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HEAT DISTRIBUTION PATTERNS IN CANNED PRAWNS

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Abstract

Temperature measurements were made with the aid of thermocouples located at different points in cans of size 301×206, filled with cooked prawns in 3 per cent brine, during the sterilization process, to study the heat distribution patterns in the can. The slowest heating zone was found to lie midway between the geometric centre and bottom of the can on the central longitudinal axis and the mechanism of heat transfer was predominantly convection type. The variation of heating parameters f and j (slope and lag factor) of the heating curve were studied at the geometric centre and at the slowest heating point and with variation of retort temperature, initial temperature and size grade of the product. The F value (lethality of the process) was calculated by graphical and formula method (Ball and Olson) for the standard wet pack of medium grade cooked prawns.

Introduction

As a part of the programme on standardisation of methods for prawn canning, studies were carried out on the heat distribution patterns in canned prawns during sterilization process. Location of the slowest heating zone, effect of variation in retort temperature and initial temperature of the product, size grade on the heating parameters f and j (slope and lag factor) of the heat penetration curve were also investigated. F value (lethal value) of 20 minutes sterilization at 115.6°C (10.3 p.s.i.g.) (0.7 kg/cm² steam pressure) was determined by graphical and formula (Ball and Olson) methods.[1]

Experimental

The test cans used in the trials were S.R. lacquered type of size 301 × 206 (8 oz), 77.8 mm in diameter and 60.3 mm in height and the product filling the can was 142 g of medium grade cooked prawns (21 to 34 pieces/100 g) in 90 cc filling brine of 3 per cent concentration leaving a head space of about 3 mm. A vertical type retort of about 100 litre capacity was used to process the test cans. The cans were kept vertical at the centre of the retort.

The pressure inside the retort was controlled manually to the required retort temperature ± 0.5°C by means of three valves—one valve fitted to the retort and two to an external boiler. The steam was injected from the external boiler kept at a pressure 2.37 kg/cm² (35 p.s.i.g.) so that coming up time of the required temperature in the retort was minimum. Normally 20 to 30 seconds were taken initially for building up and adjusting the pressure in the retort to the required value. Similarly during the cooling process 20 to 30 seconds were taken to reduce the pressure to the normal and 15 seconds for transferring the experimental cans to the water kept at 21°C. Canonical and retort temperatures were read on a Cambridge pyrometer to an accuracy of ± 0.5°C through a multi-junction switch using copper constantan thermocouples, embedded at the centre of a prawn piece and in retort midspace. The thermocouples were lacquered and glass wool insulated and were of 36 SWG. The choice of high gauge for the thermocouples enabled conduction errors to be minimum (Cowell *et al.*, 1959, Board *et al.*, 1960)[2, 3] which is important in view of the high coefficient of heat transfer in prawn containing over 70 per cent water. A special type of thermocouple receptacle for inserting the thermocouple inside the can was designed (Figure 1). The unit was constructed from brass and made pressure tight by using rubber gaskets on either sides of can wall. It occupied less than 0.2 per cent of total surface area of the can, thus affecting very little heat transfer from the surface to the material within. Can temperatures were noted at regular intervals (4 cans were used in each experiment) during heating and cooling phases (until the can cooled to 80°C, below which the lethal rates are negligible) from the time steam entered the retort. The heating parameters f and j (slope and lag factor) were determined from the semilog plot of the difference of retort and canonical temperature against time of heating phase. The sterilizing value of 20 minute process (Fh + Fc) were calculated by the graphical (Bigelow, *et al.*) and formula method of Ball and Olson (2nd Eq. of 12.52) and table of exponential integrals

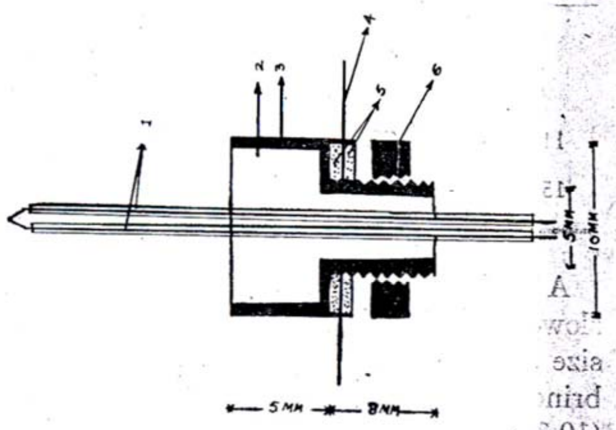

Fig. 1. Thermocouple receptacle
1. 36 SWG Copper–constantan thermocouple wire insulated with glass wool 2. Bakelite 3. Brass body 4. Can wall 5. Rubber gasket 6. Clamp nut.

