Computer-Based On-Line Assessment of Sterilizing Value for Canned Food

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ABSTRACT

Heating of canned food is to prolong shelf life and provide safety to the consumer while trying to maintain product quality. Sterilizing value or lethality process (F_o) is well accepted as an indicator for evaluating optimum thermal process time. Software and hardware used in the country for process control/design or validation are all imported. The study and development of local devices for computer-based on-line assessment of sterilizing value for canned food was the objective of this research. Design of the program for interfacing and processing to obtained on-line time-temperature history data was written by Visual Basic 6.0. This program displayed heat penetration curve during sterilizing graphically and also dynamically analyzed the data for accomplished F_o from all thermocouple probes in every 4.5 seconds. The accomplished F_o was calculated by general method and it was kept on recalculating until being reached the specified target F_o of that particular product. The program then would display warning message for the operator to shut off steam but the calculation still went on during cooling. The demonstration of such a computer-based on-line assessment with concentrated pineapple juice for process design and heat distribution in retort could be obtained.

Key words: sterilizing value, process lethality, heat processing, sterilization, canned food

INTRODUCTION

Heating process for food is of importance to the consumers since it is considered to be one of food preservation techniques. Under these techniques food can be stored or edible within a long period. One of them which requires heating is sterilization process. Thermal sterilization of prepackaged canned foods in retort has been the most widely used during the twentieth century. Typically this method consists of heating food containers in pressurized retorts at specified temperatures for prescribed lengths of times (Teixeira and Tucker, 1997).

The process time for canned food is calculated on the basis of achieving sufficient bacterial inactivation in each container to have the compliance with public health standards or food safety as well as minimize the probability of food spoilage. The traditional methods for thermal process calculations or validation such as Ball and Stumbo methods were developed and widely used but they required the use of tables and a series of calculation steps. In general foods should not be overheat-processed since it leads to detrimental effect to food quality as well as the waste of energy and water. Thus heat should be minimally applied or applied as necessary as it needs. In order to get

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the above mentioned process, it is essential to have proper machine or devices associated with analysis method to assess the process efficacy involving heat treatment. However, in Thailand most of the hardware and software available now are imported. They are designed basically on either the post assessment (after completely heating foods) or undergo heating. Up to now more efforts have been carried out for developing the intelligent on-line retort control system which is capable of rapid evaluation, on-line correction and printed documentation. The development of local devices or software for such purposes is rarely found but it should get supported from Thai government to develop our own technology. Thus the objectives of the research were to develop visual basic computer software for on-line data acquisition and assess sterilizing value or process lethality (F_o) while heating. The system F_o of the process could be further used in process design and investigate heat distribution in retort. The coldest point in container is validated by using accomplished F_o as an indicator of heat accumulation. The software also can be used as an educational tool for thermal processing study.

Accomplished F_o of the coldest point in canned food can be expressed as

$$F_o = \int_0^{t_h} 10^{(T - T_{ref})/z} \, \mathrm{dt} \qquad (1)$$

It is calculated in the unit of minutes at reference temperature (T_{ref}); T is the temperature at coldest point in the container; T_{ref} is a standardized reference temperature, usually 121.1 °C or 250°F ; z is temperature dependency factor from microbial thermal death time curve and expressed as temperature change required for a ten-fold change of destruction time. Usually it is 10°C for Botulinum cook. Equation (1) can be usually evaluated by numerical integration as general method or computed from the sum of the different sterilizing values (ΔF_i) accomplished after small time intervals (Δt) as temperature

changes throughout the process (Teixeira and Tucker, 1997).

$$F_o = \sum_{i=1}^{n} \Delta F_i = \sum_{i=1}^{n} 10^{(T_i - T_{ref})/z} \Delta t \qquad (2)$$

When comparing to all other methods to calculate F_o, the general method has been accepted to be the most accurate (Govaris and Scholefield, 1988). However, the disadvantage of this method is used to be the clumsiness since it has to obtain the lethal rate in every time step. The smaller time step, the more accurate it will be. But when using computer as a tool to perform all these calculation, F_o determination becomes rapid and simple.

