Fishery Technology
2008, Vol. 45(1) pp : 55 - 62

Effect of Rotation on the Heat Transfer Characteristics and Texture of Canned Skipjack Tuna in Tin-free Steel Cans

K.A. Martin Xavier, P.G. Sreenath, S. Sil, *C.N. Ravishankar, J. Bindu and T.K. Srinivasa Gopal

Central Institute of Fisheries Technology,
Cochin - 682 029, India

Heat transfer characteristics of Tuna (*Katsuwonus pelamis*) in indigenous polyester coated easy open-end tin free steel cans processed in rotary retort were studied at different rotational speeds. Precooked tuna meat was processed in groundnut oil medium to an F_0 value of 10 minutes and the effects of rotation were compared with a Stationary retort. Heat penetration data were recorded using Ellab TM 9608 Temperature recorder cum process value integrator. The study reveals that rotation decreases the heating rate index to 25%. Cook value reduced to 11.51-17.46% during rotation. Total process time also reduced when subjected to rotation, but the magnitude of reduction in processing time decreased with increase in speed of rotation. Textural parameters like hardness, cohesiveness, springiness and chewiness are also increased during rotation due to less process time and faster heat penetration.

Keywords : **Skipjack tuna, Tin free steel can, rotation, heat penetration, F_0 Value, cook value, texture profile analysis**

Canned products enjoy wide acceptance in domestic as well as international markets due to the convenience and ready to eat features. The scope for heat processed foods are appears to be bright in the future years in developing countries due to urbanization and busy life style. Heat penetration in canned foods are influenced by several factors like can material, size of the container, thickness of the can wall, thermo physical properties of food, filling medium, temperature of the process, chemical additives etc. Rotation of the cans has an effect on the heat penetration characteristics, which reduces process time (Sablani & Ramaswamy, 1996). Reduction in process time has an advantageous effect on the sensory and nutritional qualities of the thermally processed fish products. Heat transfer in liquid, semi viscous or particulate foods can be significantly increased by mechanical agitation during processing; this is the underlying principle of agitating sterilization of retorts. Influence of particle shape and particle motion on heat transfer in cans during end-over-end rotation and the influence of rotational speeds were carried out by Ramaswamy & Sablani (1997a, 1997b). The effect of rotational speeds and headspace were more significant than those of retort temperature and radius of rotation (Sablani & Ramaswamy, 1996). The roles of different agitation speeds (0-30 rpm) during end over end rotation of containers filled with water and model food system were studied by Knap & Durance, (1999). Taherian (1996) reported the effect of agitation processing on thermal softening of vegetable texture. End over end rotation resulted in a faster heat penetration and better quality retention (Vanloey, 1994). Thus the aim of thermal processing with rotation or agitation is to produce a product that is safe to consume with maximum nutrient retention.

The over all objective of this study was to determine the effect of rotation on the heat transfer characteristics and quality of canned

* Corresponding Author : cnrs2000@rediffmail.com

tuna in indigenous tin free steel cans by subjecting the cage of the retort to different rotational speeds.

Materials and methods

Raw material and Sample preparation

Skipjack Tuna (*Katsuwonus pelamis*) collected from Cochin fisheries harbour was brought to laboratory in iced condition. After removing head and viscera, it was kept in cold running water to remove the blood from meat. Fish was then precooked in steam at steam pressure of 10 psig for 60 minutes to attain a temperature 90 - 92°C at the central bone surface, cooled and kept in 4° C in the chill room over night. The skin was separated off from the cooked tuna piece and it was split dorso-ventrally and then along lateral line to get four loins. Red meat lying along the lateral line was removed and white meat carefully seperated from the cooked tuna loin and cut into slices of 1.5-inch thickness.

Indigenous polymer coated TFS cans of 307 X 109 size (6 oz capacity) manufactured by M/S Amtech packs, Mysore were used for the study. The can is made of ECCS plate with clear PET coating on either sides. The finished plate has a thickness of 0.19 mm (0.15 mm of base steel + 20 μ PET coating on either sides). The cans are made out of the steel plate produced by Draw and Redraw (DRD) process. The easy open lids are of the same material as that of cans with a thickness of 0.28 mm.

