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Optimization of Process Parameters for Ready-to-Serve Bread Spread from Blue Swimmer Crab *Portunus pelagicus* in Tin-Free Steel Cans

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Abstract

The aim of the study was to develop ready-to-serve bread spread from crab meat. Bread spread was processed at 115, 121.1 and 130^{0}C to an F_0 value of 6 min. The effect of three different process temperatures on the chemical, physical and microbial quality was analysed. Heating lag factor (Jh) was highest for the product processed at 115^{0}C whereas cooling lag factor (Jc) was highest for the product processed at 130^{0}C. A reduction of 39.25 and 29.21% in process time was observed for the product processed at 130 and 121.1^{0}C respectively compared to product processed at 115^{0}C. All the products were commercially sterile. TVB-N, TMA-N, TBA and FFA values increased upon thermal processing. Least increase of TVB-N and TMA-N was for the product processed at 130^{0}C whereas least increase of FFA value was observed for the product processed at 121.1^{0}C. Thermal processing at higher temperature increased the loss of amino acids significantly ($p<0.05$). Sensorially, the product processed at 121.1^{0}C rated better compared to 115 and 130^{0}C.

Keywords: Thermal processing, tin-free steel cans, bread spread, *Portunus pelagicus*

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Introduction

Seafood is generally accepted as a healthy, safe, nutritious and balanced diet. Crab meat not only has a delicious taste and a unique pleasant aroma, but also has good nutritive value (Naiguang, 2004). Crab meat is an excellent source of minerals, particularly calcium, iron, zinc, potassium and phosphorus (Adeyeye, 2002). Blue swimmer crab, *Portunus pelagicus* is widely distributed throughout the coastal and estuarine areas of the tropical Western Pacific and Eastern Indian oceans (Xiao & Kumar, 2004).

Thermal processing is a method for long term preservation of fish and fishery products. Fishery products in ready-to-consume form in metal containers are popular items in foreign markets. One of the recent developments in rigid containers is the tin-free steel (TFS) cans. Suitability of TFS cans for canning fish was studied by Mallick et al. (2006a). Thermal processing of food results in an extended shelf-life but affects both the nutritional and the sensory quality of the product. One of the challenges to the food canning industry is to minimize these quality losses, while providing an adequate process to achieve the desired degree of sterility.

Thermal processed crab based products like canned and pasteurized colossal crab meat, jumbo lump, lump, back fin, special meat, claw meat, claw fingers etc are widely available in the market. Crab meat spread is a paste based product where there is less information available about the thermal processed shelf stable spread from crab meat. By considering the high demand for crab as a delicacy, an attempt was made to standardize the procedure for the development of bread spread from blue swimmer crab (*Portunus pelagicus*) which retains quality attributes.

Materials and Methods

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 was made of electrochemically coated chromium steel (ECCS) plate with clear polyethylene tetrephthalate (PET) coating on either side. The finished plate had a thickness of 0.19 mm.

Fresh blue swimmer crabs (*Portunus pelagicus*) were purchased from a local fish landing centre in Cochin, Kerala, India and brought to the laboratory in iced condition (1:1 ratio of crab to ice, 1-2^{0}C). Upon arrival at the laboratory, the samples were washed with chilled potable water. The samples were then pre-cooked in boiling water for five min. After cooling, the meat was separated manually using stainless steel fork and knife. The separated meat was then made into paste and used for making recipes. Four different bread spread recipes were prepared and sensory analysis was carried out by a trained panel of ten judges using a nine point hedonic scale (Meilgaard et al., 1999). All the four samples were well accepted by the panel. The preparations were thermal processed in a laboratory scale overpressure autoclave (Model No 5682; John Fraser and Sons Ltd, Newcastle-upon-Tyne, UK) at 121.1^{0}C for 45 min in order to check the organoleptic acceptability of the samples after processing. The thermal processed spread samples were again analysed by a sensory panel of ten judges (Meilgaard et al., 1999). Based on the panel opinion, one recipe was selected and used for further studies. The ingredients used in the selected bread spread were crab meat paste, grated onion (50% of crab paste), lemon juice (6% of crab paste), mayonnaise (50% of crab paste) and white pepper powder (1% of crab paste).