Many researchers (Lappo and Povey, 1986; Ryniecki and Jayas, 1993) had employed the accumulated process lethality to design system process control for batch steam retort. A number of thermocouples were connected to the cans. The mean temperature at the center of those cans was used for calculating process lethality in real time. Datta et al. (1986) used the numerical solution of two dimensional heat transfer in a finite cylinder as a part of the decision-making software in a computer-based retort control system. Actual retort temperature was read directly from sensors located in the retort and it was continually updated with each iteration of the numerical solution. Heating was continued until the accumulated lethality was reached some designated target value and the process would always end with the desired level of sterilization. However their solution of the model has some limitations since purely conduction-heated canned food was simulated for. Later many research works (Teixeira, 1992; Bichier et al., 1995) had been done without these limitations.

Visual Basics computer simulation package for thermal process calculation was developed by Chen and Ramaswamy (2007). This graphical user interface (GUI) program was designed for training and testing of artificial neural artwork models and for study of process design or

other research purposes. It is applicable to different retort thermal processing with different types of food such as solids, liquids and liquids containing particles in containers of different shapes and sizes. Temperature in container was solved by using finite difference and a numerical integration method was used for calculating process lethality and quality retention. In recent years, there are several commercial software packages developed for thermal processing such as ThermSys, Cal-Soft, STERILMATE, Can-Calc, TPRO™, etc. These computer simulations can provide versatile and flexible data for a variety of thermal process applications. For example, Can-Calc software package can accurately predict internal product temperatures in response to any dynamic boundary temperature for products of any shape and size that heated by any combination of conduction or convection heat transfer (Teixeira et al., 1999).

There have been several attempts to develop control approaches for thermal process operation in food canning. Traditionally it consists of maintaining specified operating conditions that have been predetermined from product or process heat penetration test. The first control strategy was to employ real-time heat penetration data acquisition for intelligent on-line control of thermally processed foods. It was the most effective way to handle process deviation. However prior to start thermal operation, a number of product containers are instrumented with temperature probes then filling and seaming. Connection is made between these containers to data logger through the lead wires. Computer thus have the real-time accessing the data from data logger and perform calculation for accomplished sterilizing value at the coldest spot of container. The calculated accomplished sterilizing value is continually compared with the target value required at the end of heating. This strategy provides very accurate calculation of process lethality and is able to handle the process deviation without operator intervention and without any

unnecessary degree of over-processing. The most valuable feature of this control strategy is that it is nearly foolproof since any thing that might have gone wrong earlier in the product preparation is revealed and accounted for. However, the obvious disadvantage for this type of control strategy would be cost prohibitive (Simpson et al., 2007).

Another retort control strategy that many researchers had worked on is about on-line correction of process deviation which is integrating of the real-time data acquisition for retort temperature, on-line correction factor and mathematical heat-transfer model of can temperature (Teixeira and Manson, 1982; Datta et al., 1986; Teixeira and Tucker, 1997). However, the strategy that will be the future trend is microcontroller-based retort control system or simply on-line temperature measurement of retort to lap top computer. When the calculated accomplished lethality reaches the specified target value, computer will automatic shut off or turn on valves (Simpson et al., 2007). Awuah et al. (2007) discussed that Can-Calc process simulation software also was tested for its performance and further integrated into a computer-based on-line control system by Noronha et al. (1995) and Teixeira et al. (1999).

MATERIALS AND METHODS

On-line data acquisition and sterilizing value (F_o) assessment

Quick Basics program was designed and developed to obtain the interfacing data. PCL-812PG card (multifunction data acquisition card) together with PCLD-889 boards (amplifier/ multiplexer board with signal conditioning and cold junction sensing circuit) (Figure 1) were used as interface cards and connecting to the computer and 4 thermocouples. These thermocouples instrumented to the can and hard-wired through retort were sensing the analog input of temperature from different locations in the retort and then they
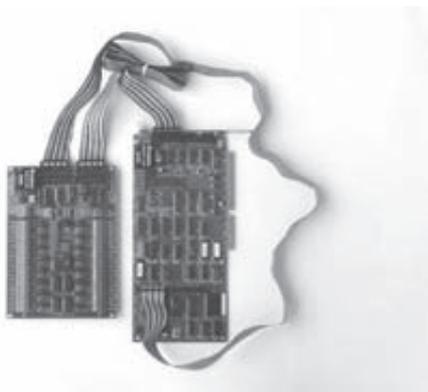
Figure 1 Enhanced A/D multi-lab card & programmable gain amplifier / multiplexer board.

were transformed to digital temperature data via interface cards. Three time-temperature history data from tested cans and one for temperature in the retort were recorded and displayed graphically in every 4.5 second in the developed program as GUI software coded by Visual Basic 6.0. Prior to the test, all the temperatures reading probes were calibrated from the temperature range of ambient to 140°C by comparing to the reading of reliable portable digital thermometer measuring hot oil.