The cans were thoroughly washed to remove adhering impurities and dried well to remove traces of water. Before filling the cans, a thermocouple was fixed at about one third from the bottom of the can to record the core temperature.

A specially designed Polyoxymethylen packing gland (type GKJ-13009-C042, Ellab A/S, Roedovre, Denmark) was used to enable the insertion of thermocouples into the can. It consisted of two rubber O-rings and nuts and the space bar with a hole in the center through which the thermocouple needle was inserted into the cold spot of the product. Copper /copper nickel thermocouples (type SSA 12040 – G700 -TS, Ellab Co. Denmark), capable of measuring temperature in the range of - 45°C to 135°C with an accuracy of ± 0.1°C and a response time of 0.8 second, were used. The threaded electrode used in the assembly was made of stainless steel and had a length of 80mm, and the connecting cable was made of Teflon.

For the purpose of determining the pressure holding capacity of the cans and to check for any leakage through the double seam, the cans were subjected to air pressure test at 25 psi for 30 seconds (IS 2471, 1963; IS 9396, 1979). The cans were pierced with a piercing type of pressure gauge and then air was pumped inside using a foot operated pump until any distortion of the can or any leakage through the double seam area was noticed. The double seamed cans have to be immersed in boiling water for 5 min prior to the test. The cans were also processed at different temperatures and pressures of 115°C (10 lbs), 121.1°C (15 lbs) and 126°C (20 lbs) in a pilot scale retort of model 24 rotary retorting systems (John Fraser and sons Ltd, UK. Model. No. 5682) to determine it's ability to withstand different processing conditions. The vacuum inside the processed cans was determined by using a vacuum gauge of piercing type as per IS 3336 (1968). Indigenous polymer coated TFS cans are provided with PET coating that comes in direct contact with the food that is processed and packed inside. Hence tests for food contact applications were done as per the method of FDA (2002). The water holding capacity of the cans were determined as per IS: 6093 (1970). The cans were tested for their resistance to sulphide blackening employing sulphide-staining test IS: 5818 (1970). The polymeric coating of TFS cans was subjected to delamination test using various organic solvents like acetone, carbon tetra chloride, chloroform, diethyl ether, ethyl acetate, n-heptane, methanol, and petroleum ether.

Panels of 1 X 1 cm size were taken and immersed in organic solvents. They were taken out after 24 hrs and examined for any delamination of the PET coating. When there was no peeling they were kept immersed for another 12 hrs. The panels were taken out and heated in water bath for few minutes and examined for delamination of the coating

110 gm of cooked fish meat were filled in TFS cans, 2% dry salt was sprinkled over the material and 60ml double refined groundnut oil was added. The filled cans were then steam exhausted for 10 minutes and immediately sealed in a double seaming machine (24 DS Metal Box Seamer)

Cans were heat processed to a F_0 value (Sterilization value) of 10 minutes in an overpressure autoclave (John Fraser and sons Ltd, model no 5682). To study the effect of rotation of Tuna Packed in tin free steel cans on heat penetration characteristics the retort was subjected to different rotational speeds ranging from 2–6 rpm. Heat penetration data were recorded through thermocouples connected to Ellab (TM 9608, Denmark) temperature recorder cum process value integrator. Containers were placed in vertical orientation in the cage and subjected to end-over-end rotation. In each test, experimental cans were placed in the corners of the cage for giving the same diameter of rotation and the remaining space was filled with dummy cans. The results of heat penetration data were compared with stationary retort (0 rpm) to find out the effect of rotation on heat penetration.

Heat penetration data were plotted on a semi logarithmic paper with temperature deficit (Retort temperature – Core temperature) on log scale against time for studying the pattern of heat penetration. From the graph the heat penetration parameters such as lag factor for heating (J_h), slope of the heating curve (fh), time in minutes for sterilization at retort temperature (U), lag factor for cooling (j_c), final temperature deficit (g) were determined. Total process time was calculated by the mathematical method of Stumbo (1973). Actual process time was determined by adding process time (B) and the effective heating period during come-up time ie, 58% of the come up time.