About 150 ± 5 g of bread spread was filled into the TFS cans and the cans were exhausted in steam for 10 min to remove the residual air. The cans were then immediately double seamed and divided into three batches. In all the batches, the cans were fixed with thermocouple glands (Model no. GKJ 13009 C042, Ellab Co. Rodovre, Denmark) and thermocouple probes (Model no. SSA 12040 G700 TS, Ellab Co. Rodovre, Denmark) were inserted through them. Tips of the thermocouple glands were inserted to the slowest heating point of the can for recording the core temperature during heat processing. The cans were loaded inside the retort (Model no. 5682, John Fraser and Sons Ltd., Newcastle upon Tyne, U.K) separately and processed at three different temperatures of 115^{o}C, 121.1^{o}C and 130^{o}C till they attained F_0 value of 6. The temperature data was acquired for every minute using Ellab data recorder (Model TM 9608, Ellab Co. Rodovre, Denmark). The lethality (F_0 value) accumulated during the entire processing was calculated from the temperature history inside by numerical integration (Ball & Olson, 1957). After thermal processing, the cans were cooled by pumping water into the retort to reduce the temperature to around 40^{0}C. The cans were removed from the retort and immersed in potable chilled water and washed thoroughly with soap solution. They were drained and kept at ambient temperature for two weeks for conditioning. After conditioning the samples were taken for various analyses.

The lag factor for heating (Jh), slope of the heating curve (f_h), time in minutes for sterilization (U), and lag factor for cooling (Jc) were calculated by plotting temperature deficit (RT-Tc) against time on semi log paper. Using these parameters, the process time (B) was calculated by mathematical method (Stumbo, 1973). The total process time was calculated by adding 58% of the come up time (CUT) to B. Cook value (C_g), a measure of heat treatment with respect to nutrient degradation and textural changes that occur during processing, was also determined by measuring the extent of cooking and nutritional loss during processing in a manner similar to D value.

Thermal processed cans were tested for the commercial sterility as per IS 2168: 1971. About four cans selected at random from each batch were incubated at 55^{0}C for four days and another four were incubated at 37^{0}C for fourteen days. The incubated cans were opened aseptically and samples were transferred into sterile thioglycollate broth (Himedia, Mumbai, India) tubes. Then a layer of sterile liquid paraffin wax was poured in each test tube to create anaerobic conditions. The tubes were then incubated at 37^{0}C for 48 h and observed for turbidity development, which indicates the survival of micro-organisms. The tubes were further incubated for 48 h to ascertain sterility.

The proximate composition of the samples was determined by AOAC (2000) method. pH was determined according to APHA (1998) using a digital pH meter (Cyberscan 510, Eutech instruments, Singapore) after homogenizing 10 g of the sample with the same amount of distilled water. Total volatile base nitrogen (TVB-N) and Trimethylamie (TMA) were estimated by the micro-diffusion method (Conway, 1950). Thiobarbituric acid (TBA) value of the sample was estimated

spectrophotometrically (Tarladgis et al., 1960) (Spectroninc Unicam, Model-Genesys 10 UV, Rochester, NY, USA) and expressed as mg malonaldehyde kg^{-1} of sample. Free fatty acid (FFA) was measured and expressed as mg% oleic acid (AOCS, 1989). Peroxide value (PV) was analysed and expressed as milli equivalent of O_2 kg^{-1} fat (AOCS, 1989).

The amino acid analysis was done with non-switching flow method and fluorescence detection after post column derivatization with O-phthalaldehyde according to the method of Ishida et al. (1981). Tryptophan content was determined by Sastry & Tummuru (1985) method. The absorbance was measured against a reagent blank at 500 nm in a spectrophotometer (Spectroninc Unicam, Model-Genesys 10 UV, Rochester, NY, USA).

The colour of the sample was measured with a calibrated Hunters colorimeter (Hunter Lab colorimeter, MiniScan XE Plus Hunter Associates Lab inc., Reston, Virginia, USA). Sensory analysis of canned bread spread was carried out by ten trained panellists consisting of scientists and researchers as per Meilgaard et al. (1999) with slight modifications. Three cans from each batch were used for the analysis. The sensory attributes evaluated were appearance, colour, odour, flavour, spreadability and taste. Bread and butter knife were provided to assess the spreadability of the samples. A score of above 4 was considered as the margin of acceptance.

Texture profile analysis of tempered (16^0C for 4 h) samples (25 X 25 mm) were measured with a Universal Testing Machine (Lloyd instruments LRX plus, UK) with a cylindrical probe of 50 mm diameter. Force was applied at a speed of 12 mm^{-1} using 50 N load cell.

