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Computer-Based On-Line Assessment of Sterilizing Value and Heat Distribution in Retort for Canning Process

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1. 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 of time. One of them which require heat treatment 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 indicated based on the sufficient achievement of bacterial inactivation in each container in order to comply with public health standards or food safety. In addition it will 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 ever since. However they required the off-line input of tables and consequently series of calculation steps which might be resulting in too-long or too short heating process. At present there are a lot of commercial software available which could be used either on-line or off-line analysis for sufficient heat treatment or process lethality (F_o) such as CAN-CALC©, and CALSoft™ etc. Balaban (1996 cited by Teixeira et al., 1999) described that CAN-CALC software needed to get f_h (heating rate factor) and j_h (heating lag factor) from heat penetration test prior to be able to predict internal center product temperatures in response to any dynamic boundary temperature for products of any shape and size as shown in figure 1 and 2. Therefore if assumed that the selected can was at the slowest heating point of the retort, simulated system F_o for food products that heated by any combination of conduction or convection heat transfer also could be obtained. However, the software performance was emphasizing with its capability to deal with process deviation such as steam shutting off and back on. The CALSoft™ software (Anonymous, 2011) was designed specifically for conducting heat penetration and temperature distribution testing, evaluating the collected data, calculating a thermal process or vent schedule/come-up time, and evaluating process deviations. It was supposed to use with CALPlex™ data logger and claimed for the most widely used commercial thermal processing software.

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

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

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 value (ΔF_i) accomplished after small time intervals (Δt) as temperature change throughout the process (Teixeira and Tucker, 1997).

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

When comparing to all other methods to calculate F_o, the general method has been accepted to be the most accurate. 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 become rapid and simple.

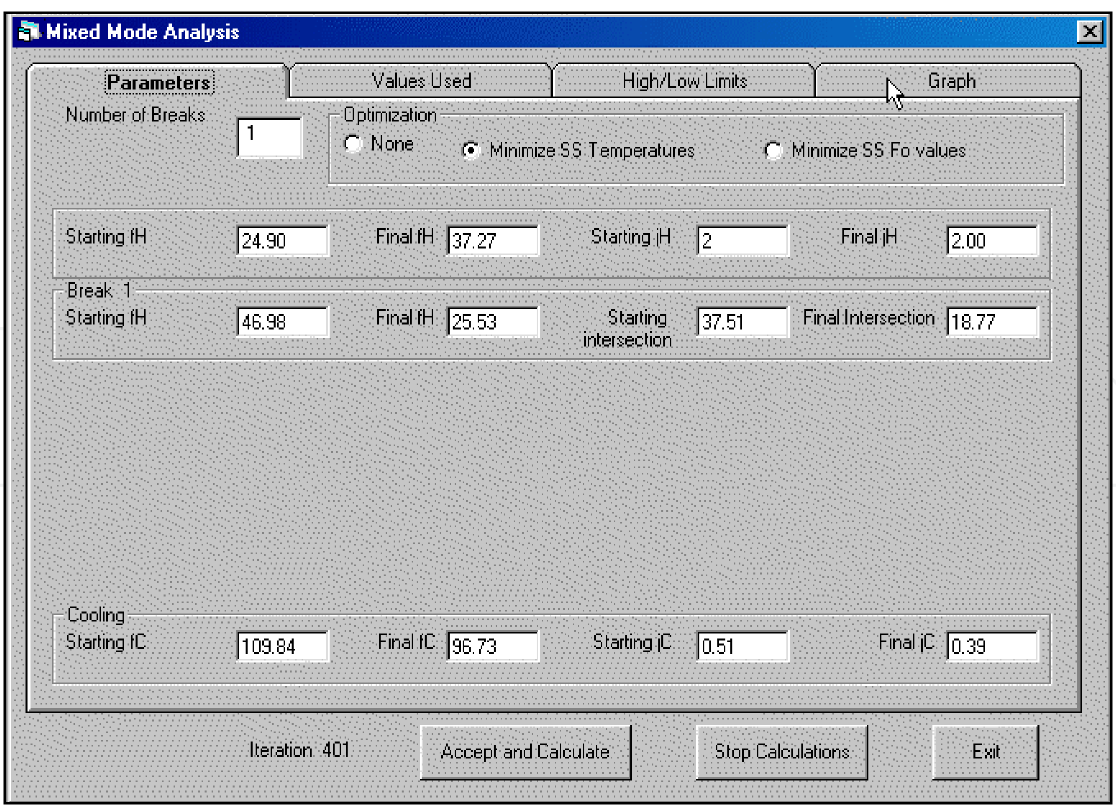


Fig. 1. Parameters input in CAN-CALC software before simulating for system F_o (Balaban, 2004)

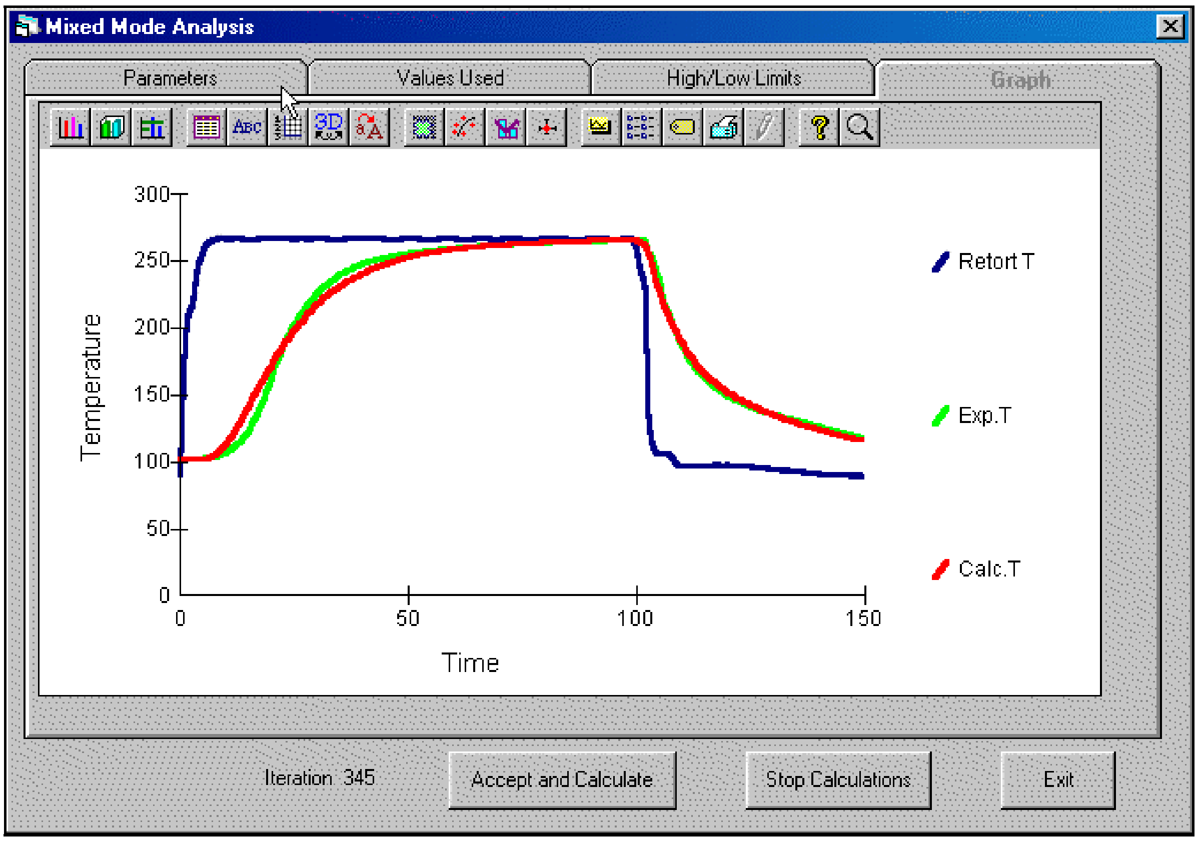


Fig. 2. Graphical display of calculated or predicted and experimented temperature at coldest point in CAN-CALC software (Balaban, 2004)

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 2 dimensional heat transfers 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 (Bichier et al.,1995 ; Teixeira, 1992) 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 size. Temperature in container was solved by using finite difference and a numerical integration method was used for calculating process lethality and quality retention.

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 el 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).

As a whole, the purpose of software design and hardware control was based on the fact that foods should not be overheated 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 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 for any one of canned products and heat distribution in sterilizing device.

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 still rarely found in Thailand. Thus the objectives of the research are to develop visual basic computer software to integrate the on-line data acquisition. The assessment of sterilizing value or process lethality (F_o) as well as heat distribution in retort was performed while heating. The software also can be used as an education tool for thermal processing study.

