0.73±0.01 |
| Titratable acidity % (as citric acid) | 1.79±0.08 | 0.129±0.001 |
| pH value | 3.84±0.09 | 5.43±0.12 |
| Ascorbic acid (mg/100 ml) | 11.86±0.11 | 86.30±2.13 |
| Protein % | 0.841±0.02 | 0.768±0.01 |
| Fat % | 0.162±0.01 | 0.529±0.01 |
| Fibre % | 1.734±0.06 | 1.188±0.02 |
| Starch% | 0.368±0.01 | 0.517±0.004 |
| Total sugars % | 7.194±0.09 | 7.321±0.07 |
| Reducing sugars % | 3.234 ±0.08 | 3.119±0.05 |
| Non-reducing sugars % | 3.960±0.11 | 4.202±0.09 |
| Total pectic substances % | 3.42±0.04 | 2.239±0.002 |
| Water soluble pectin % | 1.07±0.05 | 0.993±0.006 |
| Ammonium oxalate soluble pectin % | 1.62±0.04 | 0.841±0.007 |
| Acid soluble pectin % | 0.73±0.04 | 0.405±0.000 |
| Pulp Content (V/V) % | 27.54±0.33 | 47.09±1.03 |
| Color index (O.D. at 420 nm) | 0.502±0.0009 | 0.286±0.002 |
| Anthocyanine (O.D.) | 0.171±0.004 | 0.013±0.000 |
| Carotenoids (mg/L) | 21.08±0.41 | 26.84±0.93 |
| Specific heat capacity kJ/kg K | 1.952±0.03 | 3.548±0.05 |
| Density at temperature 30 °C (kg/m$^3$) | 1076.21±1.01 | 1036.09±0.96 |
| Water activity ($a_w$) | 0.9492±0.0009 | 0.9609±0.001 |

*Each value is the average of three replicates ± S.E.

*Chemical composition on wet weight basis

**Thermal process calculations for apricot and papaya purees and nectar's**

The reviewed heat resistance parameters of pectin methylstrase were used in the required calculations that this enzyme is more heat resistant than the non sporulating bacteria like *Lactobacilli* and *Leuconostoc*, yeast and moulds which are responsible for the spoilage of high acid food (Dastur *et al.* (1968), Nath and Ranganna (1983) and Magalhaes, *et al.* (1999).

**Heat penetration parameters:**

Data (not presented) indicated that the slowest point is at ¼ height from the can bottom for all product except papaya puree the slowest point is at ⅓ height from the can bottom that the highest $f_h$ values obtained at the slowest point were 14.41, 17.76, 10.64, 15.80, 8.81 and 9.71 minutes for apricot juice, papaya purees, apricot nectar, papaya nectar, blend 6 and blend 7, respectively, at retort temperatures 100°C.

Table (2): Sensory properties of papaya and apricot nectar blends

| Products (Nectar Blends) | Sensory attributes | | | | | |
|---|---|---|---|---|---|---|
| | Color (20) | Appearance (20) | Taste (20) | Flavor (20) | Mouthfeel (20) | Overall acceptability (100) |
| Apricot nectar | 15.74±0.51b | 17.87±0.36 b | 16.07±0.21 ab | 15.82±0.60 b | 17.03±0.65 ab | 81.15±1.78 b |
| P10 +A 90 % | 15.91±0.26 b | 17.39±0.27 b | 16.40±0.76 ab | 15.94±0.60 b | 16.80±0.49 b | 78.79±2.31 b |
| P20 +A 80 % | 16.16±0.26 b | 17.71±0.26 b | 16.63±0.45 ab | 16.34±0.50 ab | 17.31±0.35 ab | 79.57±1.09 b |
| P30 +A 70 % | 16.46±0.27 b | 17.83±0.25 b | 16.86±0.40 ab | 16.63±0.43 ab | 17.20±0.36 ab | 83.43±1.74 b |
| P40 +A 60 % | 16.57±0.28 b | 18.06±0.28 ab | 17.09±0.51 ab | 16.86±0.40 ab | 17.31±0.42 ab | 86.86±1.27 ab |
| P50 +A 50 % | 18.46±0.33 a | 18.68±0.23 a | 17.54±0.62 a | 17.37±0.49 a | 17.89±0.45 a | 93.43±0.82 a |
| P60 +A 40 % | 18.51±0.33 a | 18.61±0.22 ab | 17.54±0.37 a | 17.20±0.40 ab | 17.66±0.41 ab | 91.50±0.58 ab |
| P70 +A 30 % | 17.66±0.34 a | 17.72±0.32 b | 16.34±0.75 ab | 16.63±0.39 ab | 17.83±0.30 ab | 85.71±1.86 b |
| P80 +A 20 % | 17.69±0.33 a | 17.67±0.34 b | 16.40±0.75 ab | 16.51±0.41 ab | 17.26±0.33 ab | 84.36±1.73 b |
| P90 +A 10 % | 17.72±0.35 a | 17.71±0.32 b | 15.77±0.71 b | 16.69±0.44 ab | 17.20±0.32 ab | 83.00±1.41 b |
| L.S.D at P<0.05 | 0.8547 | 0.7787 | 1.6955 | 1.2581 | 1.0707 | 7.0705 |

Values represent means of 12 panellists (Mean ± S.E.) P: (Papaya) A: (Apricot)
[a,b] There is no significant different (P > 0.05) between any two means, within the same attribute have the same letter.