All analyses were carried out in triplicate. Results were expressed as mean values ± standard deviation (SD). Data were analysed by using one way ANOVA and the least significant difference (LSD) was calculated at the probability level $p<0.05$.

Results and Discussion

The heat penetration characteristics of the processed samples are given in Fig. 1, 2 and 3. The various process parameters obtained by plotting time temperature data on a semi-logarithmic paper are given in Table 1. The total process time for 115^0C was 52.67 min, for 121.1^0C was 37.29 min and for 130^0C was 32 min, which included 58% of the come up time. Sample processed at 115^0C exhibited higher heating lag factor while sample processed at 130^0C showed the least. The samples processed at 130^0C showed highest cooling lag factor and at 115^0C showed the least. Similar results were reported for prawn kurma packed in aluminium cans (Mohan et al., 2008).

Table 1. Thermal process parameters of bread spread processed at various temperatures

Process parameters	Process temperature		
	115^0C	121.1^0C	130^0C
Heating lag factor (J_h)	1.45	1.17	1.09
Cooling lag factor (J_c)	0.99	1.05	1.08
Heating rate index (f_h) (min)	23	27.8	22
Lethality (F_0) (min)	6	6	6
Time in minutes for sterilization (U)	24.4	6	0.77
F_h/u	0.94	4.6	28.4
Balls process time (B) (min)	49.1	34.9	27.9
Total process time (min)	52.67	37.29	32

Microbial growth was not observed in the samples incubated in thioglycolate, which indicates that all the processes were sufficient to achieve the commercial sterility.

The proximate composition of blue swimmer crab muscle showed a high protein and low fat content (Table 2). During thermal processing, loss of moisture content with an increase in protein, ash and fat was observed ($p<0.05$). A similar result was

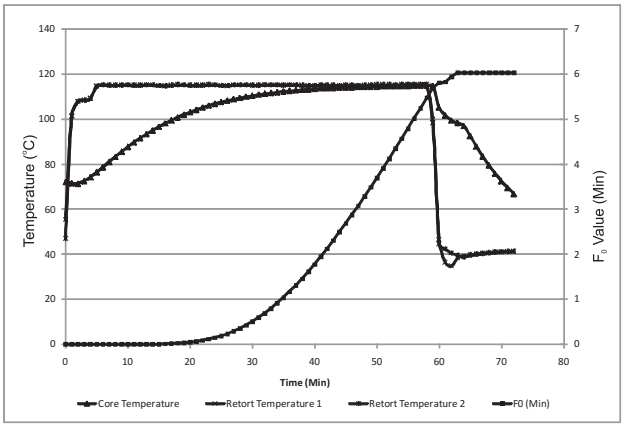

Fig. 1. Heat penetration characteristics and F_0 value of bread spread processed at 115^0C

Table 2. Proximate composition of raw and processed bread meat spread

	Raw crab meat	Raw bread spread mix	Process temperature		
			115^0C	121.1^0C	130^0C
Moisture	76.80±0.2	78.90±0.50[a]	72.9±0.28[b]	72.8±0.48[b]	72.1±0.8[b]
Protein	18.51±0.5	17.30±0.2[c]	20.7±0.3[ba]	20.9±0.05[a]	20.3±0.1[b]
Fat	0.58±0.1	2.20±0.2[d]	3.50±0.3[c]	3.56±0.3[b]	3.65±0.07[a]
Ash	1.70±0.1	1.80±0.2[a]	2.05±0.05 [a]	2.09±0.05 [a]	2.13±0.08[a]

Means in the same row with different superscript letters are significantly different at $p<0.05$

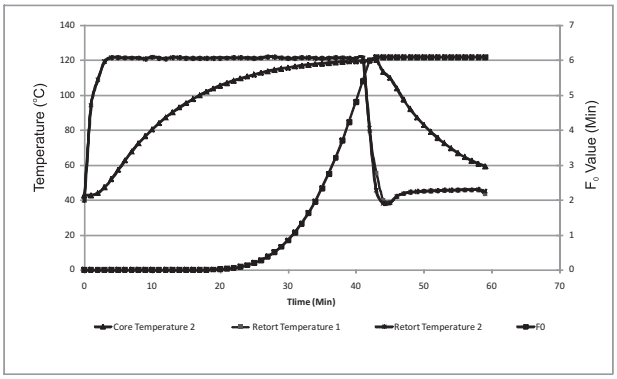

Fig. 2. Heat penetration characteristics and F_0 value of bread spread processed at 121.1^0C