Cook value (cg), a measure of nutrient degradation with respect to the heat treatment and textural changes that occur during processing, was determined by measuring the extent of cooking and nutrient loss during processing in a manner similar to the D-value, except that the reference temperature is 100°C, and the Z-value is 33°C, which is required for the denaturation of Thiamine(Ranganna, 2000)

Texture profile analyses of canned tuna were done using the food texture analyzer of Lloyd Instruments, U.K. Model LRX plus (F.T-39 No-2) with software Nexygen. The test was done at a speed of 12mm/second using 500N load cell. The probe used for the experiment was a 50mm diameter cylindrical probe. The canned tuna meat was subjected to 40% compression with a trigger force of 0.5 kg. From the double compressions parameters like hardness 1 and hardness 2, Cohesiveness, Springiness, Chewiness were calculated.

Results and Discussion

The various physical properties of indigenous polymer-coated TFS cans were studied and the results are presented in Table 1. The air pressure test showed that the cans are capable of withstanding internal pressure up to 25 psig. Fish and fishery products are usually processed at 121.1°C with a corresponding pressure of 15 psig cans were found to retain their original shape without any distortion, and they do not require any overpressure during processing. The results of the test for food contact application indicated that the cans are suitable for processing food products as the migration residues were within the limits prescribed. The results of test for seam integrity using double seam analyses are

Table 1. Physical properties of indigenous TFS cans

Parameters	Result
1. Air pressure test	Withstands up to 25 psig
2. Test for food contact application	
a) Water soluble extractives	6.9±0.003 mg/litre
b) n-heptane soluble extractives	25 ±0.002mg/litre
3. % Overlap	63 ±0.03 %
4. Body plate thickness	0.18±0.001 mm
5. Endplate thickness	0.28±0.002 mm
6. Water holding capacity	180 ml
7. Sulphur staining test	No blackening
8. Determination of vacuum	100 mm Hg

given in Fig.1. The overlap was 63%, which is well above the requirement. These results indicate that the indigenous polymer coated easy open-end TFS cans are suitable for the thermal processing of fish and fish products.

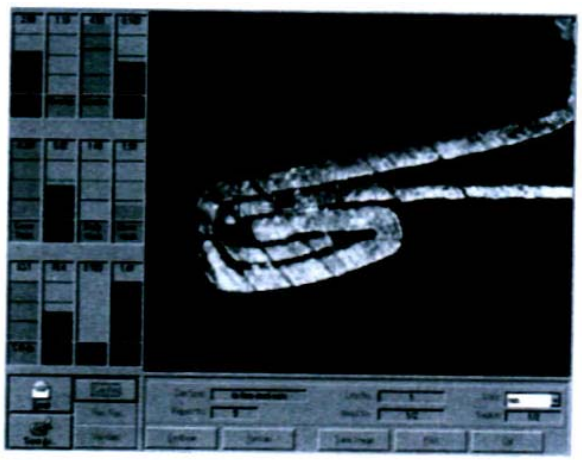

Fig. 1. Seam integrity test using double seam analyses

Effect of different rotational speeds on the heat penetration parameters of thermally processed tuna in oil in tin free steel cans was presented in Table 2. The come up time of the retort to reach 121.1°C varied between 4-6 minutes and the variation is within the range (NCA, 1968). Heating rate index (f_h Value) is one of the primary outputs of the heat penetration test. It is a negative reciprocal slope of the semi-logarithmic heating curve. The fh values of rotary retort processing were always lower than the fh values of processing in stationary retort at similar temperatures. It can be seen that the oil packs have a definitely higher fh values than the corresponding brine packs (Ali *et al.* 2006). This can be attributed to mainly the higher viscosity of the oil, which prevents rapid convection movement within the cans. Ramaswamy & Grabowski (1999) have found that shape of the container was the most significant factor affecting the heating rate index. The fh Value for thermally processed tuna with 2, 4 and 6 rpm were 21.5min, 21.0 min and 19.5 min respectively, while that processed in stationary retort has an fh value of 27 minutes. This indicates that the fh-value decreases with increasing rotational speed. Ramswamy & Marcotte (2006) reported that rotating the cage results in agitation of contents and this can create turbulence in products being sterilized resulting in the greatest rate of heat penetration. Several researches have studied axial or end - over - end rotation and came to the conclusion that increasing rotational speed resulted in faster heat penetration;