Heat penetration data at the slowest point were obtained for apricot juice, papaya puree, apricot and papaya nectars separated and blended canned in (Ø 65 x 110 mm) which were processed at three thermal processes at retort temperatures 90, 95 and 100°C for 35, 25 and 15 minutes, respectively, after come up time, with initial temperatures ranged between 37.8 to 47.1 °C. Come up times were ranged between 8 to 12 minutes. Cooling water temperature was 24°C. Heat penetration data were plotted as heating and cooling curves on semilog paper Fig. (1). Linear trend lines were obtained and squares correlations coefficient were greater than 0.98. The $f_h$, $J_h$, $f_c$, and $J_c$ were calculated and tabulated in Table (3).

**Evaluation of the optimum thermal process time:**

Heating and cooling curves parameters combined with heat resistance parameters of pectin methylstrase were used to evaluate the carried out thermal processing as indicating in Table (4), using Stumbo mathematical method Ramaswamy and Marcotte (2006). To evaluate the optimum thermal process time, the required F value must be determined. Usually the required F value in the non acidic foods must cover the high value for either healthy 12 D concept or commercial concept. In the case of high acid foods it must cover the commercial concept. In this work it was designed to calculate F value, which cover 12 D for pectin methyl esterase. This means that it will be the F value required to retain $10^{-10}$ % of this enzyme. Using $D_{100}$ value of 0.39 minutes for papaya (Siddaling *et al.*, 1985) resulted in calculated F value of 4.68 minutes. Calculation required the values of "g" which were obtained by carrying out multiple interpolations in the tables prepared by Stumbo (1973) which represent the relationship ($f_h$/U:g) for different Z values at different $J_c$ value. To facilitate the multiple interpolation we prepared special program with Microsoft excel software. This program included the required mathematical equations. This was done through input the available g values, so it is possible to obtaine instantly the required g values at given Z and $J_{cc}$ values. The calculation procedure is summarized in Table (4). It could be noticed that the required optimum process time were 27.48, 27.78, 27.15, 28.92, 25.20 and 24.15 for canned apricot juice, papaya puree, apricot nectar, papaya nectar, blend 6 and blend 7, respectively, at retort and initial temperature of 90 °C and 40°C, respectively.

**Table (3): Values of $f_{ch}$, $J_{ch}$ during heating process and $f_{cc}$, $J_{cc}$ during cooling process at 24°C for apricot juice, papaya puree, apricot and papaya nectars separated and blended canned in cans (Ø 65x110 mm)**

| Para-meters | Retort temperature °C | Apricot juice | Papaya puree | Apricot nectar | Papaya nectar | Blend (6) | Blend (7) |
|---|---|---|---|---|---|---|---|
| $f_{ch}$ | 90 °C | 22.17 | 29.33 | 14.18 | 18.48 | 13.18 | 12.17 |
| | 95°C | 17.70 | 23.75 | 12.59 | 18.80 | 10.73 | 10.82 |
| | 100°C | 14.41 | 17.76 | 10.64 | 15.80 | 8.81 | 9.71 |
| $J_{ch}$ | 90 °C | 1.031 | 0.967 | 1.272 | 0.912 | 0.980 | 0.895 |
| | 95°C | 0.895 | 0.826 | 0.836 | 0.851 | 0.882 | 0.839 |
| | 100°C | 0.595 | 0.615 | 0.796 | 0.769 | 0.844 | 0.780 |
| $T_{ih}$ | 90 °C | 47.10 | 41.30 | 39.20 | 39.80 | 38.80 | 39.20 |
| | 95°C | 42.00 | 45.80 | 39.90 | 39.90 | 37.80 | 39.50 |
| | 100°C | 44.50 | 45.90 | 38.50 | 40.20 | 39.50 | 38.90 |
| $f_{cc}$ | 90 °C | 18.12 | 27.03 | 15.38 | 17.70 | 15.87 | 15.34 |
| | 95°C | 15.90 | 26.88 | 14.97 | 15.15 | 15.48 | 14.14 |
| | 100°C | 14.33 | 20.79 | 13.14 | 14.99 | 14.84 | 11.86 |
| $J_{cc}$ | 90 °C | 1.783 | 1.816 | 1.653 | 0.931 | 1.703 | 1.797 |
| | 95°C | 1.922 | 1.858 | 1.928 | 1.096 | 1.776 | 1.738 |
| | 100°C | 1.542 | 1.782 | 1.683 | 1.497 | 1.997 | 1.517 |

**Establishing thermal process schedule for optimum thermal process time at different retort and initial temperatures:**

The obtained heat penetration data at the laboratory (90, 95 and 100 °C retort temperature) at the slowest point were used to predict other heat penetration data at other initial temperatures (40, 45, 50, 55, 60, 65, 70 and 75°C), applying equation of (Schultz and Olson 1940), mentioned by Holdsworth (1997). The new data were plotted. It was noticed that $f_{ch}$ and $J_{ch}$ have not changed with the new data. This is logic that Schultz and Olson equation which is:

$$T' = Tr - \frac{Tr - Ti'}{Tr - Ti}(Tr - T)$$

could be expressed as follows:

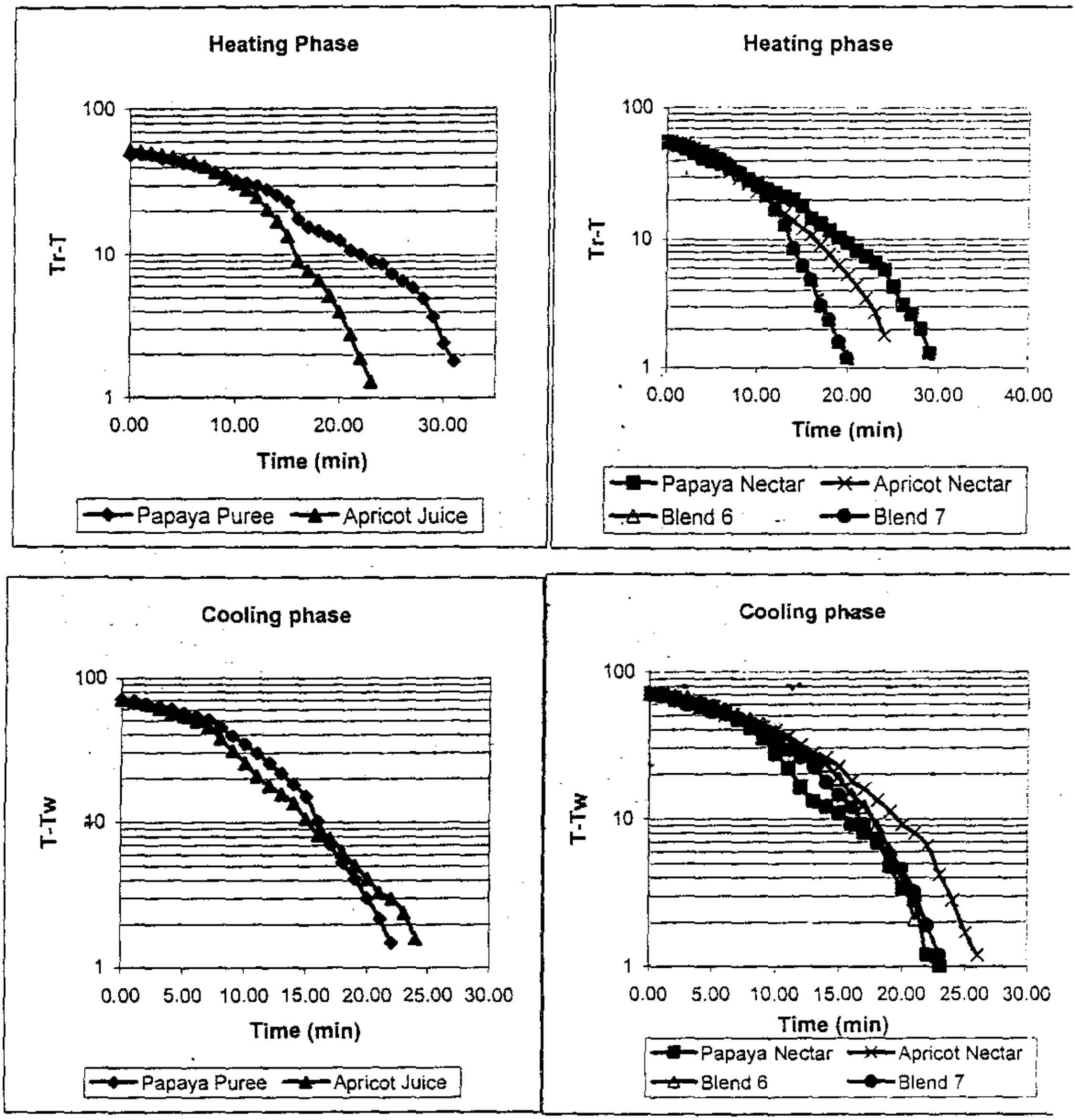


Fig. (1): Heat penetration curves of apricot juice, papaya puree, apricot & papaya nectars and nectar blends at 95, 24 °C retort and cooling temperatures, respectively.

$$\frac{Tr - T'}{Tr - Ti'} = \frac{Tr - T}{Tr - Ti}$$

This means that any new transformed temperature (T') expressed in dimensionless form is the same for the original temperature (T). So $f_{ch}$ and $J_{ch}$ must be the same and the square correlation coefficient $R^2$ for the linear trend line of the straight portion of the heating curve also must be the same. The old $f_{ch}$ and $J_{ch}$ values in Table 4 were used. New parameters were obtained and new calculations were carried out (Table 5).

**Table (4): Evaluation of the optimum thermal process time when enzyme retention =$10^{-10}$ % for apricot juice, papaya puree, apricot and papaya nectars and nectar blends canned in cans (Ø 65x110 mm)**

| Thermal process parameters | Retort temp. °C | Apricot juice | Papaya puree | Apricot nectar | Papaya nectar | Blend (6) | Blend (7) |
|---|---|---|---|---|---|---|---|
| Come up time (min) | 90 °C | 10.00 | 10.00 | 8.00 | 8.50 | 8.00 | 8.50 |
| | 95°C | 10.00 | 11.00 | 9.00 | 9.00 | 8.50 | 9.00 |
| | 100°C | 11.00 | 12.00 | 9.00 | 10.00 | 9.00 | 9.50 |
| Initial temperature °C | 90 °C | 47.10 | 41.30 | 39.20 | 39.80 | 38.80 | 39.20 |
| | 95°C | 42.00 | 45.80 | 39.90 | 39.90 | 37.80 | 39.50 |
| | 100°C | 44.50 | 45.90 | 38.50 | 40.20 | 39.50 | 38.90 |
| $f_{ch}$ (min) | 90 °C | 22.17 | 29.33 | 14.18 | 18.48 | 13.18 | 12.17 |
| | 95°C | 17.70 | 23.75 | 12.59 | 18.80 | 10.73 | 10.827 |
| | 100°C | 14.41 | 17.76 | 10.64 | 15.80 | 8.81 | 9.71 |
| $f_{cc}$ (min) | 90 °C | 18.12 | 27.03 | 15.38 | 17.70 | 15.87 | 15.34 |
| | 95°C | 15.90 | 26.88 | 14.97 | 15.15 | 15.48 | 14.14 |
| | 100°C | 14.33 | 20.79 | 13.14 | 14.99 | 14.84 | 11.86 |
| $J_{ch}$ | 90 °C | 1.031 | 0.967 | 1.272 | 0.912 | 0.980 | 0.895 |
| | 95°C | 0.895 | 0.826 | 0.836 | 0.851 | 0.882 | 0.839 |
| | 100°C | 0.595 | 0.615 | 0.796 | 0.769 | 0.844 | 0.780 |
| $J_{cc}$ | 90 °C | 1.783 | 1.816 | 1.653 | 0.931 | 1.703 | 1.797 |
| | 95°C | 1.922 | 1.858 | 1.928 | 1.096 | 1.776 | 1.738 |
| | 100°C | 1.542 | 1.782 | 1.683 | 1.497 | 1.997 | 1.517 |
| Z value reference °C* | | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 |
| Reference temperature °C | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| D value of (P.M.E.) (min) * | | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| % of enzyme retention | | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ |
| Required F value (min) | | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 |
| Optimum holding time (min) | 90 °C | 26.01 | 27.45 | 27.25 | 28.95 | 25.34 | 24.24 |
| | 95°C | 12.99 | 11.92 | 12.30 | 16.20 | 12.79 | 12.50 |
| | 100°C | 5.20 | 5.11 | 6.76 | 7.03 | 6.27 | 6.84 |