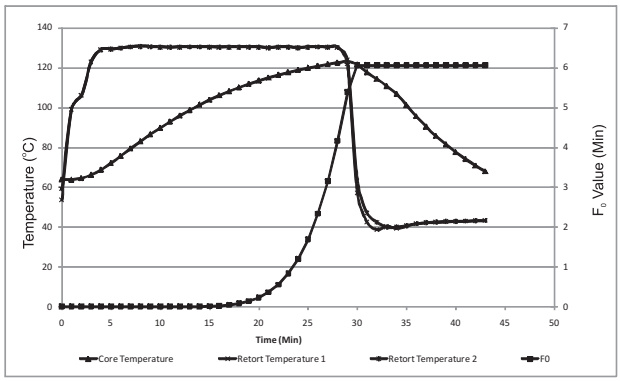

Fig. 3. Heat penetration characteristics and F_0 value of bread spread processed at 130^0C

reported by Gokoglu et al. (2003) in thermal processed fish products. Water loss in spread can be explained in terms of heat treatment and protein degradation of muscle, leading to a decreasing water holding capacity of the myofibrillar protein fraction (Castrillon et al., 1996). The relative increase in lipid content in the raw bread spread was due to the addition of mayonnaise as an ingredient in the bread spread mix. The increased fat content in the canned samples may be due to the water loss from the muscle during sterilization steps (Castrillon et al., 1996).

The pH of the raw crab meat sample was around 6.94 (Table 3) indicating that the crabs used were of post rigor stage and of good quality, according to Riaz & Quadri (1985). pH of the samples decreased on heat processing ($p<0.05$) and the sample processed at 130^0C exhibited the lowest pH compared to the other samples. Decrease of pH after thermal processing was reported in squid masala and shrimp curry in TFS cans (Sreenath, 2010), and rohu curry in TFS cans (Mallick et al., 2006b).

The average TMA value of crab meat was 0.69 mg%, which indicated that the crab used in the study was in good condition. A significant ($p<0.05$) increase of TMA content in canned samples were observed during the present study. The differences found between the raw crab meat TMA values and those from canned spread led to the conclusion that the thermal processes have exerted a higher effect on the TMA formation. This result agrees to previous observations on fish canning (Gallardo et al., 1990; Rodriguez et al., 2009). High concentration of TMA was observed in the sample processed at 115^0C compared to the other samples.

TVBN content showed significant increase ($p<0.05$) in canned samples as a result of thermal processing (Table 3). This result agrees to previous research on canned albacore tuna (Gallardo et al., 1990), yellow fin tuna (Gill et al., 1987), canned farmed coho salmon (Rodriguez et al., 2009) and montery sardine (Uriarte-Montoya et al., 2010). Samples processed at 115^0C had higher TVN content compared to the other samples. It may be due to the large

concentrations of ammonia, DMA, and TMA produced during the longer process time.

Canning processing has led to a significant ($p<0.05$) increase in FFA content (Table 3) which was in agreement with Rodriguez et al. (2009); Aubourg et al. (1990; 1997). During thermal treatment, breakdown of high-molecular weight lipids like triglycerides and phospholipids would be likely to occur and be the source of new FFA formation (Aubourg et al., 1997). The PV (Table 3) did not show any differences as a result of thermal treatment, which was in agreement with the results reported by Rodríguez et al. (2009) and Uriarte-Montoya et al. (2010). The overall quality and flavour of thermal processed product can be highly influenced by lipid oxidation products. Thiobarbituric acid value showed significant difference ($p<0.05$) in thermal processed samples (Table 3). Samples processed at 130^0C showed higher values compared to the samples processed at 121.1^0C and 115^0C. It may be due to the effect of higher temperature treatment of sample. However, the values were below those reported as lipid spoilage indices, established at 3 or less mg malonaldehyde kg^{-1} of muscle TBA (Huss, 1998).

The non essential amino acids like aspartic acid and glutamic acid dominated in the raw bread spread mix and a significant difference ($p<0.05$) in the amino acid composition of thermal processed samples was observed. It was in agreement with the results reported by Seet et al. (1983) that histidine, tryptophan, lysine and arginine are affected by heating. It may be due to the effect of thermal processing on the amino acids. Samples processed at 130^0C showed the maximum reduction of amino acid content followed by samples processed at 121.1^0C and 115^0C. The total amino acid concentration was lower in the samples processed at 130^0C. Amino acid profile of spread samples are presented in Table 4. Even though thermal processed spreads showed lower amino acid content compared to the raw spread, it was well balanced with respect to essential amino acids and can be considered as a food source with high quality proteins to fulfil consumer's requirements.