2. Materials and method

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

Quick Basics program was designed and developed to obtain the interfacing data from PCL-812PG card (multifunction data acquisition card) together with PCLD-889 boards (amplifier/multiplexer board with signal conditioning and cold junction sensing circuit) as in figure 3. Up to 8 thermocouples could be instrumented to the loaded cans and hard-wired through a retort (figure 4). They were used for sensing the analog inputs of temperatures from different locations in the retort and then they were transformed to digital temperature data via the interface PCL-812PG A/D card.

Thus time-temperature history data from tested cans and some 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 temperature reading probes were calibrated from the temperature range of ambient to 140^{o}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 5. 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.

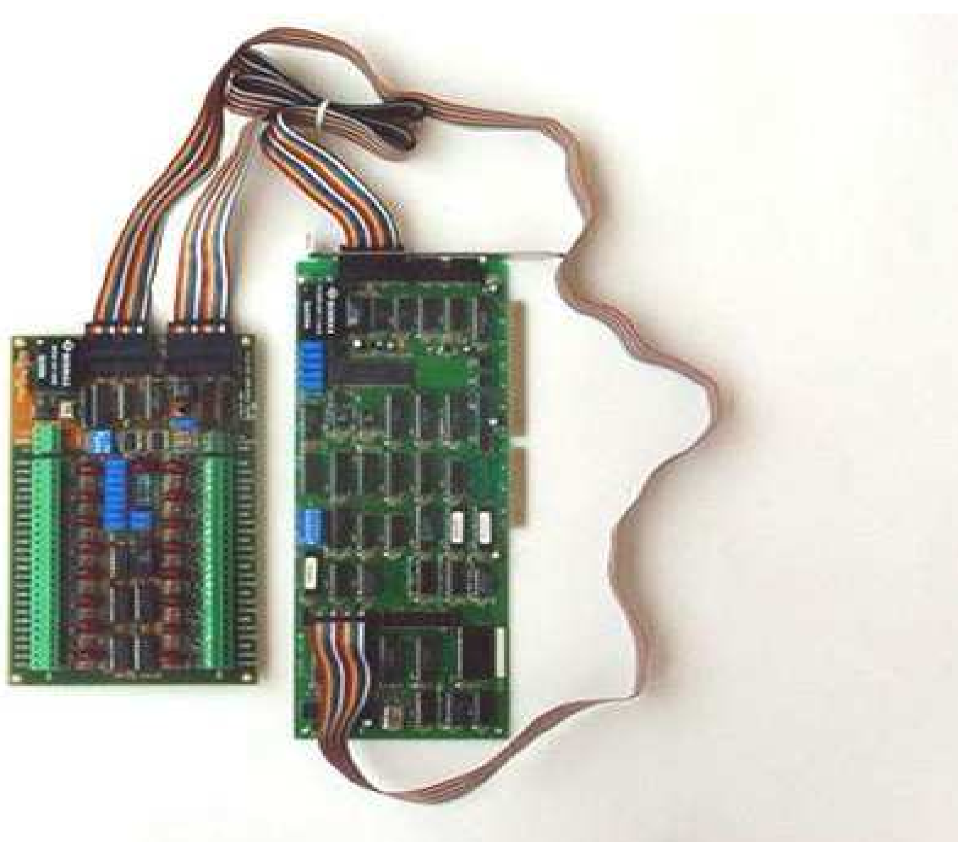


Fig. 3. Enhanced A/D multi-lab card & programmable gain amplifier/multiplexer board