The designed computer program is able to access the recorded Quick-Basic data file which provide real-time of time-temperature history in cans and retort, and calculate them for lethal rate in every 4.5 second by Simpson's rule of numerical integration to obtain accomplished F_o dynamically during sterilizing. In order to evaluate the accuracy of this program, time-temperature history data was also tested with F-ADDING which is a computer program for calculating F_o coded by Rouweler (2000). The minimum accomplished F_o among all of them from each probe is obtained as system F_o and it is compared simultaneously with the target F_o needed to end the process in the minimum of process time. The flowchart of the algorithm for on-line F_o assessment is shown in Figure 2. This approach was accepted as unquestionably the most effective and most certainly the very safest on-

line correction when process deviation occurs (Teixeira and Tucker, 1997; Simpson *et al.*, 2007) since thermocouples were used to on-line measure temperature not only retort but also the cans.

Process design and heat distribution in retort

A small vertical retort with diameter of 38.8 cm and electric boiler were constructed for the test as shown in Figure 3. The interfacing devices was assembled – interface cards, thermocouples, connectors, computer and peripheral equipments- vertical retort and electric boiler. Three probes of thermocouples were connected to the cans and locate those (3 cans) in the basket since these 3 locations tended to be the cold points of system - probes # 3, 4, and 5 attached to the cans located at the positions 1, 3, and 5 in the basket, respectively (Figure 4) - probe # 6 exposed directly to the temperature of the air in the retort.