Table 2. Heat penetration data of thermally processed Tuna in different Rotational speeds in polymer coated TFS cans (Process temperature: 121.1°C)

Rotation Speed (rpm)	fh (min)	j_h	j_c	fh/U	g(°C)	Cg(min)	Total B (min)	Process time (min)
0	27.00	1.134	1.189	2.428	2.66	109.4	38.60	42.76
2	21.50	1.089	1.081	2.15	2.19	96.8	37.30	40.86
4	21.00	1.485	1.079	2.10	2.12	93.7	35.07	38.50
6	19.50	1.03	1.013	1.95	1.87	86.74	32.60	36.10

(Lag factor for heating (j_h), slope of the heating curve (fh), time in minutes for sterilization at retort temperature (U), lag factor for cooling (j_c), final temperature deficit (g), Cook value (cg), total process time (B) that is lower fh values (Vanloey, 1994., Ali *et al.*, 2006). However influence of rotation speed on heat penetration rate is limited. Vanloey (1994) reported that increasing the 20-rpm resulted in breakage of the product.

The lag factor of heating (j_h) and the lag factor of cooling (j_c) are above 1 indicating prefect heating and cooling rate. U value, which is the lethality of a process expressed in terms of time at retort temperature, differed significantly with the rotational speed. Hence time needed at different rpm for obtaining lethality of 10 min is less. g-value is a measure of the difference between the intended retort holding temperature and the product temperature at the time steam is cut-off. The value was lower at higher rpm indicating that there is still scope for attaining better heat penetration into the food at these temperatures.

The values of fh/U and g decreased with increased speed of rotation, since these parameters dependent on the heat penetration factor fh. Cook Value is aimed at achieving an optimal tenderness in a finished product. However it can also be a measure of quality deterioration. Cook value of Tuna processed in stationary retort was 109.4 min and when retorted with agitation, the cook value was reduced to 96.8, 93.7 and 86.74 for 2,4 and 6 rpm, respectively and the reduction were 11.51%, 13.53%, 17.46% respectively. Process time required for canning tuna in oil medium in stationary retort to F_0 value 10 was 42.76 minutes. For attaining the same F_0 value, the process time in stationary retort is higher than processing with agitation. For 2 rpm there was a reduction of 5% time compared to the product processed in stationary retort for the same F_0 value. The process time was reduced by 11.6% when rotation was given at 6rpm. Heat penetration characteristic and cook value of thermally processed tuna in tin free steel can in oil medium at different rotation where given in figure 2 to 9. The higher process associated with stationary retort processing resulted in quality loss depending on the length of process time.

If the term quality is regarded as anything that affects the value of the product, then process time can be considered as an important quality parameter. Hence from the results of the present study it can be implied that processing tuna at 6 rpm in a rotary retort clearly enhances the quality of the canned product. The retorting operation in canning is often the bottleneck operation and hence it determines the output of the plant. Retort energy consumption is largely a function of process time (Durance, 1997). Hence it can also be seen that using a rotary retort for canning can significantly reduce the retort energy consumption.

Results of Texture Profile Analysis of canned tuna with different rotational speeds were presented in Table 3. Texture ranks high among the factors that determine the consumer acceptance of a food. Since texture is a multi-parametric attribute, various terminologies are used to describe it. Hardness is the force necessary to create a given deformation in the food. Hardness value shows an increasing trend during higher

Table 3. Instrumental texture profile analysis of tuna meat processed at different rotational speeds