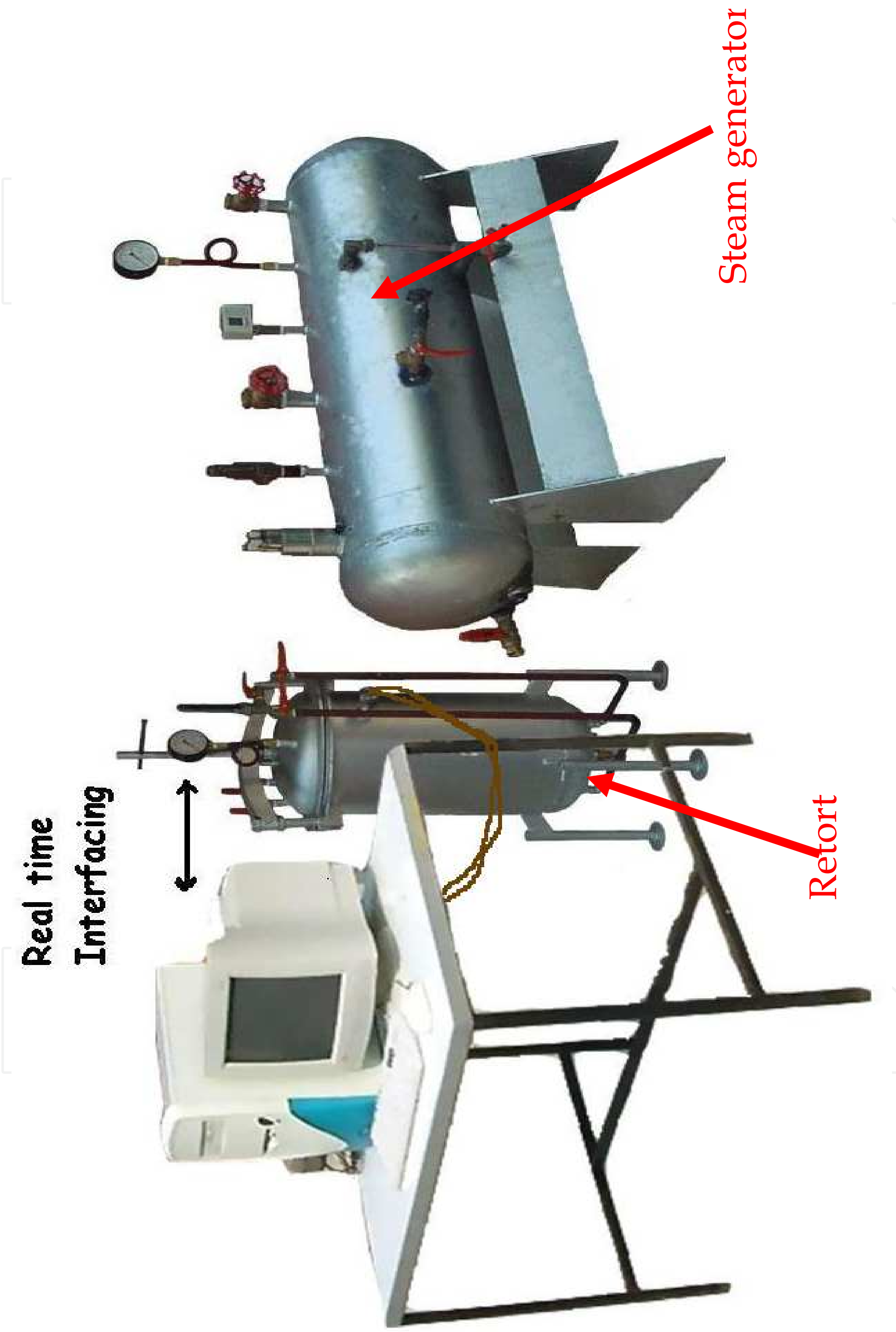


Fig. 4. Computer-based on-line assessment systems

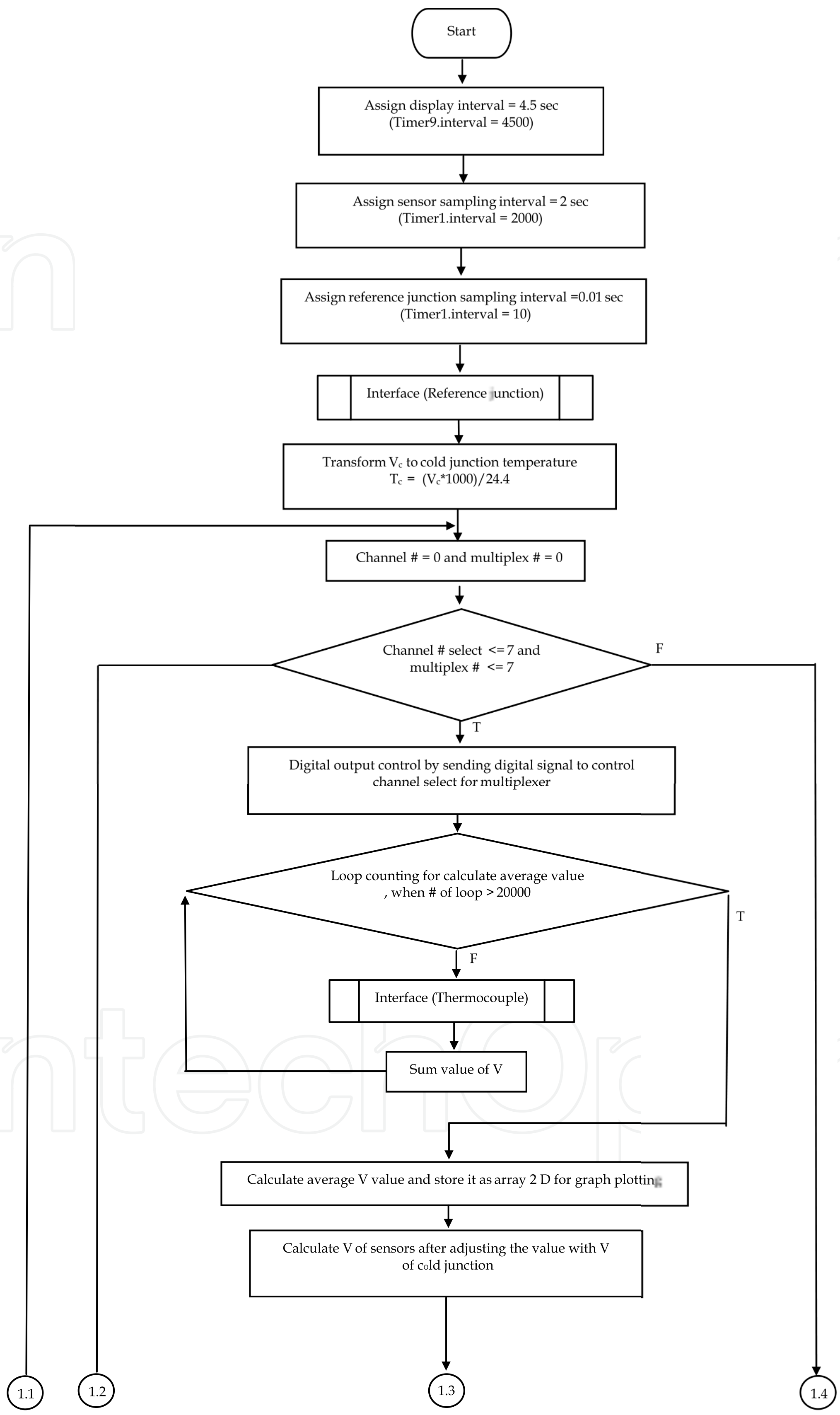


Fig. 5. Program algorithm for dynamic accomplished F_o determination

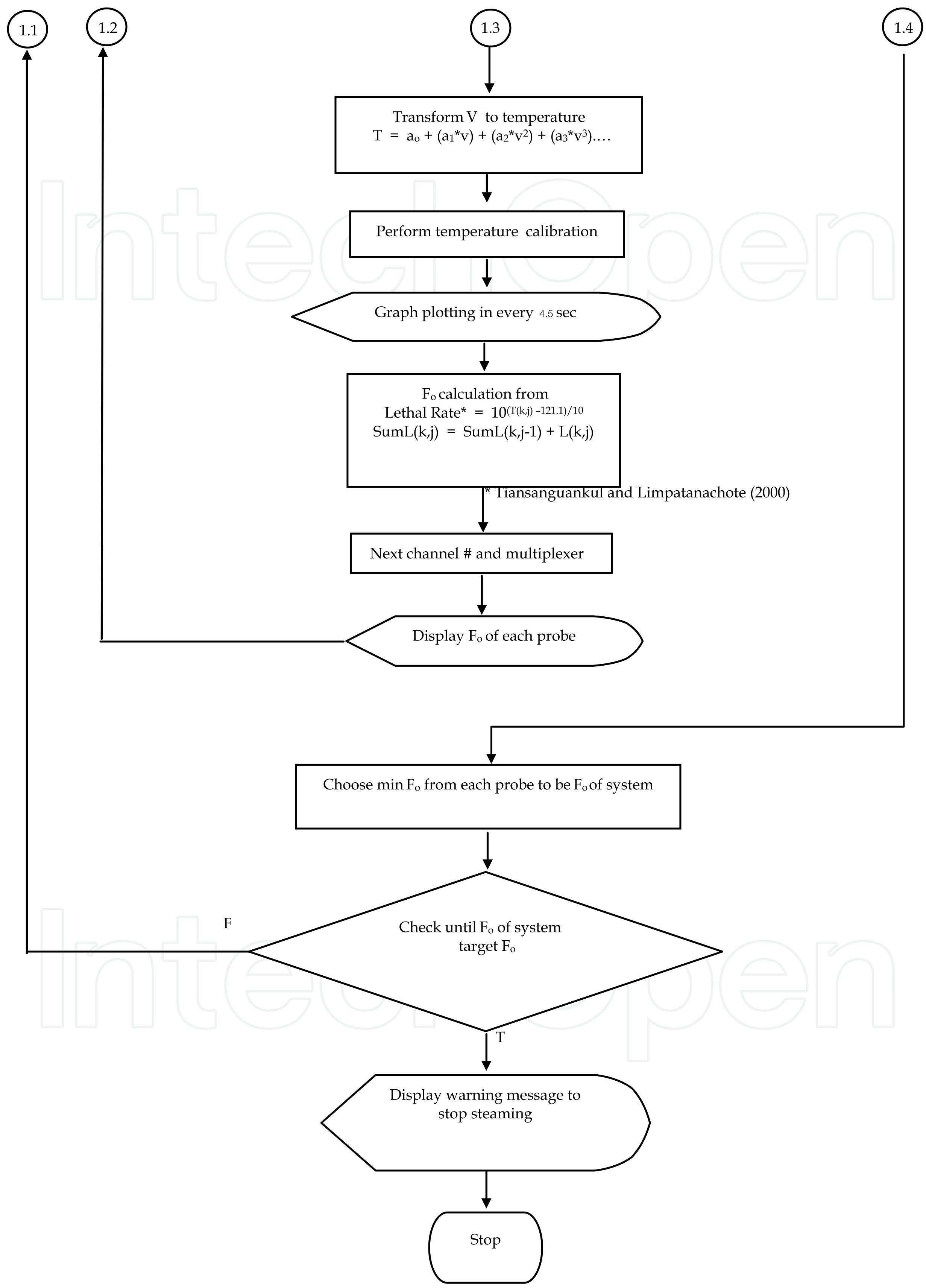


Fig. 5. Program algorithm for dynamic accomplished F_o determination (continue)

2.2 Heat distribution performance in retort

A small vertical retort with diameter of 38.8 cm and electric boiler were constructed for the test as shown in figure 4. The interfacing devices was assembled – interface cards, thermocouples, connectors, computer and peripheral equipments- vertical retort and electric boiler. One probe of thermocouples (probe # 1) were connected to the end tip of mercury thermometer in the retort and one (probe # 8) connected to the center of can which was hot filled with distilled water and then seamed. The rest of them (6 probes) were distributed appropriately inside the retort as shown in figure 6. The on-line graphical display of temperature from 8 thermocouple probes was shown while heating. In addition, the probes # which provides minimum and maximum temperature, as well as maximum temperature difference were indicated through out the heating process. The sterilization temperature at 110 and 121°C were chosen to investigate the heat distribution in the retort.