* Siddaling *et al.* (1985)

The optimum thermal process times are tabulated in Table (6). Such thermal process schedule may be helpful for the manufacturers, wishing to introduce these new products.

**Table (5): Calculations to obtain the optimum thermal time at 90, 95 and 100°C retorts and initial temperatures for apricot juice, papaya puree, apricot and papaya nectars and nectar blends canned in cans (Ø 65x110 mm)**

| Thermal processing parameters | | Apricot juice | | | Papaya puree | | |
|---|---|---|---|---|---|---|---|
| | | 90 | 95 | 100 | 90 | 95 | 100 |
| Come up time "*l*" (min) | | 10.00 | 10.00 | 11.00 | 10.00 | 11.00 | 12.00 |
| Lab $T_i$ °C | | 47.10 | 42.00 | 44.50 | 41.30 | 45.80 | 45.90 |
| $f_{ch}$ (min) | | 22.17 | 17.70 | 14.41 | 29.33 | 23.75 | 17.76 |
| $f_{cc}$ (min) | | 18.12 | 15.90 | 14.33 | 27.03 | 26.88 | 20.79 |
| $J_{ch}$ | | 1.031 | 0.895 | 0.595 | 0.967 | 0.826 | 0.615 |
| $J_{cc}$ | | 1.783 | 1.922 | 1.542 | 1.816 | 1.858 | 1.782 |
| Z value °C * | | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 |
| Reference temperature °C | | 100 | 100 | 100 | 100 | 100 | 100 |
| D value of (PME) (min) * | | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| % of retention enzyme | | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ |
| Required F value (min) | | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 |
| $T_i$ 40°C | $I_h = (T_r - T_i)$ | 50.00 | 55.00 | 60.00 | 50.00 | 55.00 | 60.00 |
| | B | 27.48 | 13.27 | 5.69 | 27.78 | 13.07 | 5.91 |
| $T_i$ 45°C | $I_h = (T_r - T_i)$ | 45.00 | 50.00 | 55.00 | 45.00 | 50.00 | 55.00 |
| | B | 26.47 | 12.54 | 5.14 | 26.44 | 12.09 | 5.24 |
| $T_i$ 50°C | $I_h = (T_r - T_i)$ | 40.00 | 45.00 | 50.00 | 40.00 | 45.00 | 50.00 |
| | B | 25.33 | 11.73 | 4.55 | 24.94 | 11.00 | 4.50 |
| $T_i$ 55°C | $I_h = (T_r - T_i)$ | 35.00 | 40.00 | 45.00 | 35.00 | 40.00 | 45.00 |
| | B | 24.05 | 10.82 | 3.89 | 23.24 | 9.78 | 3.69 |
| $T_i$ 60°C | $I_h = (T_r - T_i)$ | 30.00 | 35.00 | 40.00 | 30.00 | 35.00 | 40.00 |
| | B | 22.56 | 9.80 | 3.15 | 21.28 | 8.41 | 2.78 |
| $T_i$ 65°C | $I_h = (T_r - T_i)$ | 25.00 | 30.00 | 35.00 | 25.00 | 30.00 | 35.00 |
| | B | 20.81 | 8.61 | 2.31 | 18.96 | 6.82 | 1.75 |
| $T_i$ 70°C | $I_h = (T_r - T_i)$ | 20.00 | 25.00 | 30.00 | 20.00 | 25.00 | 30.00 |
| | B | 18.66 | 7.21 | 1.35 | 16.11 | 4.94 | 0.98 |
| $T_i$ 75°C | $I_h = (T_r - T_i)$ | 15.00 | 20.00 | 25.00 | 15.00 | 20.00 | 25.00 |
| | B | 15.89 | 5.50 | 0.21 | 12.45 | 2.63 | 0.49 |

* Siddaling *et al.* (1985)

