CAFEi2012-164

INCREASING RESISTANT STARCH CONTENT IN FISH CRACKERS THROUGH DIFFERENT COOKING TEMPERATURES IN REPETITIVE COOKING-CHILLING CYCLES

M. Z. M. Nor1, R.A. Talib[1]*, Noranizan, M. A.[2], N. L. Chin1 and K. Hashim[3]

[1]Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor Malaysia
[2]Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor Malaysia
[3]Malaysian Nuclear Agency, Bangi, 43000 Kajang, Selangor, Malaysia
* Email: rosnita@eng.upm.edu.my

ABSTRACT

This work describes the effect of different cooking temperatures in repetitive cooking-chilling (RCC) process on resistant starch (RS) content in fish crackers prepared from a ratio of 1:1 fish:sago starch formulation. Three sets of 4 RCC cycles were performed on the fish crackers where each set was cooked at a fixed temperature of 100, 115 or 121°C respectively. Meanwhile, the chilling temperature was fixed at 4°C in all cases. Subjecting the fish crackers to higher cooking temperature for up to 4 cycles of RCC increased the RS content; however, some drawbacks on the quality characteristics namely linear expansion and physical attributes of the crackers were observed. Application of higher cooking temperature in the RCC caused more damages (cracks, burst and fragments) to the shape of the fish cracker gels as observed during the first RCC cycle and when the products were subjected to frying, their linear expansion decreased. This work demonstrated that the application of higher cooking temperature up to 4 RCC cycles was able to enhance the RS content in the fish crackers, but was less able to attain higher percentage of product with perfect shape. On the contrary, fish crackers that were exposed to a lower cooking temperature contained lower RS but with less damaged shape.

***Keywords*:** *resistant starch, fish cracker, cooking, chilling, snack.*

INTRODUCTION

Fish crackers or "keropok" are well-known amongst Malaysians as one of most popular snacks. It consists of dough formed from a mixture of starch, fish flesh and water. The dough will then be shaped, boiled to gelatinize the starch, cut into thin slices and dried before it can be sold. It is eaten after being fried in hot oil [1]. The content of resistant starch (RS), a starch that goes through the small intestine without being digested which provides a similar effect as dietary fibre can be improved in fish crackers production via application of repetitive cooking-chilling (RCC) process although some minor drawbacks of the other quality characteristics of chilled and fried products were also reported [2]. The repeated cooking-chilling cycles by using cooking temperature of 100°C and chilling at 4°C increased the extent of starch gelatinization with each successive cooking cycle and promoted retrogradation upon cooling, thus, promoting the formation of RS. In addition, Nor et al. [3] reported that fish crackers formulated from sago starch had the highest RS content in the dried samples compared to tapioca and wheat starches since it has higher amylose content. There is possibility of improving this RCC approach by increasing its cooking temperature above 100°C for better RS yield in the treated products since previous studies reported that high temperature treatment via autoclaving and pressure cooking produced better RS yield in processed food. The RS yield from wheat starch increased progressively as the autoclaving temperature was increased, from about 2.5 % at 100 °C to about 9 % at 134°C [4]. Parchure and Kulkarni [5] reported a 10 minute pressure cooking of native rice and amaranth produced RS content which was 1.7 times higher compared to those boiled for 15 minutes. Meanwhile,

e-ISBN 978-967-960-322-4

repetition of heat treatment and cooling at different heating temperatures was undertaken by Sievert and Pomeranz [6] who reported that by 20 repetitions of autoclaving (121°C, 134°C and 148°C for 1 hour) and cooling (4°C for overnight) of amylomaize VII starch the RS level was raised from 20 to over 40%. Considering the potential of producing fish crackers with better RS increment via higher cooking temperature in RCC treatment, thus, the objective of this study was to investigate the effect of different cooking temperature in RCC treatment of the RS content and other quality characteristics of fish crackers.

MATERIALS AND METHODS

Materials

Fresh sardines (Sardina pilchardus) were purchased from wet market in Serdang, Malaysia; and salt, sugar and monosodium glutamate (MSG) were purchased from a grocery store. Sago starch (Metroxylon sagu) was purchased from Songiing Holding Sdn. Bhd., Sibu, Malaysia and filtered ice water was obtained from the laboratory.