The cans were hot filled with concentrated pineapple juice then seamed and put into the basket at specific locations in the retort as mentioned above. The retort was full loaded with the rest of the cans. Specify target sterilizing value was chosen according to product characteristics (Table 1) in GUI window of Figure 6. Sterilization was commenced by removing air in retort with steam. Start button in F_o determination GUI window as shown in 7 (a) and (b) was pressed to begin record time-temperature data via the interfacing devices until the minimum value of accomplished F_o (system F_o) reaches specified target F_o. Thus process schedule was recorded automatically and displayed graphically. Even though concentrated pineapple juice is acid food (pH > 4.0), mild sterilizing is usually sufficient. Specified target F_o would be chosen as $F_{121.1}^{10} =$ 0.6-0.8 min (Rouweler, 2000). However in order to demonstrate the process design with this educational tool, the experiments were carried out with the holding temperature during sterilization selected to be at 110°C and 120°C.
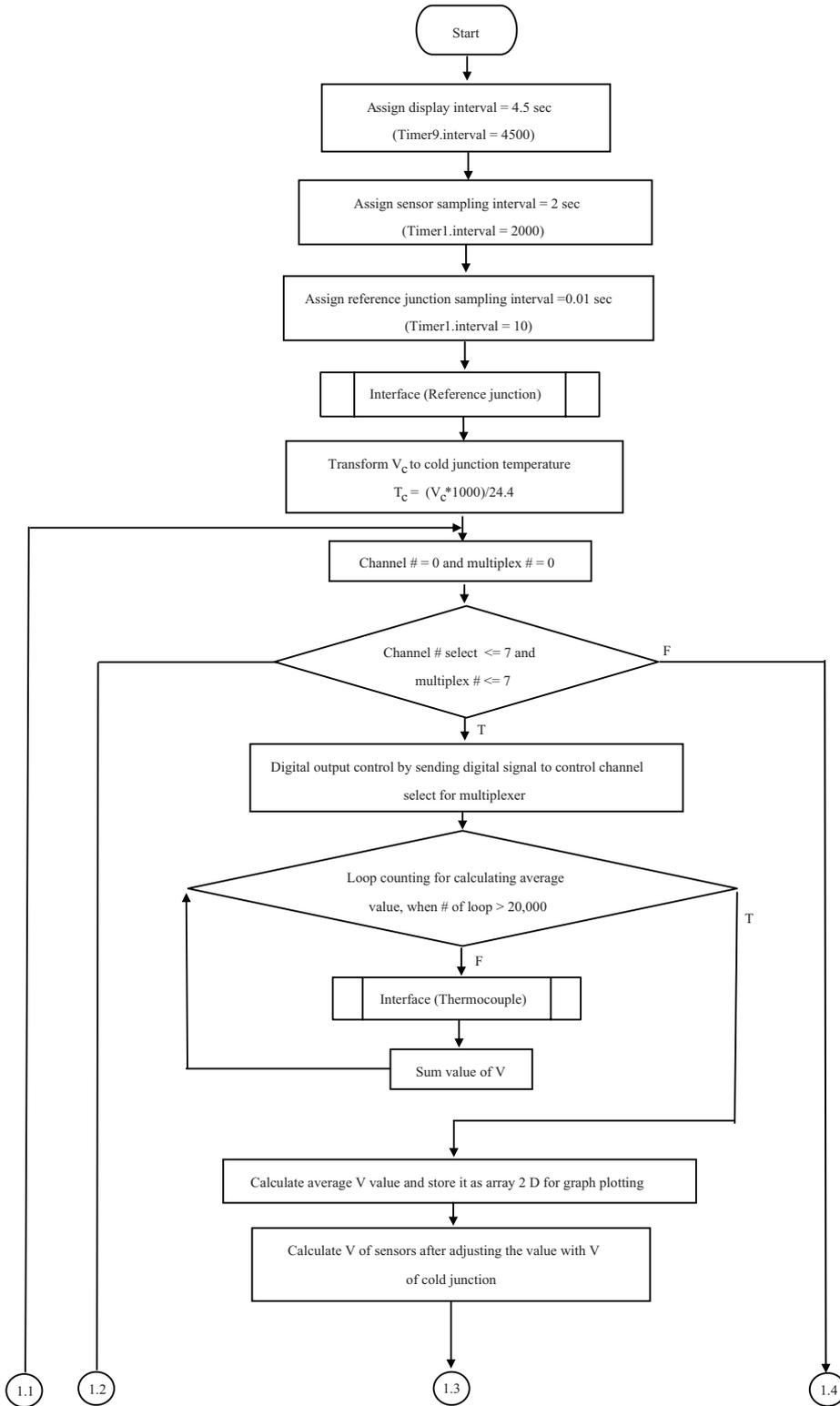
Start

Assign display interval = 4.5 sec
(Timer9.interval = 4500)

Assign sensor sampling interval = 2 sec
(Timer1.interval = 2000)

Assign reference junction sampling interval =0.01 sec
(Timer1.interval = 10)

Interface (Reference junction)

Transform V_c to cold junction temperature
$T_c = (V_c*1000)/24.4$

Channel # = 0 and multiplex # = 0

Channel # select <= 7 and
multiplex # <= 7   F

T

Digital output control by sending digital signal to control channel
select for multiplexer

Loop counting for calculating average
value, when # of loop > 20,000   T

F

Interface (Thermocouple)

Sum value of V

Calculate average V value and store it as array 2 D for graph plotting

Calculate V of sensors after adjusting the value with V
of cold junction

1.1   1.2   1.3   1.4

Figure 2   Program algorithm for dynamic accomplished F_o determination.

Figure 2 Program algorithm for dynamic accomplished F_o determination (Continued).

Coldest spot in container

      To validate the capability of program when it was used to find the coldest spot in a container, the interfacing devices were assembled as before. One of the cans was hard-wire with 2 probes: probe# 4 at 1/4 of central axis from bottom of can, and probe# 5 at half of central axis as shown in Figure 5 while probe# 6 was for measuring temperature in the retort. This can was filled up with baby corn in saline solution which

was solids in liquid type of canned food, and then seamed. The retort was full loaded with cans as before. Product sterilization was carried out at 121°C for some certain period.