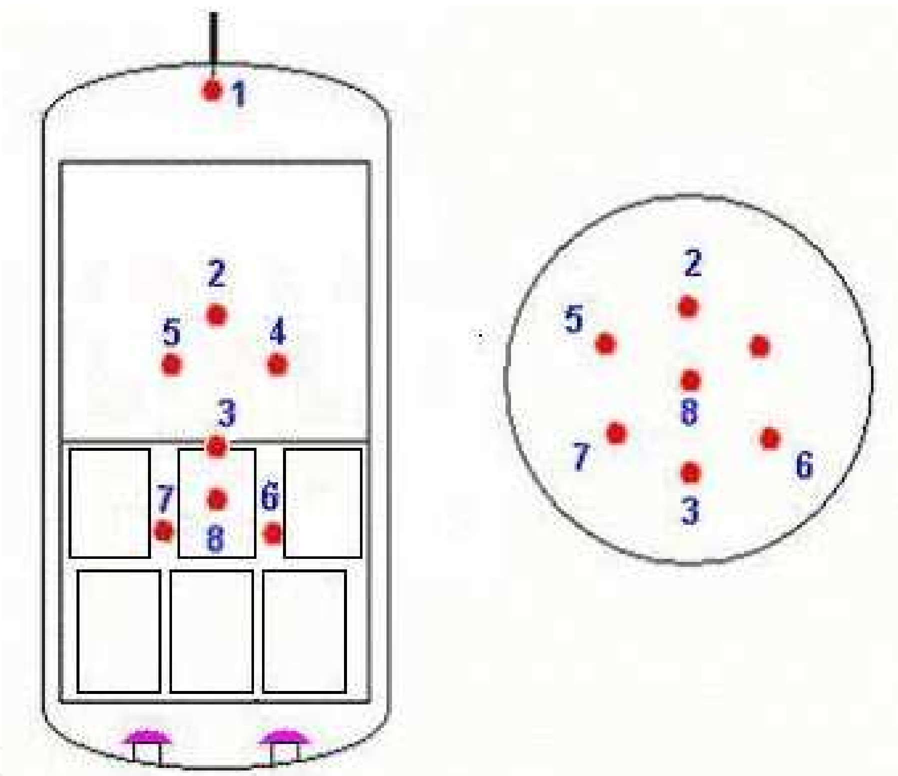


Fig. 6. Positions of thermocouple probes in heat distribution test

2.3 Process design and minimum heat accumulation in canned products

Heat accumulation in canned products during sterilizing could be investigated either from their heat penetration profiles or accomplished F_o values. Thus three probes of thermocouples were connected to the cans and located those (3 cans) in the basket since these 3 locations tend 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 7) and probe # 6 exposed directly to the temperature of the heating medium 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. The information about target sterilizing value could be added to the file by pressing updated button. Subsequently sterilization was commenced by removing air in retort by replacing it with steam. Start button in F_o determination GUI window was pressed to begin recording time-temperature data via the interfacing devices until the minimum value of accomplished F_o (system F_o) reached 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 and therefore could be applied. Specified target F_o would be chosen as $F_{121.1}^{10}$ = 0.6-0.8 minutes (Rouweler, 2000) in this case. 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.

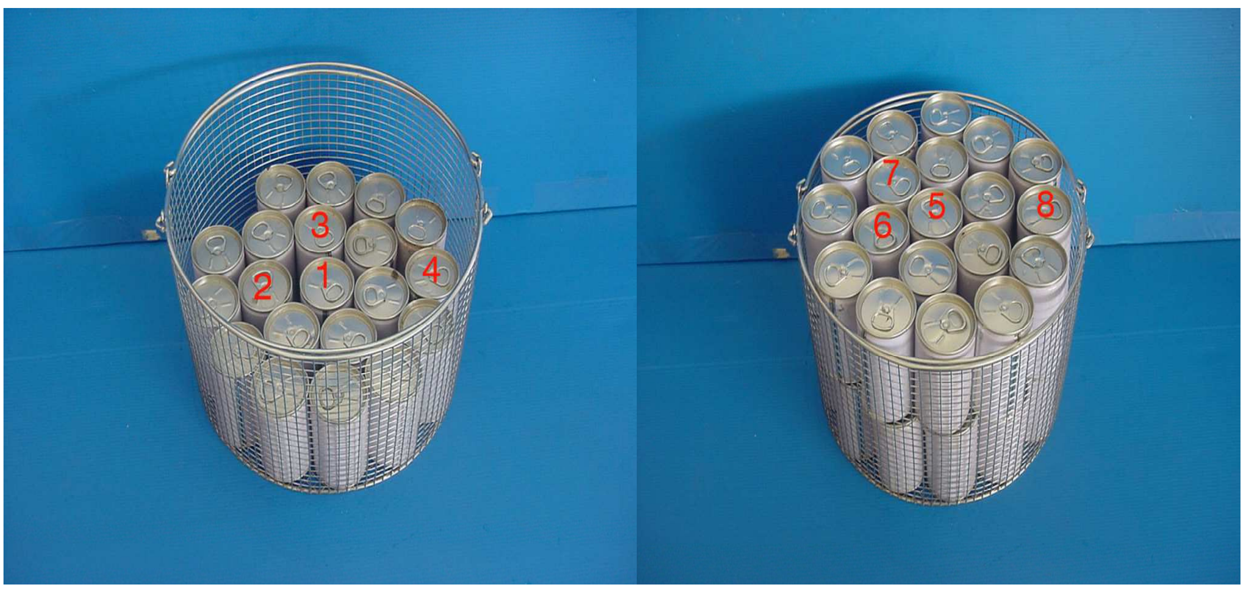


Fig. 7. Location of cans which connected to thermocouples in the bask

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

Table 1. The characteristics of tested product.

2.4 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-wired with 2 thermocouple 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 8 while probe# 6 was for measuring temperature of medium in the retort. This can was filled up with baby corns in saline solution which was solids in liquid type of canned food, and then seamed. The position to put this can in the retort was the slowest heating point of this equipment. After the retort was full loaded with cans, sterilization process was carried out at 121°C for some certain period of time as before, minimum accomplished F_o of which could be obtained.

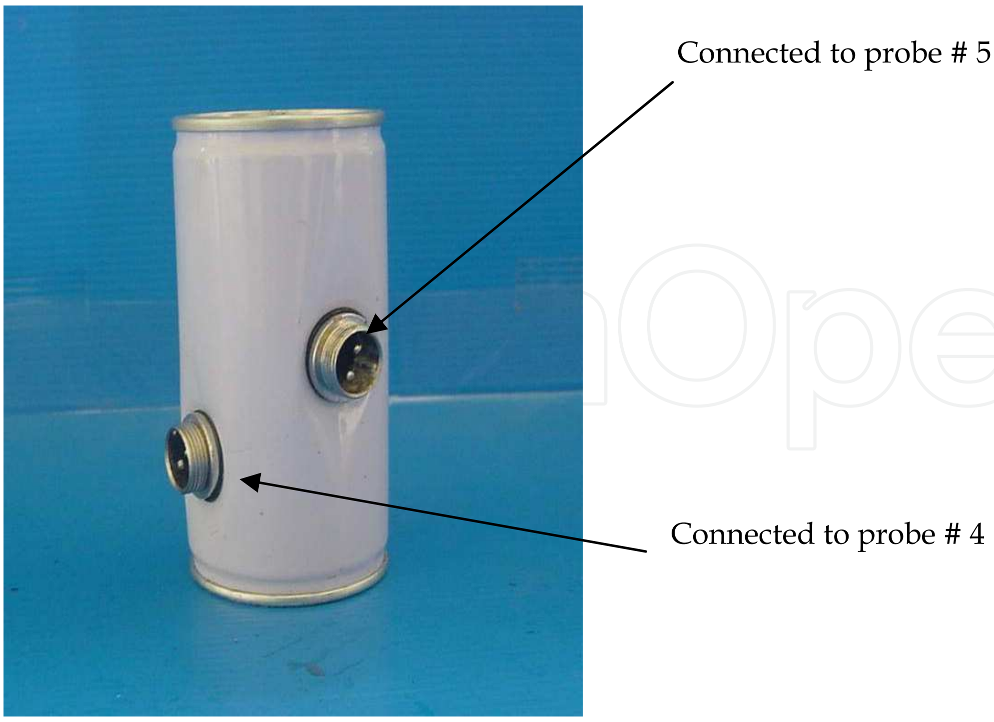


Fig. 8. The connecting points to validate the coldest spot in a can

2.5 Portable educational tools for computer-based off-line assessment of sterilizing unit

The objective of this part was to design the computer program for assessing process lethality from interfacing data system via USB-A/D board. Thus the driver and interfacing program for data logger, National Instrument USB-9211A, 4 Channel 24 bit (figure 9) was installed to a note book computer. The commercial interfacing software was sensing voltage signal through 1 to 4 type-T thermocouples and transforming to digital data stored in a note book computer (figure 10).

Fig. 9. USB A/D board (NI USB-9211A 4 CH, 24 BIT)