Preparation of Fish Crackers

Fig. 1 illustrates the fish crackers preparation methods using a modified version of the procedure previously described by Siaw et al. [7]. The fish cracker formulation was as follows: 1:1 fish to sago starch ratio (1kg:1kg), 2% salt, 1% sugar, 0.1% monosodium glutamate (MSG) and 30% ice water (% weight based on the total weight of starch and wet fish). First, the fresh sardines were manually beheaded, degutted and deboned using a knife to obtain fresh flesh after the fish were transported from the local wet market to the laboratory. The fish flesh was ground using a meat grinder (National, Japan) then transferred into a silent cutter (Khin Shang Hoo Iron Works, Taiwan) before being mixed with salt, sugar and MSG. Ice water and sago starch were added until the mixture formed a homogenous dough. This mixing process took approximately 20 minutes. A sausage stuffer (F-Dick, Germany) was used to stuff the dough-like mixture into circular cellulose casings (2.5 cm diameter and 12 cm length). Both ends of the stuffed casings were tied with cotton strings, and the stuffed rods were cooked for 30 minutes a at fixed temperature of 100°C, 115°C and 121°C respectively [8]. After cooking, the cooked gels were immediately immersed in ice water to prevent shrinkage and to facilitate separation from the casings. The gels were then chilled overnight in a cold room at 4°C to complete one cooking-chilling cycle. The cooking-chilling cycle was repeated up to four times by following the RCC treatment [2]. The chilled gels were manually cut into 3 mm slices, which were oven dried at 45°C overnight until the final moisture content was 8 – 10%. The dried gels were deep fried in palm oil at 200°C for 15 seconds until fully expanded. Samples were taken after chilling (in gel form), after drying (in dried slice form) and after frying (in expanded cracker form) to obtain measurements. The protein contents for single cooking-chilling fish crackers with a similar formulation of tapioca, wheat and sago starches were found at 15.6%, 24.9% and 15.7% respectively at a standard fat content of 0.4% [9].

Measurement of Resistant Starch in Dried Fish Crackers

Protein removal was performed prior to RS analysis [10], and the Resistant Starch Assay Analysis (Megazyme International Ireland Ltd. Co., Ireland) was used for the RS content determination. The method includes incubation with α-amylase (37°C, 16 hours) to hydrolyze the digestible starch, solubilization of precipitate using 2M KOH, incubation with amyloglucosidase (50°C, 30 minutes) and quantification of glucose using a glucose oxidase/peroxidase reagent.

Measurement of Linear Expansion, Hardness and Color in Fried Fish Crackers

The percent linear expansion of the fried fish cracker sample was determined according to Yu et al. [11]. Three parallel lines were drawn on the dried fish crackers using a marker. The length of each line was measured before and after frying. The calculation for linear expansion is as follows:

% linear expansion = (length after puffing – length before puffing) x 100/length before puffing (1)

Observation of Physical Attributes of Fish Cracker Gels after Cooking

Observations were made of the physical attribute of the chilled fish cracker gels subjected to a single cycle of repetitive cooking-chilling (RCC). Each sample was classified according to the attributes listed in Appendix.

Data Analysis

All tests were conducted in triplicate, and statistical analysis was performed using Microsoft Excel 2007 (Vista Edition, Microsoft Corporation, USA) and Statistical Analysis System (SAS) software (Version 9.2, SAS Institute, Inc., USA). A significance level of $\alpha = 0.05$ was used throughout the analysis, and p-values larger than α ($p>0.05$) indicated that the difference between treatments was not significant. When a significant difference was found from the ANOVA results, the treatments were compared using a t-test.