Sample	Hardness I (kgf)	Hardness II (kgf)	Cohesiveness	Springiness (mm)	Chewiness (kgf.mm)
Fresh Tuna	3.07±0.29	2.48±0.25	0.21±0.03	1.73±0.37	1.15±0.38
Precooked Tuna	5.67±0.46	4.16±0.23	0.28±0.02	4.88±0.40	7.71±0.82
Tuna in oil (0 rpm)	3.55±0.50	2.66±0.41	0.28±0.03	3.98±0.62	3.89±1.05
Tuna in oil (2 rpm)	4.04±0.65	3.10±0.38	0.32±0.03	3.07±0.54	3.97±0.68
Tuna in oil (4 rpm)	6.89±0.35	5.81±0.14	0.36±0.01	5.61±1.21	6.28±2.91
Tuna in oil (6 rpm)	7.14±0.28	6.02±0.07	0.34±0.02	6.53±0.73	8.38±0.91

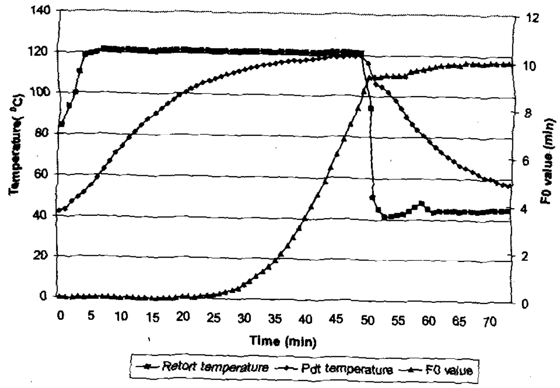

Fig. 2. Heat penetration Characteristics and F_0 value of thermally processed tuna in Oil in a Stationary retort (0 rpm)

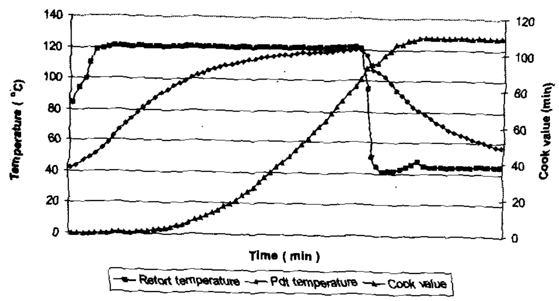

Fig. 3. Heat penetration Characteristics and Cook value of thermally processed tuna in Oil in a Stationary retort (0 rpm)

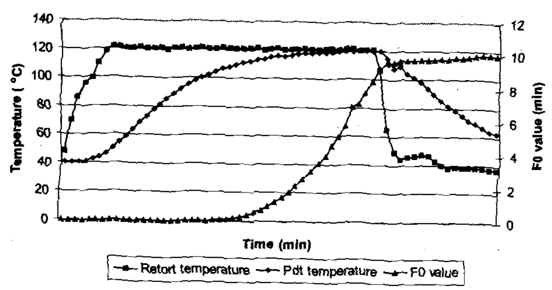

Fig. 4. Heat penetration Characteristics and F_0 value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 2 rpm

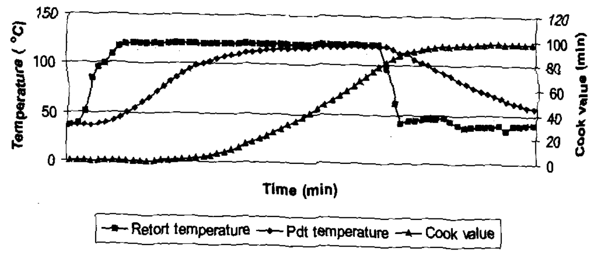

Fig. 5. Heat penetration Characteristics and Cook value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 2 rpm

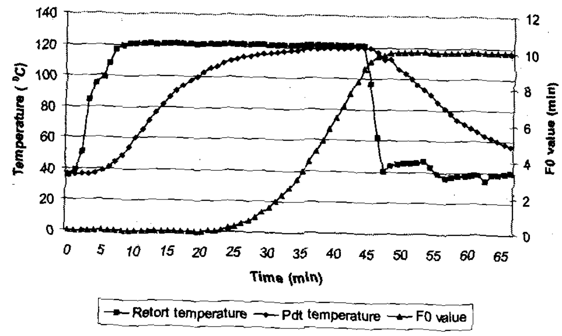

Fig. 6. Heat penetration Characteristics and F_0 value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 4 rpm