**Table (5): Continual**

| Thermal processing parameters | | Apricot nectar 90 | Apricot nectar 95 | Apricot nectar 100 | Papaya nectar 90 | Papaya nectar 95 | Papaya nectar 100 |
|---|---|---|---|---|---|---|---|
| Come up time "*l*" (min) | | 8.00 | 9.00 | 9.00 | 8.50 | 9.00 | 10.00 |
| Lab $T_i$ °C | | 39.20 | 39.90 | 38.50 | 39.80 | 39.90 | 40.20 |
| $f_{ch}$ (min) | | 14.18 | 12.59 | 10.64 | 18.48 | 18.80 | 15.80 |
| $f_{cc}$ (min) | | 15.38 | 14.97 | 13.14 | 17.70 | 15.15 | 14.99 |
| $J_{ch}$ | | 1.272 | 0.836 | 0.796 | 0.912 | 0.851 | 0.769 |
| $J_{cc}$ | | 1.653 | 1.928 | 1.683 | 0.931 | 1.096 | 1.497 |
| Z value °C * | | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 |
| Reference temperature °C | | 100 | 100 | 100 | 100 | 100 | 100 |
| D value of (PME) (min) * | | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| % of retention enzyme | | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ |
| Required F value (min) | | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 |
| $T_i$ 40°C | $I_h = (T_r - T_i)$ | 50.00 | 55.00 | 60.00 | 50.00 | 55.00 | 60.00 |
| | B | 27.15 | 12.29 | 6.65 | 28.92 | 16.18 | 7.05 |
| $T_i$ 45°C | $I_h = (T_r - T_i)$ | 45.00 | 50.00 | 55.00 | 45.00 | 50.00 | 55.00 |
| | B | 26.50 | 11.77 | 6.24 | 28.07 | 15.40 | 6.45 |
| $T_i$ 50°C | $I_h = (T_r - T_i)$ | 40.00 | 45.00 | 50.00 | 40.00 | 45.00 | 50.00 |
| | B | 25.78 | 11.19 | 5.80 | 27.12 | 14.54 | 5.80 |
| $T_i$ 55°C | $I_h = (T_r - T_i)$ | 35.00 | 40.00 | 45.00 | 35.00 | 40.00 | 45.00 |
| | B | 24.95 | 10.55 | 5.32 | 26.05 | 13.58 | 5.08 |
| $T_i$ 60°C | $I_h = (T_r - T_i)$ | 30.00 | 35.00 | 40.00 | 30.00 | 35.00 | 40.00 |
| | B | 24.00 | 9.82 | 4.77 | 24.81 | 12.49 | 4.27 |
| $T_i$ 65°C | $I_h = (T_r - T_i)$ | 25.00 | 30.00 | 35.00 | 25.00 | 30.00 | 35.00 |
| | B | 22.88 | 8.98 | 4.16 | 23.35 | 11.23 | 3.35 |
| $T_i$ 70°C | $I_h = (T_r - T_i)$ | 20.00 | 25.00 | 30.00 | 20.00 | 25.00 | 30.00 |
| | B | 21.51 | 7.98 | 3.44 | 21.56 | 9.75 | 2.29 |
| $T_i$ 75°C | $I_h = (T_r - T_i)$ | 15.00 | 20.00 | 25.00 | 15.00 | 20.00 | 25.00 |
| | B | 19.73 | 6.76 | 2.60 | 19.25 | 7.92 | 1.04 |

* Siddaling *et al.* (1985)

Table (5): Continual

| Thermal processing parameters | | Blend (6) | | | Blend (7) | | |
|---|---|---|---|---|---|---|---|
| | | 90 | 95 | 100 | 90 | 95 | 100 |
| Come up time "*l*" (min) | | 8.00 | 8.50 | 9.00 | 8.50 | 9.00 | 9.50 |
| Lab $T_i$ °C | | 38.80 | 37.80 | 39.50 | 39.20 | 39.50 | 38.90 |
| $f_{ch}$ (min) | | 13.18 | 10.73 | 8.81 | 12.17 | 10.82 | 9.71 |
| $f_{cc}$ (min) | | 15.87 | 15.48 | 14.84 | 15.34 | 14.14 | 11.86 |
| $J_{ch}$ | | 0.980 | 0.882 | 0.844 | 0.895 | 0.839 | 0.780 |
| $J_{cc}$ | | 1.703 | 1.776 | 1.997 | 1.797 | 1.738 | 1.517 |
| Z value °C * | | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 | 15.10 |
| Reference temperature °C | | 100 | 100 | 100 | 100 | 100 | 100 |
| D value of (PME) (min) * | | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| % of retention enzyme | | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ | $10^{-10}$ |
| Required F value (min) | | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 | 4.68 |
| $T_i$ 40°C | $I_h = (T_r - T_i)$ | 50.00 | 55.00 | 60.00 | 50.00 | 55.00 | 60.00 |
| | B | 25.20 | 12.61 | 6.24 | 24.15 | 12.46 | 6.77 |
| $T_i$ 45°C | $I_h = (T_r - T_i)$ | 45.00 | 50.00 | 55.00 | 45.00 | 50.00 | 55.00 |
| | B | 24.60 | 12.16 | 5.90 | 23.59 | 12.01 | 6.40 |
| $T_i$ 50°C | $I_h = (T_r - T_i)$ | 40.00 | 45.00 | 50.00 | 40.00 | 45.00 | 50.00 |
| | B | 23.92 | 11.67 | 5.53 | 22.97 | 11.51 | 6.00 |
| $T_i$ 55°C | $I_h = (T_r - T_i)$ | 35.00 | 40.00 | 45.00 | 35.00 | 40.00 | 45.00 |
| | B | 23.16 | 11.13 | 5.13 | 22.26 | 10.96 | 5.55 |
| $T_i$ 60°C | $I_h = (T_r - T_i)$ | 30.00 | 35.00 | 40.00 | 30.00 | 35.00 | 40.00 |
| | B | 22.28 | 10.50 | 4.68 | 21.45 | 10.33 | 5.06 |
| $T_i$ 65°C | $I_h = (T_r - T_i)$ | 25.00 | 30.00 | 35.00 | 25.00 | 30.00 | 35.00 |
| | B | 21.23 | 9.78 | 4.17 | 20.49 | 9.61 | 4.49 |
| $T_i$ 70°C | $I_h = (T_r - T_i)$ | 20.00 | 25.00 | 30.00 | 20.00 | 25.00 | 30.00 |
| | B | 19.96 | 8.93 | 3.58 | 19.31 | 8.75 | 3.84 |
| $T_i$ 75°C | $I_h = (T_r - T_i)$ | 15.00 | 20.00 | 25.00 | 15.00 | 20.00 | 25.00 |
| | B | 18.31 | 7.90 | 2.89 | 17.79 | 7.70 | 3.07 |