RESULTS AND DISCUSSION

Computer-based on-line assessment of sterilizing value

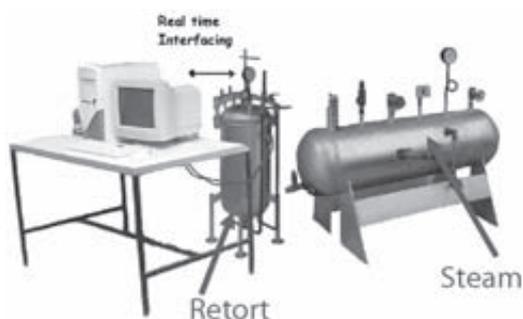The software package for process design was divided into 2 parts: (1) the main window of

Figure 3 Automatic sterilizing value (F_o) assessment devices for canned food.

the GUI as shown in Figure 6 to receive the input parameter which is target sterilizing value. The user can choose this value from pull down combo box or add/delete and update to have more choices for later use. (2) graphical window of temperature and time profiles with 8 corresponded text boxes to display accomplished sterilizing values from maximum 8 probes. There is one text box at the bottom to display system sterilizing value which is the minimum value among all of accomplished sterilizing values from each probe. System sterilizing value increases while the process is underway heating and cooling and ultimately reaches the designated target sterilizing value (Figure 7 (a) and (b)). Program then displays message for the operator to stop steaming and total process time during heating is shown in upper right corner text box. The temperature and time record can be used for process design or as documentation in quality assurance system.

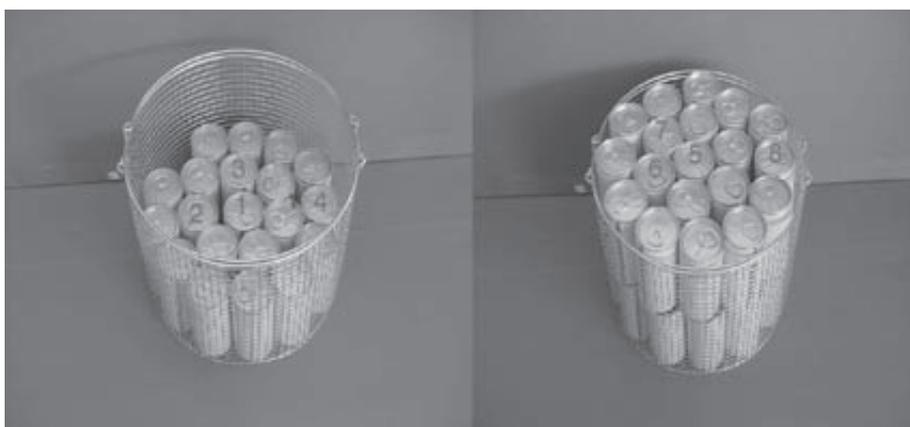### Heat distribution in retort

Heat distribution in retort can be

Figure 4 Location of cans which connected to thermocouples.

Table 1 The characteristics of tested product.

Product	Can size	pH	°Brix	Sterilizing temp.(°C)
Concentrated	200×202	4.06	60.4	110
pineapple juice				120

observed from all accomplished F_o values obtained from different locations in retort. For sterilizing at 110°C in Figure 7 (a), accumulated heat which could be indicated by accomplished F_o at positions 1, 3, and 5 were 1.29, 1.91 and 2.29 minutes, respectively, while the one outside the can was 3.53 minutes. Thus this was assuring that the coldest point was from the position 1 or at the bottom layer of cans and at the center of the basket. To get enough heat treatment for the products, heat
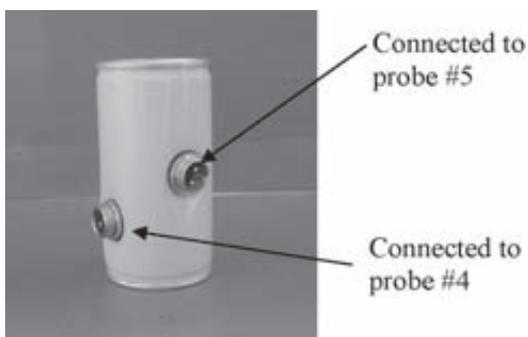
distribution test must be carried out once the machine was installed or process/product was modified.