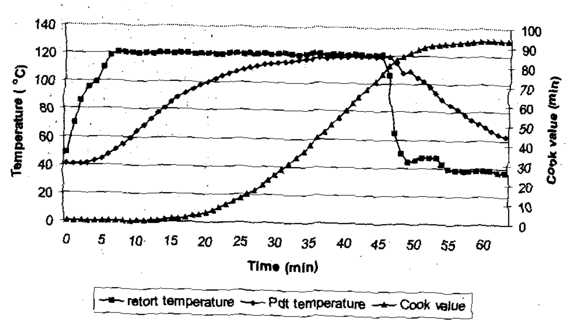

Fig. 7. Heat penetration Characteristics and Cook value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 4 rpm

rotations were as the fresh material in the fresh fish, the hardness value was 3.07 kgf which increased to 5.67 kgf in cooked meat. This increase in hardness is due to the denaturation of fish proteins during cooking. Hardness II values are also shows the same trend. The change in hardness is mainly due to heat processing which causes conversion of collagen to gelatin and dissociation of muscle proteins. At 6 rpm the fish muscle was less subjected to the heat treatment thus hardness value was higher than 4 and 2.

Cohesiveness refers to the extent to which a material can be deformed before it ruptures. This value is an indication of

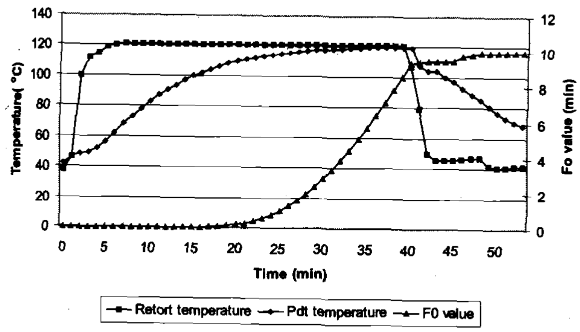

Fig. 8. Heat penetration Characteristics and F_0 value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 6 rpm

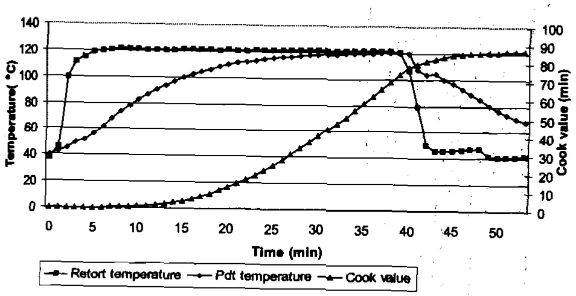

Fig. 9. Heat penetration Characteristics and Cook value of thermally processed tuna in Oil processed to F_0 value 10 in a rotary retort at 6 rpm

internal bonding of the muscle. Fresh tuna meat had a value of 0.21 for cohesiveness that increased during precooking and during thermal processing at 6 rpm it shows higher internal bonding value than other conditions. Springiness is the rate at which a deformed material goes back to its undeformed condition after the deforming force is removed which is the elastic recovery of the meat. Precooking improved the elastic property of the meat while, tuna processed in stationary retort and at 2 rpm speed springiness values are lower than precooked one. Chewiness is the energy required to masticate a solid food to a state ready for swallowing. It is a product of hardness, cohesiveness and springiness. (Szczesniak, 2002). Chewiness value was maximum for 6 rpm followed by 4 rpm while, the springiness values are much lower at stationary retort processing and also processed in rotary retort at 2 rpm rotational speed. In general precooking improved all the textural properties of canned tuna. But its further improvement is depends on the rotational speed or process time.

The present study indicated that rotation significantly influences the heat penetration characteristics and textural properties of canned tuna in oil Processed in tin free steel cans. Total process time decreases when cans are subjected to rotation and it decreases with speed of the rotation, but the influence of rotational speeds on heat penetration rate was limited. Even though the total process time was shorter at 6 rpm than 4 rpm the difference between them was not significant. Thus 4 rpm can be taken as optimum. Retort energy consumption which in turn greatly depends on the process time can thus be greatly reduced. Textural parameters shows better quality in canned tuna subjected to rotation during retorting than without rotation.