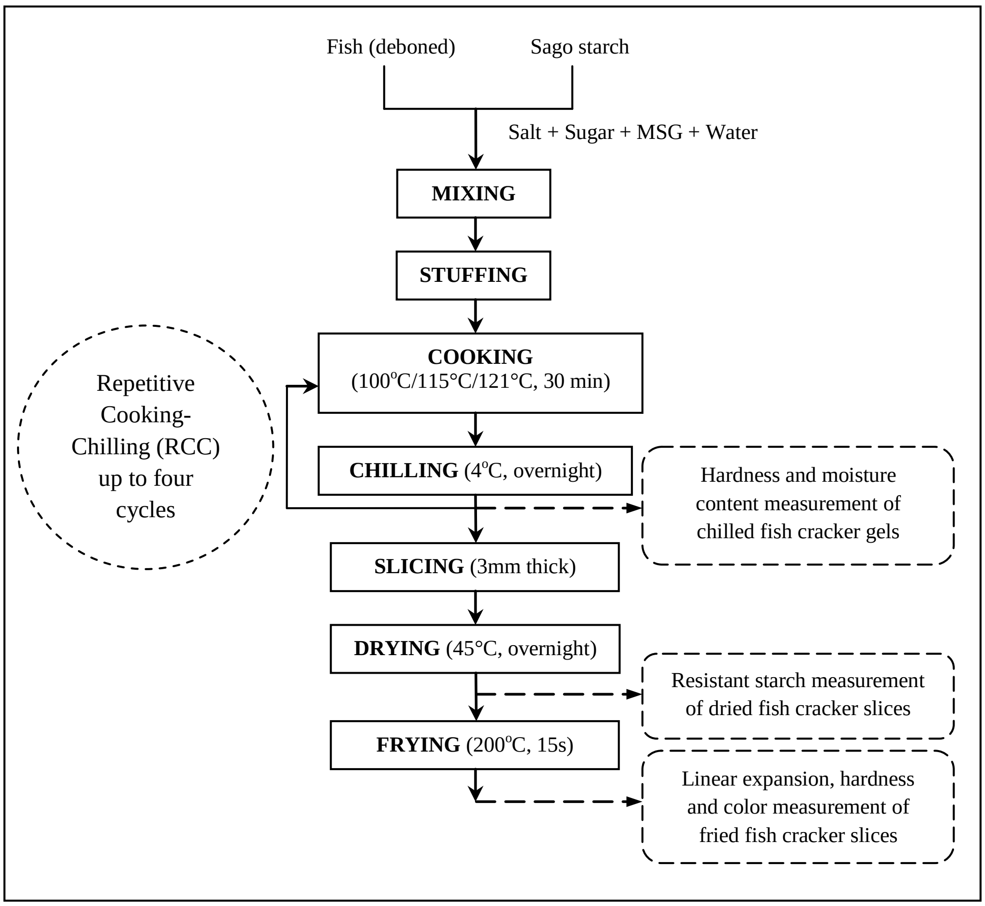

Fig. 1: Application of different cooking temperatures in RCC cycles in fish cracker production.

RESULTS AND DISCUSSION

Effect of Different Cooking Temperatures in RCC on the Resistant Starch Content of Dried Fish Crackers

The effect of one to four RCC cycles on the RS yield in dried fish crackers for different cooking temperatures is shown in Table 1. A one-way ANOVA test performed showed that the RCC treatment indicated significant ($p<0.05$) differences in resistant starch formation in each cycle for the samples with different cooking temperatures, with similar trends reported by Nor et al. [2] for different formulation samples cooked at 100°C. The repeated cooking and chilling processes facilitates further gelatinization and retrogradation of the fish crackers, thus promoting the formation of RS.

When the cooking temperatures were compared, the ranking of the RS content in the dried samples exposed to RCC treatment was as follows: 121°C > 115°C > 100°C. Sago starch-formulated fish cracker cooked at 121°C up to four cycles of RCC exhibited the highest RS yield of 4.23 % dwb. This value is higher compare to RS content in selected commercial fish crackers available in Malaysian market ranging of 0.91 – 1.77 % dwb [3].

A comparison between different cooking temperatures showed that a higher temperature will produce appreciably higher RS. This is in agreement with Shin-Kyung [12] who reported heating of corn starches at 121°C provided higher yields of RS than at 100°C. In addition, Berry [4] reported that the yield of RS from wheat starch increased progressively as the autoclaving temperature was increased, from about 2.5 % at 100 °C to about 9 % at 134°C. Sievert and Pomeranz [6] reported that amylomaize VII starch autoclaved at 134°C had a higher RS content compared to the same samples autoclaved at 121°C after completing four autoclaving-cooling cycles although the differences were small. However, they also noticed that at a higher autoclave temperature (148°C), the amount of RS obtained was lower compared to both lower temperatures, although the finding was not discussed in their report.

Table 1: Average RS values in dried sago starch based-fish crackers for each cooking-chilling cycle with different cooking temperatures.