Results

Experimental results on the heat distribution on the horizontal axis 1.3 cm from the bottom during heating and cooling (in water at 21°C) phases are given in Figure 2. Heat distribution along the central longitudinal axis are shown in Figure 3. The temperatures at a point (1.3 cm from the bottom and 2 cm from can wall) during heating and cooling processes are recorded in Figure 4. Observing the isochronals on the plane 1.3 cm from bottom, it will be noticed that there is an appreciable tempera-

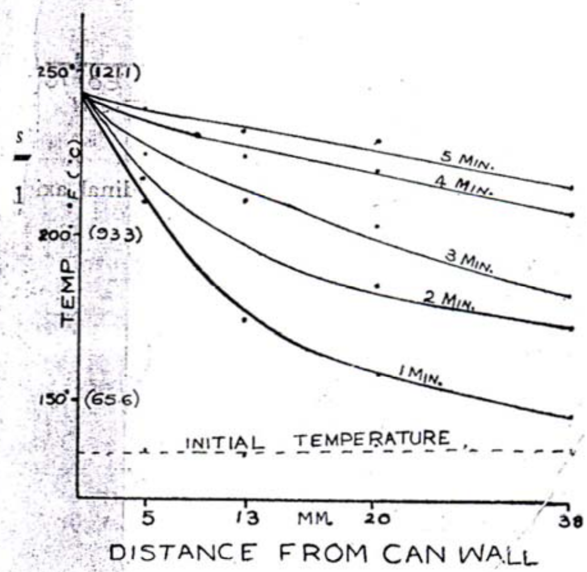

Fig. 2. Isochronals on a horizontal plane 13mm from bottom of can

ture difference in the prawns located at the centre and near the can wall, during the initial heating phase, showing that the heat transfer to the material is mainly due to convection currents of hot brine. Again in the cooling phase (Figure 3) the material in the top layer is at a higher temperature compared to the bottom layer, as less denser fluid at high temperature reaches top. Further support to this type of heat transfer was obtained from observation of isochronals

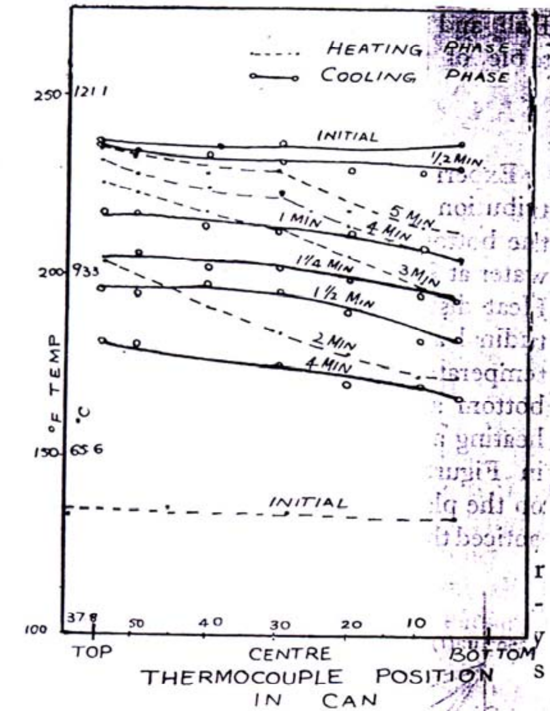

FIG. 3. Isochronals on central longitudinal axis

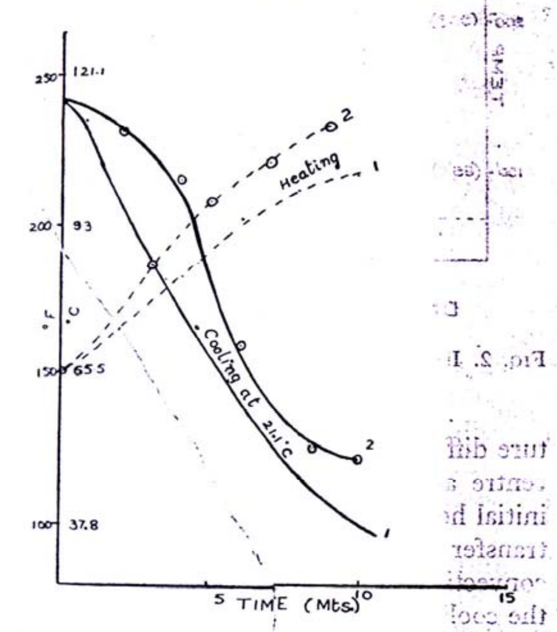

FIG. 4. Time temperature data for thermocouple positions

(1) 13 mm from bottom on central longitudinal axis.