* Siddaling *et al.* (1985)

**Table (6): Thermal process schedule for the optimum thermal process times (min) at different retort and initial temperatures for apricot juice, papaya puree, apricot and papaya nectar and nectar blends.**

| Products | $T_r$ °C | Initial temperatures °C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Lab $T_i$ | $T_i$ 40 | $T_i$ 45 | $T_i$ 50 | $T_i$ 55 | $T_i$ 60 | $T_i$ 65 | $T_i$ 70 | $T_i$ 75 |
| Apricot juice | 90 | 26.01 | 27.48 | 26.47 | 25.33 | 24.05 | 22.56 | 20.81 | 18.66 | 15.89 |
| | 95 | 12.99 | 13.27 | 12.54 | 11.73 | 10.82 | 9.80 | 8.61 | 7.21 | 5.50 |
| | 100 | 5.20 | 5.69 | 5.14 | 4.55 | 3.89 | 3.15 | 2.31 | 1.35 | 0.21 |
| Papaya puree | 90 | 27.45 | 27.78 | 26.44 | 24.94 | 23.24 | 21.28 | 18.96 | 16.11 | 12.45 |
| | 95 | 11.92 | 13.07 | 12.09 | 11.00 | 9.78 | 8.41 | 6.82 | 4.94 | 2.63 |
| | 100 | 5.11 | 5.91 | 5.24 | 4.50 | 3.69 | 2.78 | 1.75 | 0.98 | 0.49 |
| Apricot nectar | 90 | 27.25 | 27.15 | 26.50 | 25.78 | 24.95 | 24.00 | 22.88 | 21.51 | 19.73 |
| | 95 | 12.30 | 12.29 | 11.77 | 11.19 | 10.55 | 9.82 | 8.98 | 7.98 | 6.76 |
| | 100 | 6.76 | 6.65 | 6.24 | 5.80 | 5.32 | 4.77 | 4.16 | 3.44 | 2.60 |
| Papaya nectar | 90 | 28.95 | 28.92 | 28.07 | 27.12 | 26.05 | 24.81 | 23.35 | 21.56 | 19.25 |
| | 95 | 16.20 | 16.18 | 15.40 | 14.54 | 13.58 | 12.49 | 11.23 | 9.75 | 7.92 |
| | 100 | 7.03 | 7.05 | 6.45 | 5.80 | 5.08 | 4.27 | 3.35 | 2.29 | 1.04 |
| Blend (6) | 90 | 25.34 | 25.20 | 24.60 | 23.92 | 23.16 | 22.28 | 21.23 | 19.96 | 18.31 |
| | 95 | 12.79 | 12.61 | 12.16 | 11.67 | 11.13 | 10.50 | 9.78 | 8.93 | 7.90 |
| | 100 | 6.27 | 6.24 | 5.90 | 5.53 | 5.13 | 4.68 | 4.17 | 3.58 | 2.89 |
| Blend (7) | 90 | 24.24 | 24.15 | 23.59 | 22.97 | 22.26 | 21.45 | 20.49 | 19.31 | 17.79 |
| | 95 | 12.50 | 12.46 | 12.01 | 11.51 | 10.96 | 10.33 | 9.61 | 8.75 | 7.70 |
| | 100 | 6.84 | 6.77 | 6.40 | 6.00 | 5.55 | 5.06 | 4.49 | 3.84 | 3.07 |

## REFERENCES


A.O.A.C. (2000): Official Methods of Analysis, 17th Ed. Association of Official Analytical Chemists, Inc. USA.

Afaghi, M.; Ramaswamy, H.S. and Prasher, S.O. (2001): Thermal process calculations using artificial neural network models. Food Res. Int. (34) 55–65.

Alvarado, J.D. (1991): Specific heat of dehydrated pulps of fruits. J. Food Process Engineering 14; 189-195.

Ball, C.O. (1923): Thermal process time for canned food. Bulletin National Research Council, 7, Part 1, No. 37, Washington, D.C.

Ball, C.O. and Olson, F.C.W. (1957): Sterilization in food technology. McGraw-Hill, New York.

Brekke, J.E.; Cavaletto, C.G.; Nakayama, T.O.M. and Suehisa, R.H. (1976): Effect of storage temperature and container lining on some quality attributes of papaya nectar. J. Agric. Food Chem., 24, 341-343.

Carmen, A.M.; Menchu, J.F.; Rolz, C.; Garcia, R. and Calzada, F. (1978): The papaya. Abstracts of Papers, American Chemical Society; 176, AGFD 43.

Castaldo, D.; Quaglivolo, L.; Servillo, L.; Balestrieri, C. and Giovane, A. (1989): Isolation and characterization of pectin methylesterase from apple fruit. J. Food Sci., 54, 653-655.

Cleland, A.C. and Robertson, G.L. (1985): Determination of thermal processes to ensure commercial sterility of food in cans, In: Developments in food preservation 3. Throne, S., Ed., Elsevier Applied Science, New York.

Dastur, K.; Weckel, K. and Von Elbe, J. (1968): Thermal process for canned cherries. Food Technol., 22: 1176-1182.