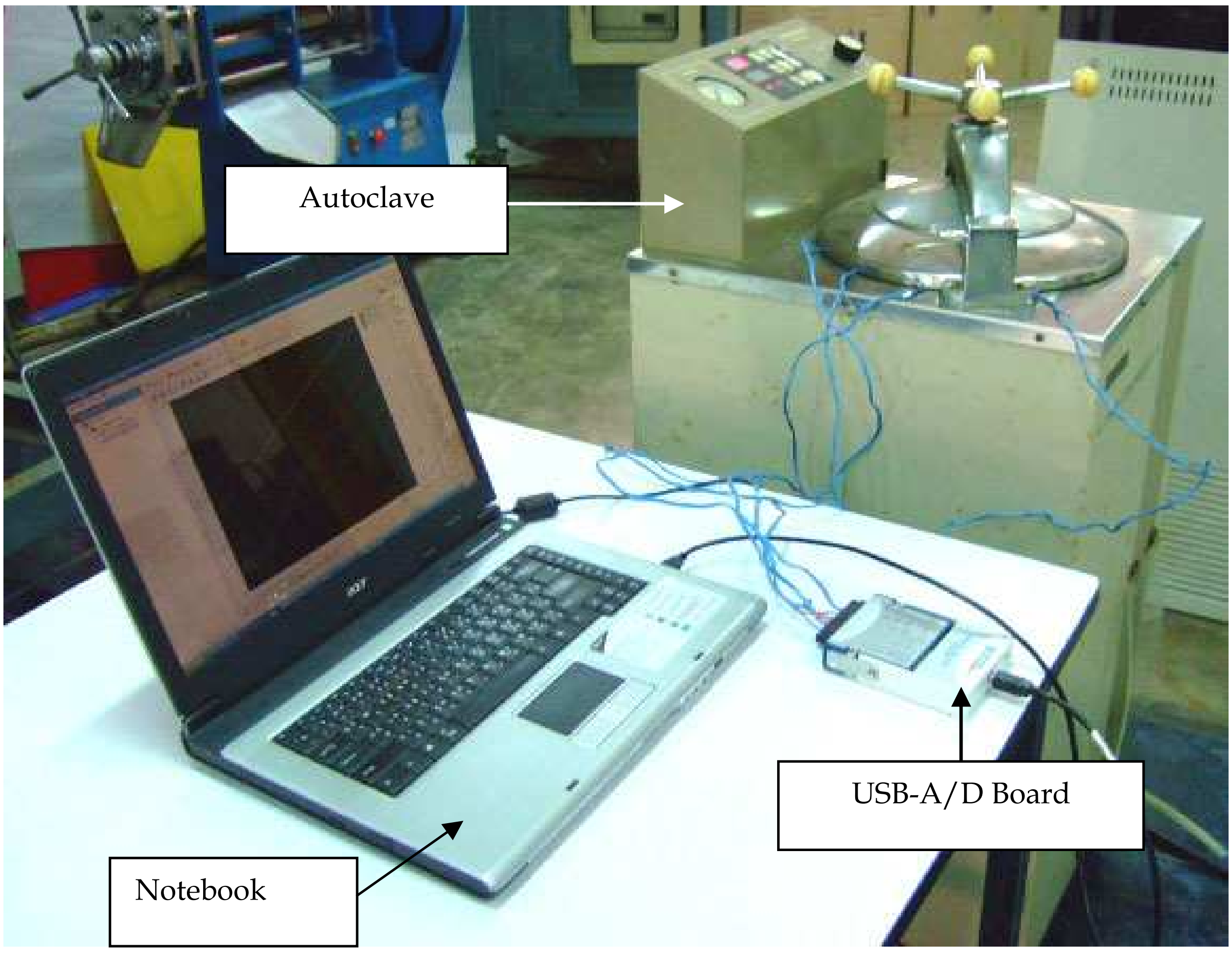


Fig. 10. Hardware installed for the off-line assessment of sterilizing unit

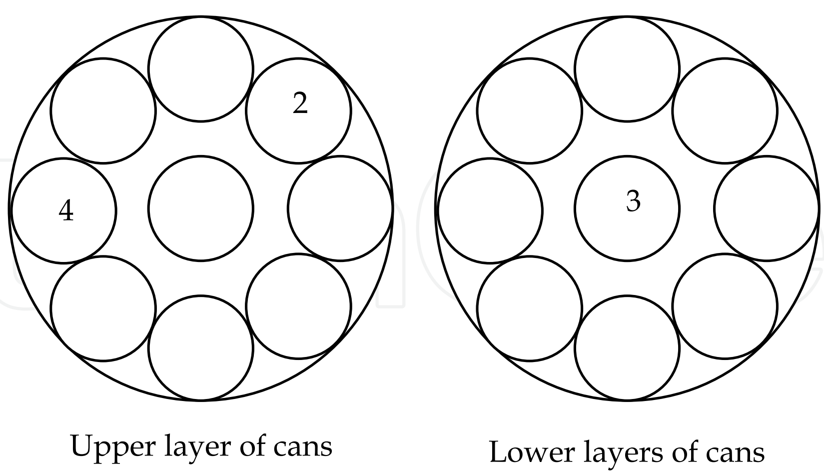


Fig. 11. The locations of cans connected to thermocouple probes # 2-4 in the autoclave

Tab water samples in 300*407 size cans were prepared to be full loaded in vertical commercial autoclave (HA-240MII/-300MII, Japan). Three cans were hard-wired to the thermocouple probes # 2-4 at the coldest point of cans (figure 11) and located at possibly slowest heating point in the autoclave. Therefore one of the can attached to probe # 3 was located in the basket at the center of bottom layer as the most probably slowest heating point. However one thermocouple (probe # 1) was exposed in the autoclave indicating medium temperature measurement during sterilizing. Temperature of 121 °C for 15 min was chosen for demonstrating sterilizing condition. Temperatures from 4 channels was recorded and stored in text file (*.txt) for every 2 seconds after running autoclave until finishing cooling process. QuickCalFo (Chamchong et al., 2008) was software designed to perform the off-line process lethality assessment by using Visual Basic 6.0 program. Input data of temperature and time during sterilization was retrieved from stored text file (figure 12) while target F_o for each product with specific can size was pre-entered and saved into the program or selected from the list of available data before starting analysis for system F_o. The result could display the temperature and time record in a spread sheet as well as heat penetrating curves and lethal rate profiles. F_o values from each temperature-time profile were calculated by Simpson's rule general method and the minimum value was shown in the combo box nearby as system F_o or accomplished F_o. The accuracy of F_o calculation from this software was validated as before by comparing it with that obtained from F-ADDING program coded by Rouweler (2000).

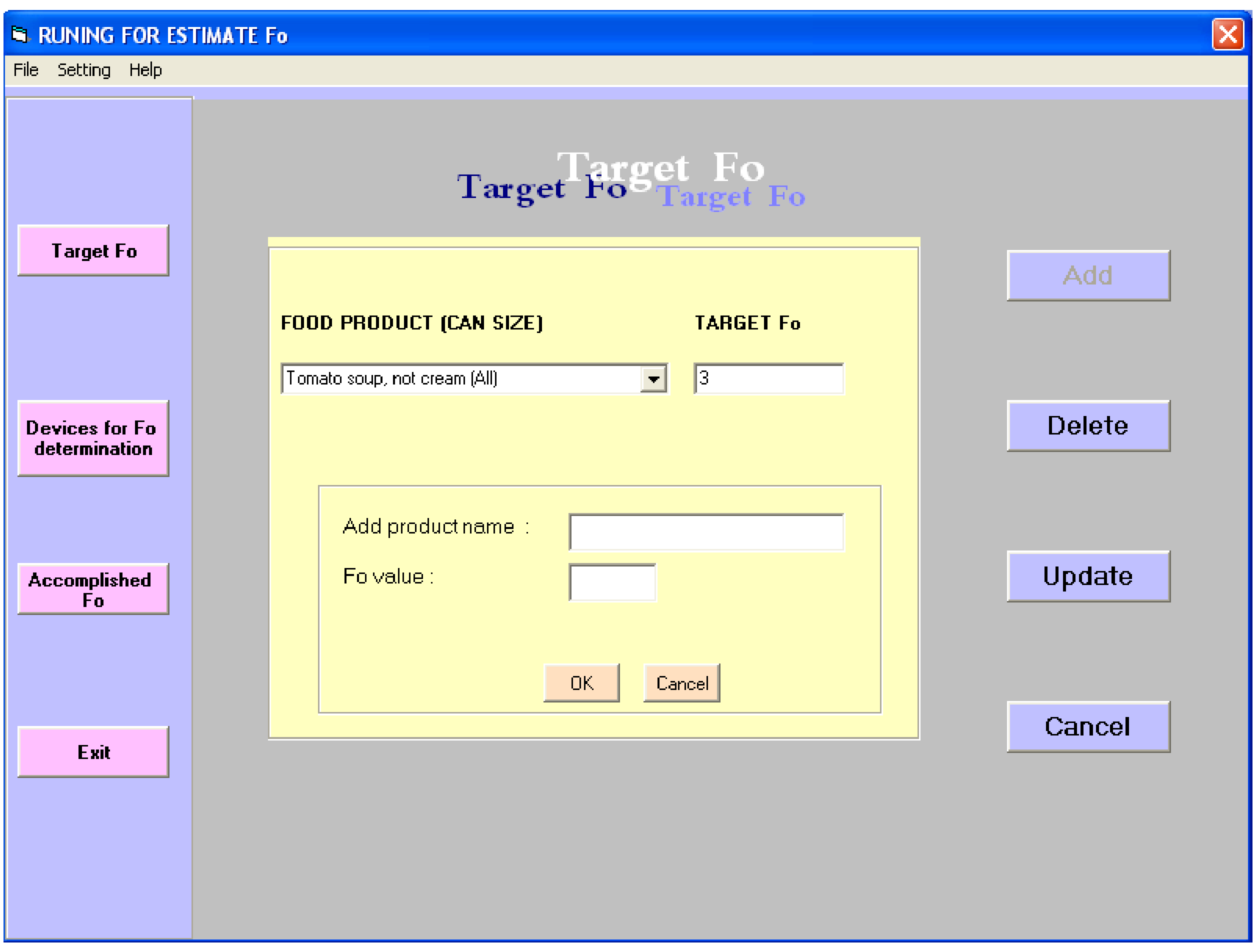


Fig. 12. Visual Basics form to specified target sterilizing value (F_o)