From heat penetration curve, F_o of the system represents the minimum accumulated heat at coldest point of can in the retort. As in Figure 7 (a) and (b), system F_o was obtained from different probes or positions of can i.e. probe #3 (position 1) from Figure 7 (a) and probe #5 (position 5) from Figure 7 (b), the F_o of which were 1.29 and 0.94 minutes respectively. According to the steam flow pattern of this retort shown in Figure 8, the cans located at positions 1 and 5 were supposed to be the stagnation points and had minimum convective heat accumulation in each run. However the minimum accumulated heating point was found to get changed from position 1 located at the bottom center of the basket to position 5 located at the upper center of the basket while sterilizing at higher temperature. This was possible because the more amount of steam used during heating at 120°C, the narrower the stagnation area would be. In addition, while cooling, the can at position 5

Figure 5 The connecting points to validate the coldest spot in can.

Figure 6 Visual Basics form to specified target sterilizing value (F_o).
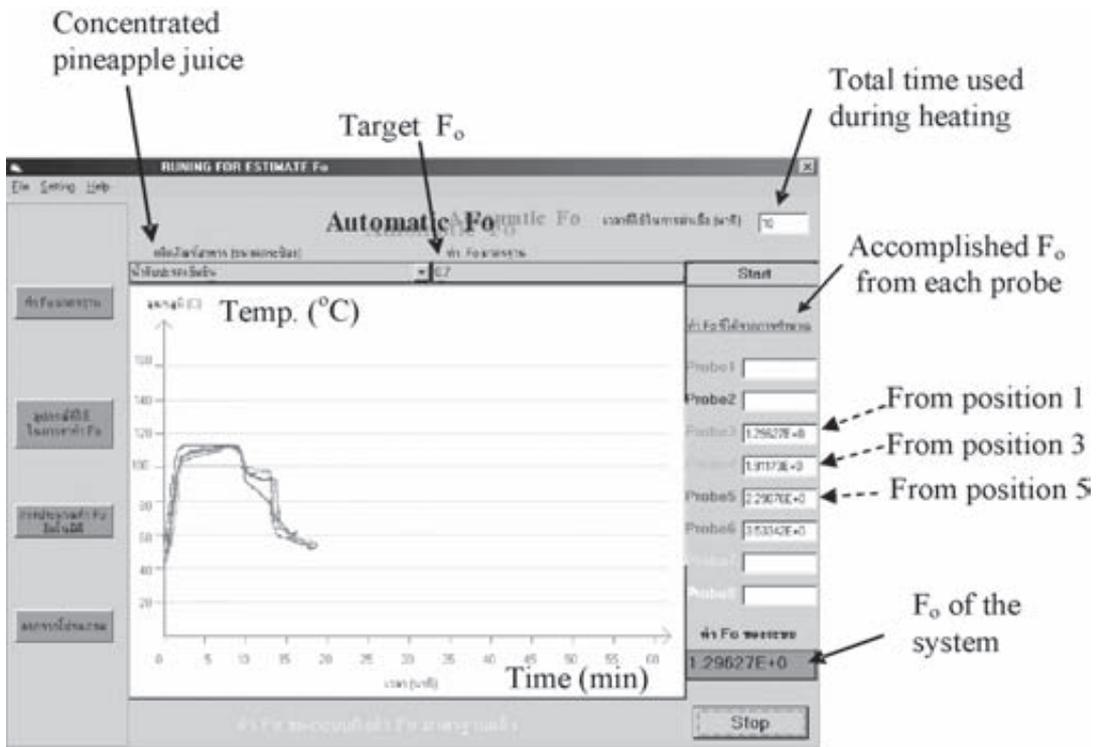
(a)
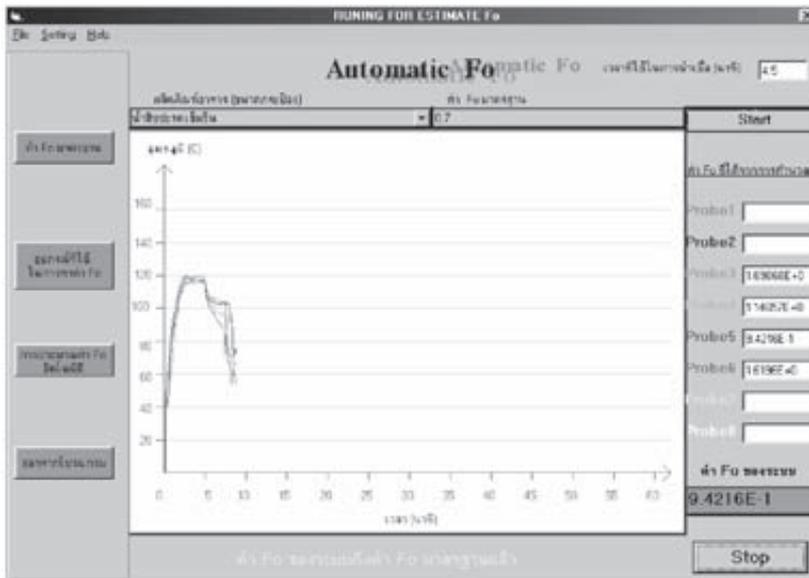
(b)