El-Mansy, H.A; Bahlol, H.E.M.; Mahmoud, H.M. and Sharoba, M.A. (2000): Comparative study on chemical and rheological properties of orange juice and its concentrates. Annals of Agric Sc. Moshtohor 38 (3) 1557-1574.

Fayyaz, A.; Asbi, B.A.; Ghazali, H.M..; CheMan, Y.B. and Jinap, S. (1995): Kinetics of papaya pectinesterase. Food Chemistry 53, 129-135.

Fellows, P. (1988): Food processing technology principles and practices, Ellis Horwood, Chichester, England.

Gomez, K.A. and Gomez, A.A. (1984): Statistical Procedures for Agriculture Research. John Wiliy and Sons Editor Inc. USA 2Ed., Chapter 3,129-184.

Guerrero, S.N. and Alzamora, S.M. (1998): Effect of pH, temperature and glucose addition on flow behavior of fruit purees: Π. Peach, papaya and mango purees. J. Food Eng., 37; 77-101.

Harvey, T.C. and Catherine, G.C. (1982): Aseptically packaged papaya and guava puree: Changes in chemical and sensory quality during processing and storage. J. Food Sci., (47) 1164-1169.

Hasahallis, S.; Ramaswamy and Singh, R.P. (1997): Sterilization Process Engineering. In Valentas, R.J.; Rostein, E. and Singh, R.P. Hand book of Food Engineering Practice CRC Press New York.

Hayakawa, K.I. (1970): Evperimental formulas for accurate estimation of transient temperature of food and their application to thermal process evaluation, Food Technol. 24(12): 89.

Hayakawa, K.I.(1978): A critical review of mathematical procedures for determining proper heat sterilization processes. Food Technol. 32(3) 59-65.

Holdsworth, S.D. (1997): Thermal processing of packaged foods. Blackie Academic & Professional, London.

Larkin, J.W. (1989): Use of modified Ball's formula method to evaluate aseptic processing in liquid foods containing particulates. Food Technol 43(3) 124-131.

Larkin, J.W. and Berry, R.B. (1991): Estimating cooling process lethality for different cooling J values. J. Food Sci., 56(4) 1063-1067.

Lopez, A. (1987): A complete course in canning and related processes, $12^{th}$ ed. The canning trade Baltimare, MD.

Magalhaes, M.A.; Tosello, R.M. and Massaguer, P.R. (1999): Thermal design process for acidified canned papaya (*Carica papaya* L.) pulp. J Food Process Engineering 22(2)103-112.

Magalhaes, M.A.; Tosello, R.M.; Massaguer, P.R. (1996): Thermal inactivation of pectinesterase in papaya pulp (pH 3.8). J Food Process Engineering 19, 353-361.

MALR (2005): Study of the indicators agricultural statistics. Vol., 2, Summer and Nile crops 2004. Ministry of Agriculture and Land Reclamation, Egypt.

Merson, R.L.; Singh, R.P. and Carroad, P.A. (1978): An evaluation of Ball's formula method of thermal process calculations. Food Technol., 32(3) 66-72,75.

Meydov, S.; Saguy, I. and Kopelman, I.J. (1977): Browning determination in citrus products. J. Agri. Food Chem., 25 (3): 602.

Nath, N. and Ranganna, S. (1983): Determination of thermal process schedule for guava (Psidium guajava Linn.). J.Fd. Technol., 18: 301-316.

Onweluzo, J.C.; Vijayalakshmi, M.R.; Vijayanand, P. and Eipeson, W.E. (1999): Detarium Microcarpum Polysaccharide as a Stabilizer in Processed Fruit Products. Lebensm.-Wiss. u.-Technol., 32, 521- 526.

Ramaswamy, H.S., Abdelrahim, K.; and Smith, J. (1992): Thermal processing and computer modeling. In H. Hui (Ed.), Encyclopedia of Food Science and Technology (pp. 2538-2552). New York: Wiley.

Ramaswamy, H. and Marcotte,. M. (2006): Food processing ' principles and applications'.CRC Press, Taylor & Francis Group.

Rao, V. and Tapia, M.S. (1991): Evaluation of water activity measurements with a dew point electronic humidity meter. Lebensmittel Wissenschaft und Technologie, 24; 208-213.

Robertson, G.L. (1979): The fractional extraction and quantitative determination of pectic substances in grapes and musts. American Journal of Enolvogyol. and Viticulture, 30; 182-186.

Rodrigo, M. and Martinez, A. (1988): Determination of a process time for a new product: canned low acid artichoke hearts. International J. of Food Sci. and Techn. 23: 31-41.

Rodrigo, M. and Safòn, J. (1982): Optimizatiòn del proceso de esterilizaciòn. Bases cientificas. Revista Agroquimica Tecnologia de Alimentos, 22(1): 22-38. c.f. Rodrigo and Martinez (1988).

Rodrigues, C.A.; Cunha, L.R. and Hubinger, D. (2003): Rheological properties and colour evaluation of papaya during osmotic dehydration processing. J. Food Eng. (59) 129–135.

Rutledge, P. (1996): Production of non fermented fruit products. In Fruit Processing (ed. Arthey, D. and Ashurst, P.R. Blackie Academic & Professional, an imprint of Chapman & Hall.

Sablani, S.S. and Shayya, W.H. (2001): Computarization of Stumbo's method of thermal process calculations using neural networks. J. Food Eng. (47) 233–240.

Schultz, O.T. and Olsen, F.E.W. (1940): Thermal processing of food in tin containers. III. Recent improvement in the general method of thermal process calculation special coordinate paper and methods of converting initial and retort temperature. Food Res. 5: 399. (C.f. Stumbo, 1973, P 150-151).