(2) 20 mm from can wall on central horizontal axis.

on central longitudinal axis and rates of heating and cooling at 1.3 cm from the bottom of the can and 2 cm from can wall on the central horizontal axis.

Temperature variation along the central longitudinal axis during heating phase at different intervals are shown in Table 1. Taking into consideration the variation in size, shape, orientation of test samples (prawn pieces) wherein the thermocouples were introduced, the slowest heating zone was found to lie 1.3 to 1.5 cm from the bottom of can on the central longitudinal axis.

TABLE 1. *Temperature distribution along central longitudinal axis of the can (301 × 206) during the initial heating phase*

Position of thermocouple from bottom	Experiment 1			
	Temperature recorded (°C) at different intervals of time			
	2 min.	3 min.	4 min.	5 min.
5 mm	90.6	99.0	102.8	105.0
10 mm	85.0	97.1	100.6	103.2
13 mm	74.0	84.5	88.3	91.8
20 mm	93.4	101.8	104.4	106.2
	Experiment 2			
9 mm	91.1	98.2	105.0	
11 mm	76.2	91.1	101.1	
15 mm	75.4	90.6	97.3	

A typical heat penetration curve at the slowest heating point of 142 g medium size grade prawn packed in 90 cc filling brine and sterilised at 115.6°C (0.7 kg/cm^2 (10.3 p.s.i.g.) steam pressure is shown in the inverted semilog graph (Fig. 5.) The slowest heating zone had reached 1° F (5/9°C) below the retort temperature in 9.5 to 10.5 minutes for medium size grade prawns. The lag factor 'j' though for convection heating should ... maximum value of 1, in all cases it is greater than 1.03 as the heat transfer within the piece is by rapid conduction aided by convection current of surrounding brine. The slope (f) was determined in the conventional manner by measuring tangent of angle between the asymptote and time axis. The tangent was drawn at a point judged by the eye where the curve appeared to be fairly linear.

From Table 2, it could be seen that heating curve factors measured at the slowest heating point are not significantly affected with variation of retort temperature 112.8°C, 115.6°C and 118.3°C corresponding to steam pressures 0.55 kg/cm² (8.1 p.s.i.g.), 0.7 kg/cm² (10.3 p.s.i.g.), 0.86 kg/cm² (12.6 p.s.i.g.). From the same table, it may be observed that lag factor and slope at the critical point were higher than at geometric

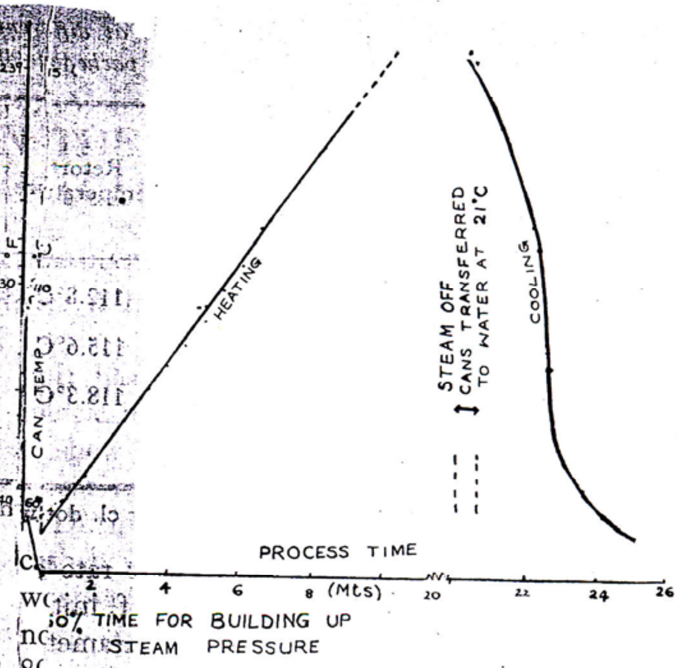

FIG. 5. Heating and cooling curves of 142g of cooked prawns (medium grade)+90 ml of 3% brine in can of size 301×206.