Colour values of raw spread mix and processed samples were done and the results are given in Table 4. Colour value varied significantly on thermal processing ($p<0.05$). The lightness (L*) value is associated with the luminous intensity which gives the light reflecting or transmitting capacity of an object. The L* values of sample decreased from 92.7 to 92.3, after thermal processing. The samples processed at 130^0C showed the least L* value. This may be due to the Maillard reaction and the formation of browning substances. The a* (positive-redness, negative-greenness) values increased upon thermal processing. The b* (positive-yellow, negative-blueness) values increased from 3.88 to 5.21 after thermal processing showing a tendency towards yellowness. The colour change during thermal processing of muscle foods are well explained by Haard (1992). The colour change occurs in two phases, a rapid whitening phase followed by a slow browning phase. The whitening phase occurs within the first 10 min and the red colour of muscle fades to whitish, which results in the maximum L* with minimum a* and b* (Kong, 2007). According to Haard (1992), whitening is due to the quick denaturation of haemoglobin and myoglobin, oxidation of carotenoids. In the second phase, Maillard reaction takes place between sugars, proteins or amines. Lipid-protein interaction also dominates in Maillard reaction (Haard, 1992). According to

Table 3. Changes in the spoilage parameters of bread spread processed at different temperatures

Sample	TVB-N (mg%)	TMA (mg%)	pH	FFA (mg% of oleic acid)	TBA (mg malonaldehyde kg^{-1})	PV
Raw crab meat	13.8±0.3	0.69±0.14	6.94±0.02	0.009±0.05	0.14±0.05	Nil
Raw crab meat spread	13.9±0.06^d	1.8±0.1^d	6.87±0.02^a	0.1±0.01d	0.16±0.01d	Nil
Spread processed at 115^0C	32.6±0.1^a	10.2±0.3^a	6.22±0.03^c	0.35±0.02a	1.07±0.01c	Nil
Spread processed at 121.1^0C	28.53±0.2^b	7.4±0.2^b	6.3±0.05^b	0.25±0.02c	1.08±0.02b	Nil
Spread processed at 130^0C	27.6±0.^{c}	6.8±0.4^c	6.16±0.05^c	0.29±0.02b	1.10±0.01a	Nil

All values are the means ±standard deviations of three replicates. Values in the same row with different superscript letters are significantly different at $p<0.05$

Table 4. Amino acid profiles (g 16^{-1}g N) and colour of crab meat spread processed at different temperatures

Amino acid	Raw crab mix	Process Temperature		
		115^{0}C	121.1^{0}C	130^{0}C
Aspartic acid	13.6±0.8^a	11.3±0.8^a	11.0±0.7^b	10.2±0.8^c
Threonine	5.7±0.8^a	5.2±0.7^b	5.1±0.8^c	4.7±0.8^d
Serine	6.7±0.7^a	6±0.7^b	5.8±0.7^c	5.2±0.7^d
Glutamic acid	21.8±0.7^b	22.6±0.7^a	14.6±0.7^c	13.5±0.7^d
Proline	5.4±0.7^a	3.6±0.7^d	4.0±0.7^b	3.7±0.7^c
Glycine	11.1±0.7^a	5.9±0.7^b	5.3±0.7^c	4.9±0.7^d
Alanine	4.0±0.7^a	3.0±0.7^c	3.1±0.7^b	2.8±0.7^d
Valine	5.9±0.7^c	6.3±0.7^a	6.2±0.7^b	5.5±0.7^d
Methionine	3.3±0.7^a	1.9±0.7^b	1.8±0.7^c	1.8±0.7^c
Isoleucine	6.0±0.7^a	4.8±0.7^c	4.9±0.7^b	4.4±0.7^d
Leucine	11.0±0.7^a	8.6±0.7^c	8.7±0.7^b	8.0±0.7^d
Tyrosine	4.1±0.7^a	2.4±0.7^d	3.0±0.7^b	2.7±0.7^c
Phenylalanine	5.9±0.7^a	5.6±0.7^b	5.5±0.7^c	5.0±0.7^d
Histidine	8.2±0.7^a	6.8±0.7^c	6.0±0.7^b	6.6±0.7^d
Lysine	7.1±0.7^a	5.7±0.7^c	6.3±0.7^b	5.4±0.7^d
Arginine	ND	ND	ND	ND
Tryptophan	0.45^a	0.29^c	0.31^b	0.28^c
Cysteine	ND	ND	ND	ND
Colour				
L*	92.774±0.08^a	92.326±0.05^c	92.544±0.05^b	92.003±0.05^b
a*	0.206±0.05^c	0.44±0.05^a	0.42±0.05^b	0.645±0.05^b
B*	3.888±0.09^b	5.216±0.05^a	5.162±0.05^a	5.378±0.05^a