Figure 7 Real-time heat penetration curve and F_o of concentrated pineapple juice when sterilizing at (a) 110 °C (b) 120°C.

(top layer of cans) would get contacted with blowing air into retort during balancing pressure right after stop steaming. Therefore system F_o would be obtained from the can at the center upper layer of the basket due to smaller heat accumulation. However cold water could significantly enhance heat removal when it was leveled up to that position in retort.

Process design or schedule

The process design or schedule of acid food like concentrated pineapple juice was shown in Table 2. The obtained process time of sterilizing acid food at 110 and 120°C was 10 and 4.5 minutes excluding cooling period, respectively. At higher sterilizing temperature (120°C), it was shorter than

that at lower temperature (110°C) since both were calculated based on the same specified target F_o (0.7) or having the same area under the heat penetration curve before stopping steaming. Although the specified target sterilizing value for such a product was chosen to be 0.7 but F_o of the system obtained was 1.29 and 0.94 minutes for sterilizing at 110 and 120ºC, respectively. This was because the calculation was including come-up time, holding and cooling period. Thus a little over-process occurred in each run since there was slow removal of heat during cooling. Improved and proper design of cooling system in the retort would provide better product quality in terms of organoleptic properties.

Coldest spot in a container

The accomplished sterilizing values at 2 different points could be used as indicated tool to validate the coldest spot in a container. As shown in Figure 5 the can was instrumented with 2 probes and hard-wire lead through retort. Probe# 4 was at 1/4 of central axis from bottom of can, and probe# 5 was at the half of central axis while probe# 6 was for measuring temperature in the retort. It was found that temperature rising and dropping from probes #4 and 5 were almost identical and hard to distinguish. However accomplished sterilizing values corresponding to probes #4, 5 and 6 were 3.69, 2.85 and 9.54 minutes, respectively. Thus according to these
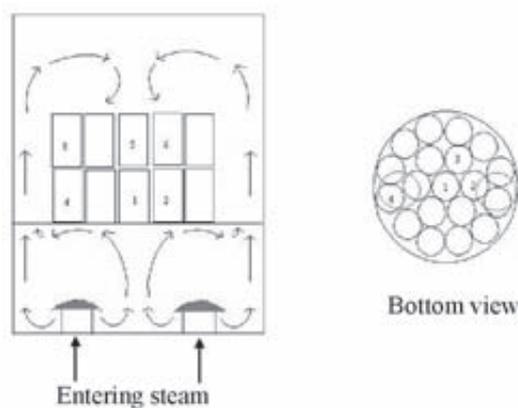

Figure 8 Configuration of steam flow pattern in retort.

Table 2 Process design or schedule obtained from heat penetration curve of concentrated pineapple juice when target $F_o = 0.7$

Sterilizing period	Time used during sterilizing at 110°C (min)	Time used during sterilizing at 120°C (min)
Come-up time	2.5	2.5
Holding period	7.5	2.0
Cooling period	7.0	1.5
Total process time	10.0	4.5
Calculated system F_o	1.29	0.94

Remark: Calculated system F_o is including come-up time, holding and cooling period. Total process time does not include cooling period.

accomplished sterilizing values, the coldest spot was found from the minimum value (2.85). For this type of food, heat transfer was the slowest at half of central axis of can.

CONCLUSION

A computer program for on-line data acquisition and accomplished F_o assessment was developed by MS Visual Basic 6.0 language. This computer-based on-line device was able to evaluate the coldest point of the can in the retort and calculate process lethality or system F_o dynamically while sterilizing. Non-uniform heat distribution in retort always exists. Too much over or under process was avoidable for process design or schedule with the integration of such a device for on-line accomplished F_o determination during preprocessing.

ACKNOWLEDGEMENT

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