The authors are indebted to the Director, Central institute of Fisheries Technology for the permission to publish this paper. We also greatly acknowledge the financial assistance provided by the ICAR for carrying out the work.

References

Ali, A. A., Sudhir, B. and Gopal, T.K.S. (2006) Effect of rotation on the heat penetration characteristics of thermally processed tuna in oil in retort pouch. *Int. J. Food Sc. Technol.*. **41**, pp. 215-219.

Durance T.D. (1997) Improving canned food quality with variable retort temperature. *Trends in Food Sc. Technol.*.**8**, pp. 113-118.

FDA. (2002) *Resinous and Polymeric coatings. Code of Federal Regulation 175: 300.* Washington, D.C.: Food and Drug Administration.

IS 2471 (1963) *Methods of test for metal containers.* Bureau of Indian Standards, New Delhi-1,

IS 3336 (1968) *Specification for prawns/shrimp canned in brine.* Bureau of Indian Standards New Delhi-1

IS 5818 (1970) *Specification for lacquers and decorative finishes for food cans,* Bureau of Indian Standards New Delhi-1.

IS 6093 (1970) *Method of determining the capacity and dimensions of hermitically sealed metal container.* Indian Standard Institutions, Menak Bhavan, Bahadur Shah Zafar Marg. New Delhi, India.

IS 9396 (1979) *Specification for round open top sanitary cans for processed foods.* Bureau of Indian Standards, New Delhi-1,

Knap R.P. and Durance T.D. (1999) Thermal Processing of Suspended Food Particles in Cans with End-Over-End Agitation. Food Res. Int. **31,** pp 635-643.

N.C.A. (1968) *Laboratory manual for Food Canners and Processors Vol. I* National Canners Association. Westport, Connecticut, USA: AVI Publishing Co., pp. 204-219.

Ramaswamy H.S. and Sablani S.S. (1997a) Particle Motion and Heat Transfer in Cans During End-Over End Rotation: Influence of Physical Properties and Rotational Speed. *J. Food Proc. Pres.* **21,** pp. 105-127.

Ramaswamy H.S. and Grabowski S. (1999) Thermal processing of pacific salmon in steam or air and water immersion still retorts: Influence of container type and shape on heating behaviour. *Lebensmittel-Wissenschaft Und-Technologie.* **32,** pp. 12-18.

Ramaswamy H.S. and Sablani S.S. (1997b) Particle Shape Influence on Heat Transfer in Cans Containing Liquid Particle Mixtures Subjected to End-Over-End Rotation. *Lebensmittel Wissenschaft und Technologie* **30,** pp. 525-535.

Ramswamy H. and Marcotte M (2006) *Food processing: principles and applications.* CRC Publications. USA. pp. 141-142.

Ranganna S. (2000) *Handbook of Canning and Aseptic Packaging.* Tata McGraw-Hill Publishing Co. Ltd, New Delhi, India. pp. 507-508.

Sablani S.S. and Ramaswamy H.S. (1996) Particle Heat Transfer Coefficients Under Various Retort Operating Conditions With End-Over-End Rotation. *J. Food Proc. Eng.* **19,** pp. 403-424.

Stumbo C.R. (1973) *Thermobacteriology in food processing.* 2nd ed., New York: Academic Press. pp. 93-120.

Szczesniak A.S. (2002) *Texture is a Sensory property.* Food Quality and Preference **13,** pp. 215-225.

Taherian A.R. and Ramaswamy H.S. (1996) *Comparison of Thin Profile and End-Over-End Agitation Processing on Thermal Softening of Vegetables Texture.* Institute of Food Technologists [1996 Annual Meeting], Book of abstracts, p. 84 ISSN 1082-1236.

Vanloey A., Francis A., Hendrickx M., Maesmans G., Noronho J. and Tobback P. (1994) Optimizing thermal process for canned white beans in water cascading retorts *J. Food Sc.* **59,** pp 828-836.