All values are the means ±standard deviations of three replicates. Values in the same row with different superscript letters are significantly different at $p<0.05$

Whistler & Daniel (1985), more browning products produce with increase in temperature and time resulting with increased b values. From the present study, it was observed that the higher processing temperature and time significantly ($p< 0.05$) affected the colour values. Process temperature of 130^{0}C resulted in greater loss of colour values.

The effect of thermal processing on sensory quality in marine products is difficult to predict because of intra and interspecific variablity of fish species and factors such as appearance, odour, colour, flavour, and texture (Mendez & Gallardo, 2006). The results of the sensory evaluation are given in Table 5. The spread processed at 121.1^{0}C rated higher overall acceptabilty compared to the samples processed at 115^{0}C and 130^{0}C. The spreadability of the sample processed at 130^{0}C showed lower value than the

Table 5. Sensory evaluation score of bread spread processed at different temperatures

Parameter	Process Temperature		
	115^{0}C	121.1^{0}C	130^{0}C
Appearance	6.95±1.2	8±0.93	6.42±1.2
Colour	7.5±1.5	8.45±0.76	6.4±1.1
Odour	7.65±1.1	8.25±1.03	7.12±1.32
Flavour	7.8±1.5	8.6±0.87	6.82±1.4
Spreadability	7.79±1.35	8.16±1.4	5.2±0.95
Taste	7.58±1.32	8.42±1.3	6.5±0.76
Overall acceptability	7.54±1.32	8.31±1.04	6.41±1.12

The data represent mean ± standard deviations of 10 observations

Table 6. Ratings for textural attributes of processed bread spreads

Parameter	Process Temperature		
	115^0C	121.1^0C	130^0C
Hardness 1 (kg f)	0.146±0.04[a]	0.177±0.05[b]	0.2±0.05[c]
Hardness 2 (kg f)	0.125±0.05[a]	0.138±0.05[b]	0.15±0.05[c]
Cohesiveness	0.372±0.06[a]	0.398±0.05[b]	0.426±0.05[b]
Springiness (mm)	1.24±0.05[b]	1.47±0.06[a]	1.32±0.04[c]
Springiness index	0.45±0.05[a]	0.528±0.05[a]	0.534±0.05[b]
Gumminess (kg f)	0.05±0.05[a]	0.07±0.05[b]	0.085±0.05[c]
Chewiness (kg f mm)	0.06±0.05[a]	0.10±0.001[a]	0.113±0.001[b]
Fracture force (kg f)	0.06±0.003[a]	0.049±0.002[c]	0.567±0.002[b]
Adhesive force (kg f)	0.01±0.08[a]	0.011±0.003[b]	0.020±0.002[ba]
Adhesiveness (kg f mm)	0.013±0.002[ba]	0.0027±0.002[b]	0.0117±0.002[a]
Stiffness (kg f mm^{-1})	1.53±0.01[a]	0.132±0.007[b]	2.08±0.7[b]

All values are the means ±standard deviations of three replicates. Values in the same row with different superscript letters are significantly different at $p<0.05$

other two samples. Spread processed at 130^0C showed the least overall acceptability by the panelists.

Thermal processed samples showed a significant difference ($p<0.05$) in textural properties among themselves (Table 6). The hardness of the samples varied from 0.2 to 0.17. The sample processed at 130^0C showed maximum hardness and 115^0C showed the least. The samples processed at 121.1^0C showed lower fracture force, adhesive force, adhesiveness and stiffness compared to the samples processed at 115^0C and 130^0C.

The crab spread processed at 121.1 and 130^0C resulted in a reduction of 29.21 and 39.25% in process time compared to the product processed at 115^0C. The quality attributes like TVB-N, TMA-N, TBA and FFA values increased with the thermal processing. However, the increase was well within the acceptable limits. Changes in the colour and amino acid content were affected significantly ($p<0.05$) at higher temperature compared to lower temperature. The spreadability of the product processed at 121.1^0C rated better with reference to sensory attributes compared to products processed at other temperatures.

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