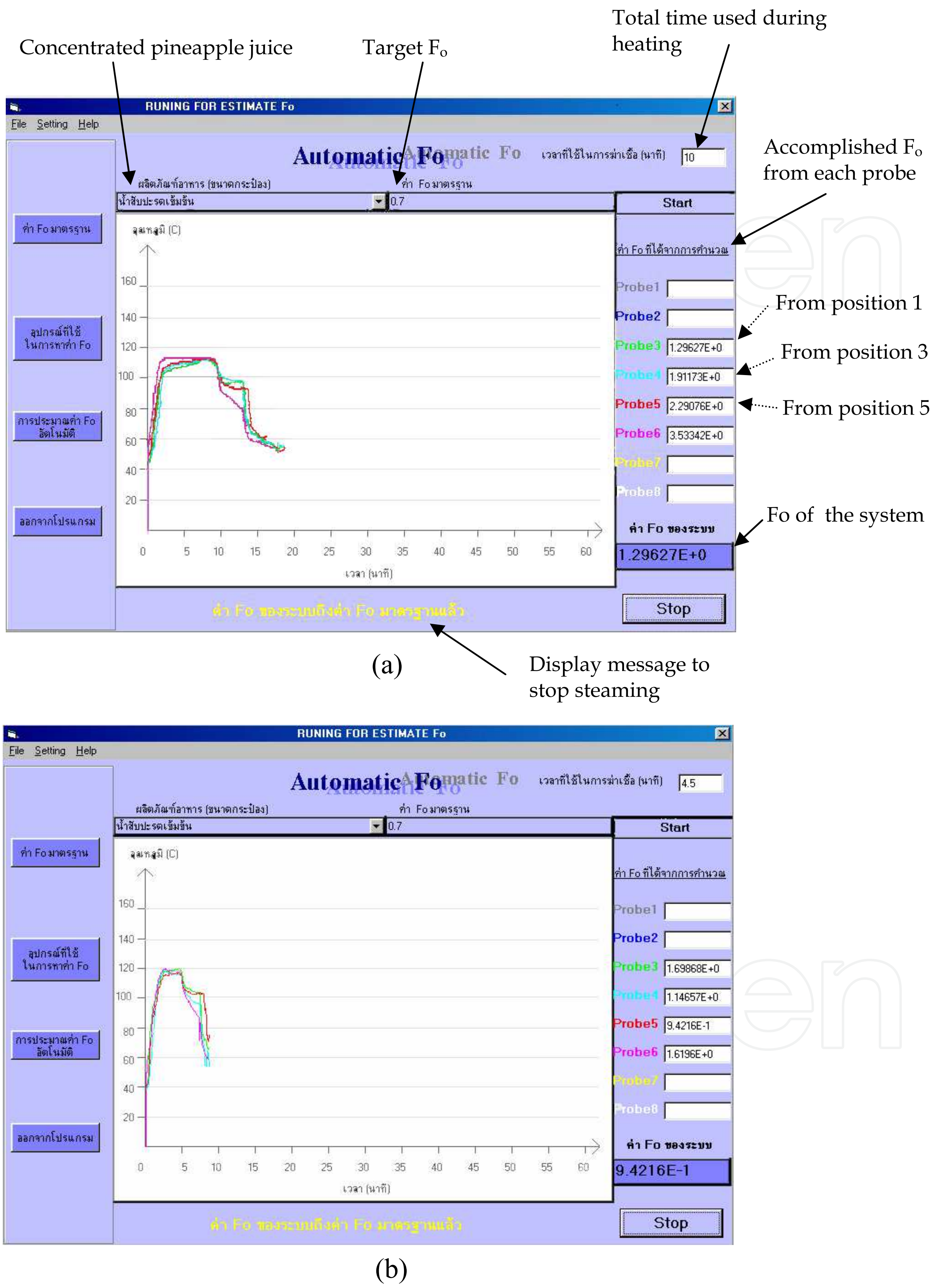


Fig. 13. Real-time heat penetration curve and F_o of concentrated pineapple juice when sterilizing at (a) 110 °C (b) 120°C

3. Results and discussion

3.1 Computer-based on-line assessment of sterilizing value

The software package for process design was divided into 3 parts: (1) the main window of the GUI 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 (figure 12). (2) Graphical window of temperature and time profiles with 8 corresponded text boxes to display accomplished sterilizing values from maximum 8 probes (figure 13). 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. Program then displays text message at the bottom of GUI 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. (3) The spread sheet of temperature-time recorded from 8 thermocouple probes which could display minimum and maximum temperature, as well as maximum temperature difference (max-min) at each time interval through out the heating process (figure 14).

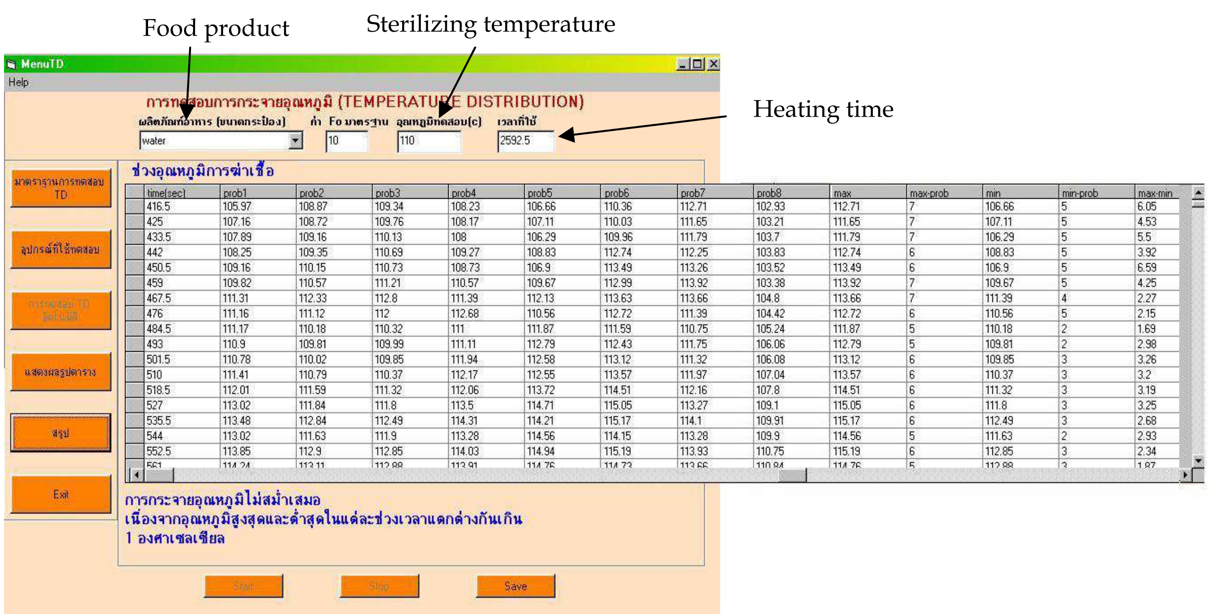


Fig. 14. Real-time heat distributions in retort, record from 8 thermocouple probes

3.2 Heat distribution in retort

Practically heat distribution in a retort should be carried out before performing the assessment of sterilizing value of the process in order to validate the slowest heating point. Therefore heat distribution in a retort (as in part 3 from mentioned above) was observed from on-line temperature record obtained from different locations of this equipment. For sterilizing at 110°C in a small retort unit distributed heat could be indicated by temperature values at positions 1-8 in the retort corresponding to probe # 1-8 (figure 6). In addition minimum heating reading from thermocouple probe which was connected to the can located at the slowest heating point was able to be quantified as the accomplished F_o for the system. Then it could be used as an indicator for stopping steaming. Therefore the display was able to assure the minimum heat distribution occurring while heating. The coldest point of the system should be coming from the can which had the thermocouple connected with and was located at position 8 or at the upper 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.