TABLE 2. *Effect of some variables on the heating curve factors*

Type of test pack	Position of thermo-couple (from bottom)	Can vacuum	Initial temperature of can	Retort temperature (pressure)	Lag factor (Min.) j	Slope f	Remarks
				(Effect of retort temperature)			
142 g medium size prawns + 90 ml 3% brine	1.3 cm	17 cm	60°C	112.8°C	1.03	4.2–4.4	Variation in f or j is not significant
,,	1.3 cm	5 cm	58°C	115.6°C (0.7kg/cm²)	1.04	4.3–4.4	
,,	1.3 cm	6 cm	63°C	118.3°C (0.86kg/cm²)	1.06	4.6	
				(Effect of size grade)			
142 g small size prawns + 90 ml 3% brine (35-53 Nos/100g)	1.3 cm	7 cm	55°C	115.6°C	1.03	3.7–4.0	f, j vary with size grade
,, medium grade (21-34 pieces/100g)	1.3 cm	10 cm	52°C	,,	1.03–1.07	4.2–4.6	
,, large size (13-20 pieces/100g)	1.3 cm	9 cm	54.5°C	,,	1.17–1.27	5.5–6.8	
				(Effect of initial temperature of can)			
142 g medium size prawns + 90 ml 3% brine	1.3 cm	10 cm	35.5°C	112.8°C (0.55kg/cm²)	1.07	4.8	Variation in f or j is not significant
,,	1.3 cm	8 cm	70°C	,,	1.07	4.6	
142 g medium size prawns + 90 ml 3% brine	1.3 cm	10 cm	32.[illegible]°C	115.6°C (0.7kg/cm²)	1.10	5.0	f, j are higher at bottom thermo-couple position
,,	Geometric centre of can	5 cm	35.5°C	,,	1.02	3.8	

TABLE 3. *Lethality of the retort process at different sterilization temperatures given to 142 g of medium grade cooked prawns packed in 90 ml brine in can of size 301 × 206*

Process time	Can vacuum cm	Retort pressure	Retort temperature	Initial tempe-rature of can	Time taken to reach 1°F (5/9°C) below retort temp. (Rt)	'j' Lag factor	f Slope Min.	Graphi-cal Fh	For-mula +Fc
25 Min.	9 cm	0.55 kg/cm²	112.8°C	70°C	9.5 Min.	1.02	4.2	2.58	2.81
20 Min.	10 cm	0.7 kg/cm²	115.6°C	52°C	9.5 Min.	1.03	4.2	4.17	4.11
15 Min.	7 cm	0.86 kg/cm²	118.3°C	51.5°C	13.90 Min. (0.1°F) Rt	1.06	4.6	3.67	3.96

Based on TDT curve for cl. dot, whose (slope) Z = 8 Min. (Esty, Meyer)[4]

centre due to comparatively slower rate of heating at the former. Effect of initial temperature of the can on heating parameters is also not very significant. This is important in view of the time lag normally exists between sealing first and last can after exhaust in a routine canning process in a factory.

20 minute sterilization process (at 115.6°C) is normally adopted by the local factories for the medium grade wet prawn pack (142 g solid and 90 cc brine) of 301 × 206 can size. To find the adequacy of the process, the lethality rates were calculated by the graphical method of Bigelow, *et al.*, by plotting sterility rates at different temperatures and by the formula method of Ball and Olson. Taking into consideration the contribution to the sterilization process during the initial cooling phase (upto a cooling temperature of 85°C), F values of such process were 4.17 and 4.11 minutes respectively by graphical and formula methods which is more than adequate for this type of can and contents. A process time of 14.1 minutes is enough to give an adequate sterilization process (F=2.33 minutes).

Summary

Studies on heat distribution curves at various points in the can of size 301 × 206 packed with 142 g of cooked prawns in 90 ml brine, during the sterilization process, have indicated that the main transfer of heat to the meat is by convection currents of hot brine. The slowest heating zone was found to lie 1.3 cm to 1.5 cm above the bottom, on the central longitudinal axis. The heating parameters are not significantly altered by variation in initial temperature of product and sterilization temperature. Lethality of the normal 20 minute process at retort temperature 115.5°C adopted by the factories is found to be adequate and significantly more than the minimum time required for this type of can and contents.

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