Siddaling, A.; Srinivasan, B.; Padival, R.A. and Ranganna, S. (1985): Determination of thermal process schedule for canned mango, papaya and guava pulps. Acta. Alimentoria, 14(4): 331-342.

Simpson, R.; Figueroa, I. and Teixeira, A. (2007): Simple, practical, and efficient on-line correction of process deviations in batch retort through simulation. Food Control 18, 458–465.

Skalaki, C. and Sistrunk, W.A. (1973): Factors influencing color degradation in concorde grape juice. J. Food Sci.; 38, 1060-1064.

Steele, R.J. and Board, P.W. (1979): Thermal process calculations using sterilizing ratio. J. Food Technol. 14: 227.

Steele, R.J.; Board, P.W.; Best, D.J. and Willeox, M.E. (1979): Revision of the formula method tables of thermal process evaluation. J. Food Sci. 44: 954.

Stumbo, C.R. (1973): Thermobacteriology in food processing.(2nd ed.) Academic Press, New York.

Teixeira, A..A. and Tucker, G.S. (1997): On-line retort control in thermal sterilization of canned foods. Food Control (8)13–20.

Toledo, R.T. (1997): Fundamentals of food process engineering. Chapman & Hall, Inc., New York.

Tressler, D.K. and Joslyn, M.A. (1971): Fruit and vegetable juice processing technology. AVI Publishing Company, INC, New York, U.S.A.

Vinters, J.E.; Patel, R.H. and Halaby, G.A. (1975): Thermal process evaluation by programmable calculator, Food Technol. 29(3): 42.

Voi, A.L.; Impembo, M.; Fasanaro, G. and Castaldo, D. (1995): Chemical characterization of apricot puree. Journal of Food Composition and Analysis; 8 (1) 78-85.

Yang, W.H. and Rao, M.A. (1998): Numerical study of parameters affecting broken heating curve. J. Food Eng. (37) 43–61.

## إعداد جدول لتقدير الوقت الأمثل للمعاملة الحرارية لبعض منتجات الفاكهة المعلبة

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هذا البحث يهدف إلى الحصول على جدول يبين الوقت الأمثل للمعاملة الحرارية عند درجات حرارة مختلفة وكذلك عند عدة درجات حرارة ابتدائية لمنتجات معلبة غير تقليدية للعصائر ومنتجاتها فى السوق المصرى. ففى هذا البحث تم استخدام فاكهة الباباظ الرخيصة الثمن والتى تزرع الآن بمساحات كبيرة فى مصر فى إنتاج بوريه ونكتار وتم أيضا تحضير عصير ونكتار المشمش وكذا تحضير عشر خلطات من مخاليط البباظ والمشمش وتم إجراء التحكيم الحسى لها لاختيار أفضل نسب الخلط وكانت كل الخلطات لها قبول لدى المحكمين. تم تعليب الخلطات التى حصلت على أعلى الدرجات فى التقييم الحسى (خلطة ٦ و خلطة ٧) بالإضافة إلى بوريه البباظ وعصير المشمش ونكتار البباظ ونكتار المشمش فى علب مقاس ٦٥ × ١١٠ مم وذلك لإجراء المعاملة الحرارية على درجات مختلفة (٩٠، ٩٥ و ١٠٠ °م) وعند البدء بعدة

درجات حرارة ابتدائية هى (٤٠، ٤٥، ٥٠، ٥٥، ٦٠، ٦٥، ٧٠ و٧٥° م). اعتمدت الحسابات على ثوابت المقاومة الحرارية لأنزيم البكتين ميثيل استيريز لحساب قيمة F التى تغطى 12D لإنزيم بكتين ميثيل إستيريز و على ثوابت منحنيات التسخين والتبريد المقدرة عمليا عند المعاملة الحرارية على ٩٠، ٩٥ و ١٠٠ ° م. ولقد تم الحصول على ثوابت تلك المنحنيات باستخدام أسلوب تحليل الانحدار. وكانت قيمة ال $f_h$ أعلى ما يكون عند مسافة ¼ من قاع العلبة لجميع المنتجات ما عدا بوريه البابـاظ فكانت أعلى قيمة لل $f_h$ عند مسافة ⅓ . ولقد تم استخدام الطريقة الحسابية فى حساب الوقت الأمثل للتعقيم وتم إنشاء جدول مقترح للمعاملات الحرارية لمنتجات العصائر تحت الدراسة باستخدام درجات حرارة ابتدائية مختلفة وكذلك درجات معاملة حرارية مختلفة وذلك لحساب أنسب وقت للمعاملة الحرارية حسب درجة الحرارة الابتدائية المستخدمة وكذلك درجة حرارة المعاملة الحرارية المتاحة. ومثل هذه الجداول يكون لهما أهمية كبيرة فى مصانع الإنتاج والتى تهتم وتقوم بإنتاج مثل هذه المنتجات حيث أنهـا تـوفر الطاقة اللازمة لأجراء المعاملة الحرارية والمحافظة على القيمة الغذائية للمنتجات ، مع الحصول على منتج آمن ذو جودة عالية. وكانت قيم الثوابت الحرارية أثنـاء مرحلـة التسخين $f_{ch}$ و $J_{ch}$ لتتروواح ما بـين (٨,٨١ –٢٩,٣٣ دقيقـة) ومـا بـين (٠,٥٩٤٥ – ١,٢٧٢) على التوالى . أما قيم $f_{cc}$ و $J_{cc}$ وهى الثوابت الحرارية التى تم تقديرها أثنـاء مرحلة التبريد فقد تروواحت ما بين (١١,٨٦ –٢٧,٠٣ دقيقة) ومـا بـين (٠,٩٣٠٧ – ١,٩٩٧٤) على التوالى.