For the same retort, it was found that when holding temperature of sterilization was moderate at 110^{o}C heat distribution was more uniform than that at 121^{o}C. Temperature difference from max and min at any holding time or temperature deviation was between 1.8 to 3.1^{o}C (1.6-2.8%) when sterilizing temperature was at 110^{o}C but it was between 5-14^{o}C (4.1-11.6%) at 121^{o}C sterilizing temperature. This was possible since heating at 121^{o}C required higher heating rate. However more of stagnant point or dead legs would appear. According to the steam flow pattern in this retort, the probe located at positions 3 (on top of the can which was at the center of basket) and 6 (upper layer and in between cans) were found to be the stagnation points and shown minimum convective heat transfer in each run at higher sterilizing temperature. However the minimum heating point for lower sterilizing temperature was found to get changed to be either position 5 or 2 (top of the retort) at the early stage of holding temperature in sterilizing period and then changed to location 3 for the rest of holding time. This was possible because the more amount of steam used during heating at 121^{o}C, the narrower the stagnation area would be. In addition, when lower amount of steam used at 110 ^{o}C sterilizing temperature, the probes at position 5 and 2 in the top layer of cans initially would get contacted with steam slower than any other locations. After heating at this temperature for a while, heating was up to the top of retort. Temperature at position 5 and 2 would be no longer the minimum.

However the exit point of coming steaming was from the bottom. Whenever steam valve was not fully opened the thermocouples in the lower layer would be affected or heated first. Therefore accomplished F_o obtained from the can at the center upper layer of the basket was suitable to be system F_o because the temperature from the probe nearby (probe 3) had demonstrated minimum heat received.

3.3 Process design or schedule and minimum heat accumulation in canned products

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^{o}C was 10 and 4.5 minutes excluding cooling period respectively. At higher sterilizing temperature (120^{o}C), it was shorter than that at lower temperature (110^{o}C) since both were calculated based on the same specified target F_o (0.7 minutes) 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 minutes but F_o of the system obtained was 1.29 and 0.94 minutes for sterilizing at 110 and 120^{o}C, respectively. This was because the calculation was including come-up time, holding and cooling period. Thus a little over-process could occur 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.

Heat accumulation in canned products can be observed from all accomplished F_o values obtained from different locations in retort. For sterilizing at 110^{o}C in figure 13 (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.

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.

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

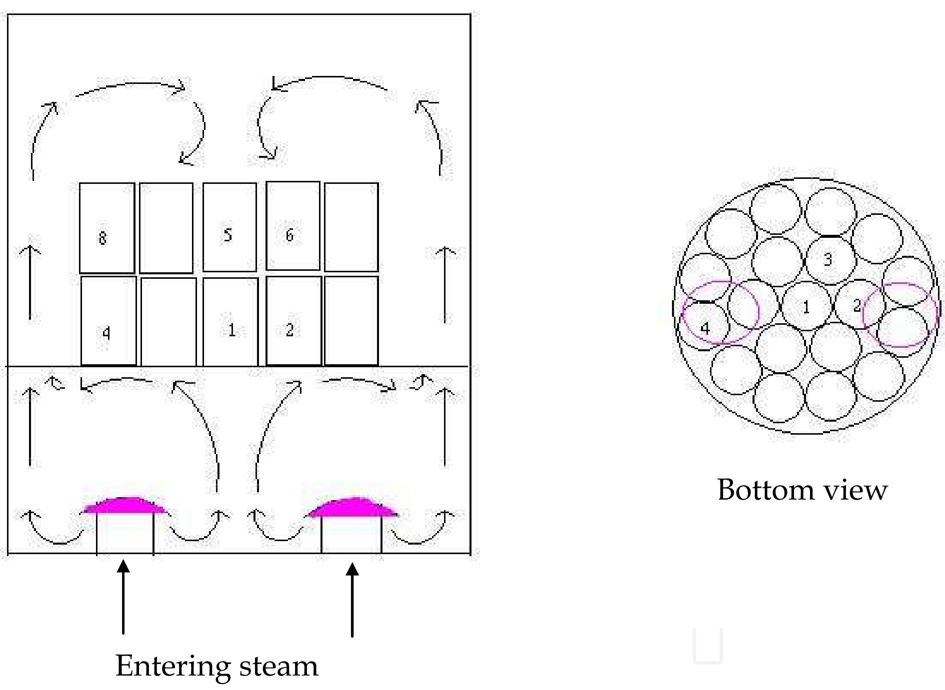


Fig. 15. Configuration of steam flow pattern in retort

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 13 (a) and (b), system F_o was obtained from different probes or positions of cans i.e. probe # 3 (position 1) from figure 13 (a) and probe # 5 (position 5) from figure 13 (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 15, the cans located at positions 1 and 5 were supposed to be at 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 (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.

3.4 Coldest spot in a container

The sterilizing values at 2 different points could be used as indicated tool to validate the coldest spot in a container while undergo sterilizing process. As shown in figure 8 the can was instrumented with 2 thermocouple probes and hard-wired through a 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. In addition, during sterilizing there were 3 main different periods of operations – come-up time, holding at sterilizing temperature and cooling periods. Heating rate at different period through the can and different spot in the can could be varied. Thus practically coldest spot in the can may not be the same point at all the time. However minimum accumulated heat in the can need to be known since it was used as critical point to evaluate for enough heat treatment of the process. Thus minimum sterilizing value was useful and reliable to represent the minimum accumulated heating point in the can. From table 3, the sterilizing values corresponding to probes # 4, 5 and 6 were 3.69, 2.85 and 9.54 minutes respectively. According to the meaning of accomplished sterilizing value of the process, the coldest spot was found from the minimum value (2.85). So for this type of food, baby corns in saline solution, heat transfer was the slowest at half of central axis of container.

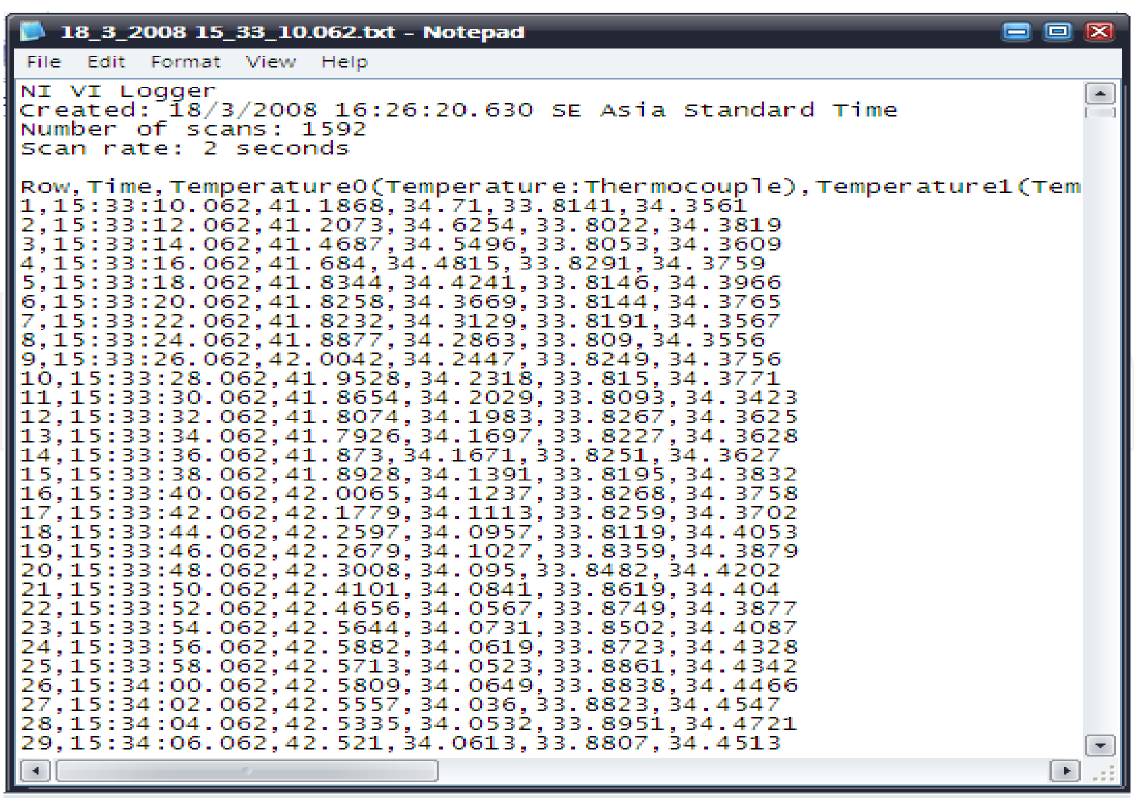
Probe #	Connecting point	Sterilizing value at 121°C (min)
4	1/4 of central axis from bottom of can	3.69
5	the half of central axis of can	2.85
6	Exposed to heating medium in retort	9.54

Table 3. Validation of coldest spot in the can by sterilizing value

3.5 Portable educational tools for computer-based off-line assessment of sterilizing unit

The temperature and time logging on-line was displayed as in figure 16 but they were retrieved off-line as a text file shown in figure 17. Then F_o was calculated from these data which were coming from thermocouple probes connected to 3 cans and one exposed to heating medium in the autoclave. From QuickCalFo as shown in figure 18, it showed that the slowest heating point in the retort was from thermocouple probe # 3 which was attached to the can located at the center bottom layer of the basket in the autoclave. Thus the accomplished sterilizing value or system F_o was chosen from the minimum of 12.81 minutes among all from 4 thermocouple probes. In analysis F_o frame box at the bottom right corner, the message after

Fig. 16. Temperature and time display in real time recording via USB-A/D board



18_3_2008 15_33_10.062.txt - Notepad
File Edit Format View Help

```
NI VI Logger
Created: 18/3/2008 16:26:20.630 SE Asia Standard Time
Number of scans: 1592
Scan rate: 2 seconds

Row,Time,Temperature0(Temperature:Thermocouple),Temperature1(Tem
1,15:33:10.062,41.1868,34.71,33.8141,34.3561
2,15:33:12.062,41.2073,34.6254,33.8022,34.3819
3,15:33:14.062,41.4687,34.5496,33.8053,34.3609
4,15:33:16.062,41.684,34.4815,33.8291,34.3759
5,15:33:18.062,41.8344,34.4241,33.8146,34.3966
6,15:33:20.062,41.8258,34.3669,33.8144,34.3765
7,15:33:22.062,41.8232,34.3129,33.8191,34.3567
8,15:33:24.062,41.8877,34.2863,33.809,34.3556
9,15:33:26.062,42.0042,34.2447,33.8249,34.3756
10,15:33:28.062,41.9528,34.2318,33.815,34.3771
11,15:33:30.062,41.8654,34.2029,33.8093,34.3423
12,15:33:32.062,41.8074,34.1983,33.8267,34.3625
13,15:33:34.062,41.7926,34.1697,33.8227,34.3628
14,15:33:36.062,41.873,34.1671,33.8251,34.3627
15,15:33:38.062,41.8928,34.1391,33.8195,34.3832
16,15:33:40.062,42.0065,34.1237,33.8268,34.3758
17,15:33:42.062,42.1779,34.1113,33.8259,34.3702
18,15:33:44.062,42.2597,34.0957,33.8119,34.4053
19,15:33:46.062,42.2679,34.1027,33.8359,34.3879
20,15:33:48.062,42.3008,34.095,33.8482,34.4202
21,15:33:50.062,42.4101,34.0841,33.8619,34.404
22,15:33:52.062,42.4656,34.0567,33.8749,34.3877
23,15:33:54.062,42.5644,34.0731,33.8502,34.4087
24,15:33:56.062,42.5882,34.0619,33.8723,34.4328
25,15:33:58.062,42.5713,34.0523,33.8861,34.4342
26,15:34:00.062,42.5809,34.0649,33.8838,34.4466
27,15:34:02.062,42.5557,34.036,33.8823,34.4547
28,15:34:04.062,42.5335,34.0532,33.8951,34.4721
29,15:34:06.062,42.521,34.0613,33.8807,34.4513
```

Fig. 17. Recorded data obtain via USB-A/D board

analyzing indicated whether the product had enough heat treatment or not. To display temperature and time as a spread sheet on the left side of this figure, time interval of data was selected first at the bottom between in every 1, 2 or 5 minutes. Then the temperature and time only at this specific interval was shown in the spread sheet of GUI. Heat penetration and lethal rate profiles from all 4 probes were also displayed graphically. The x and y range of these 2 graphs were adjusted automatically according to process temperature and time span used. In addition, this visual basic form could be printed out for food safety documents.

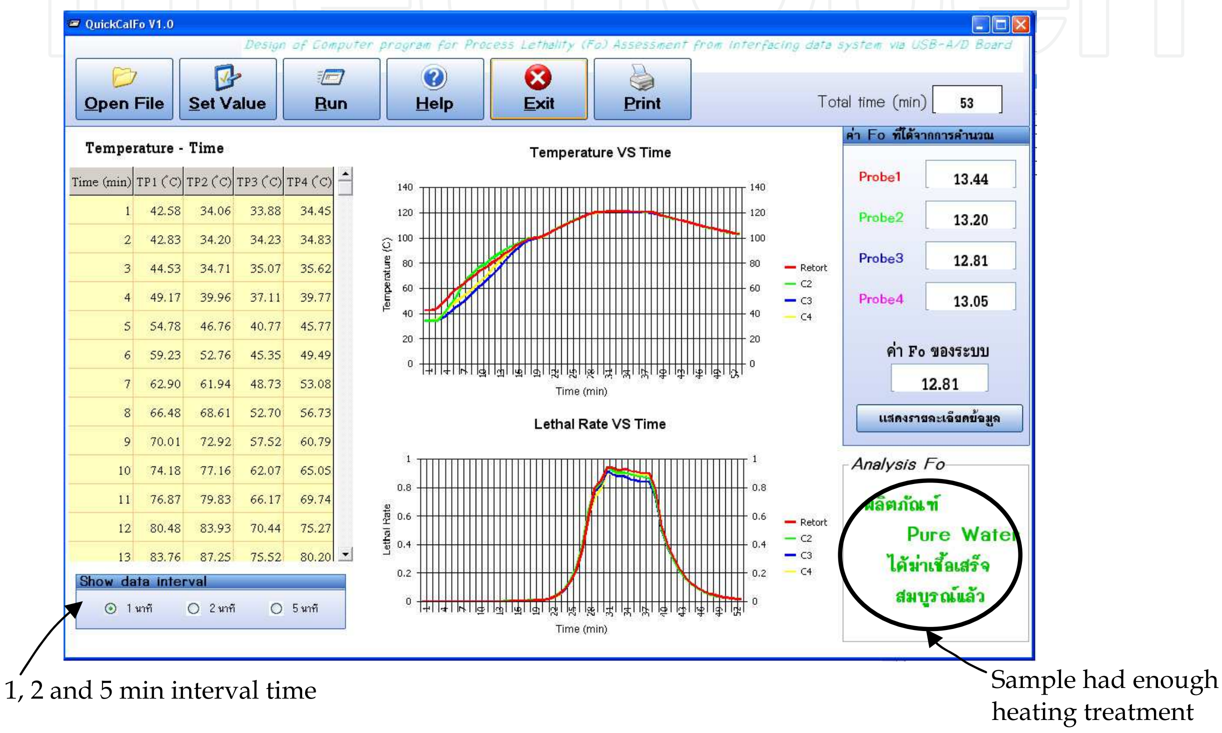


Fig. 18. The result displayed by QuickCalFo

4. 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. 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. The setup of hardware and software for computer-based on-line assessment of sterilizing unit would be needed for the cases of new products, processes or equipments.
Non-uniform heat distribution in retort always exists. The designed program was able to perform heat distribution evaluation by recording and displaying maximum/minimum temperature deviation at different locations in retort during holding temperature in sterilization process. Lower sterilization temperature at 110°C had lower temperature deviation (1.6-2.8%) in the retort during the holding temperature comparing to 4.1-11.6% at 121 °C. Thus lower temperature tended to lower the deviation.

Coldest spot in a container during sterilization process can be verified by employing sterilizing value (F_o). The minimum of these values is corresponding to the point in the can which has the lowest accumulated heat. The coldest spot in the can of baby corns in saline solution while undergo sterilizing was confirmed to be at half of central axis of can by committing minimum value of F_o.

Portable or handy educational tools for sterilizing process was necessary to be available since most of the processes may routinely carry out for the same process schedule. The result could be used to assure food safety control.

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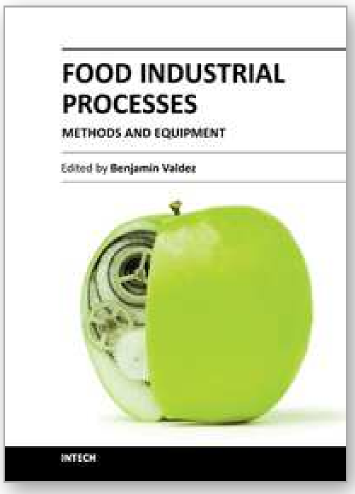

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The global food industry has the largest number of demanding and knowledgeable consumers: the world population of seven billion inhabitants, since every person eats! This population requires food products that fulfill the high quality standards established by the food industry organizations. Food shortages threaten human health and are aggravated by the disastrous, extreme climatic events such as floods, droughts, fires, storms connected to climate change, global warming and greenhouse gas emissions that modify the environment and, consequently, the production of foods in the agriculture and husbandry sectors. This collection of articles is a timely contribution to issues relating to the food industry. They were selected for use as a primer, an investigation guide and documentation based on modern, scientific and technical references. This volume is therefore appropriate for use by university researchers and practicing food developers and producers. The control of food processing and production is not only discussed in scientific terms; engineering, economic and financial aspects are also considered for the advantage of food industry managers.