Temperature	**Resistant starch in each cycle (% dwb)**			
	1	**2**	**3**	**4**
$^{\beta}$**100°C**	3.07±0.02a1	3.44±0.05b1	3.68±0.11bc1	3.81±0.12c1
115°C	3.04±0.07a1	3.56±0.26b1	3.74±0.20bc1	3.99±0.11c23
121°C	3.36±0.10a2	3.79±0.20b1	3.99±0.23bc1	4.23±0.20c3

$^{\beta}$Data source from Nor et al. [2]
*Mean of triplicate determinations ± standard deviation
**Mean within a row with different letters are significantly different (p<0.05)
***Mean within a column with different numbers are significantly different (p<0.05)

The RS increment can be explained by two possible reasons. Firstly, higher cooking temperatures caused more amylose to leach out from the starch granules. Mohd Adzahan et al. [13] reported that approximately 96% of amylose leached out at 120°C compared with only approximately 88% amylose leaching at 100°C when solubilised sago starch was heated for 1 hour. Secondly, higher cooking temperatures also caused thermal degradation of amylopectin into shorter amylopectin chains that could attribute to the formation of RS since entanglement of retrograded amylopectin molecules may reduce enzyme susceptibility [14]. Jiranuntakul et al. [15] observed thermal degradation of amylopectin molecules when subjected to heat-moisture treatment at 120°C and 140°C compare to at 100°C in waxy starches. The degradation of amylopectin is indicated by smaller molecules in the starch chain distribution. However, this was not proven in this current work.

Since this current study only used a small scale autoclave which had a safety limit of only up to 121°C, treatment at higher autoclaving temperatures could not be performed. Nevertheless, the use of a higher temperature will lead to a higher processing cost, so to limit the autoclaving temperature at 121°C is the best choice. The effect on other quality characteristics is another major concern.

Effect of Different Cooking Temperatures in RCC on the Linear Expansion of Fried Fish Crackers

Table 2 shows linear expansion values for the fried fish crackers treated with RCC at different cooking temperatures. Similar to the findings by Nor et al [2], the RCC treatment caused a decrease in the linear expansion of the treated fish crackers. The most likely factor affecting the reduction in linear expansion is the formation of resistant starch in the fish crackers [2]. The treated samples have less expandability due to the strong hydrogen bonding involved in RS formation. Further, extensive heating in excess water through repetitions of the cooking-chilling process caused maximal swelling and rupture of the starch granules which results in a reduced amount of expansion.

e-ISBN 978-967-960-322-4

Table 2: Average linear expansion values in fried sago starch based-fish crackers for each cooking-chilling cycle with different cooking temperatures.

Temperature	**Linear expansion in each cycle (%)**			
	1	**2**	**3**	**4**
100°C	77.60±2.95a1	71.88±1.32b1	66.34±4.49c1	59.45±1.91d1
115°C	73.10±5.77a1	67.10±8.21ab12	61.91±8.59ab12	59.79±3.90b1
121°C	73.79±1.51a1	61.04±3.27b2	54.58±2.66c2	48.73±1.41d2

*Mean of triplicate determinations ± standard deviation
**Mean within a row with different letters are significantly different (p<0.05)
***Mean within a column with different numbers are significantly different (p<0.05)

At higher cooking temperatures (115°C and 121°C), the samples became less expanded after frying. Most probably this was due to the extreme effect of the high temperature treatment that caused more damage to the starch granules. Kyaw et al. [8] reported that cooking of fish crackers made of tapioca starch at temperatures of more than 108°C will cause a reduced expansion due to water being released into the fused fish and starch structure.

Effect of Different Cooking Temperatures in RCC on the Physical Attributes of the Chilled Fish Cracker Gels

Table 3 shows the percentage of different physical attributes of the chilled fish cracker gels after being subjected to the first cycle of RCC treatment. The percentages were calculated based on number of samples identified in each attribute over the total samples cooked in the same batch. Observation was done of the chilled fish cracker gels from which it can be observed that all products cooked at 100°C were almost perfect in condition after the treatment compared to those cooked above 100°C. This finding is important because gels in a perfect condition will facilitate subsequent processing convenience.

Table 3: Attributes of chilled fish cracker gels after first repetitive cooking-chilling cycles.

	Physical condition of gels after first RCC cycle (%)		
Attribute	**100°C**	**115°C**	**121°C**
Perfect	98.3	77.0	36.1
Minor Crack	0.0	0.0	27.7
Major Crack	0.0	7.5	14.1
Minor Burst	1.7	7.5	12.4
Major Burst	0.0	4.0	4.8
Fragment	0.0	4.0	4.9

All samples cooked at 100°C were close to perfect in-shape for the treated fish crackers. Meanwhile, higher cooking temperatures that require a higher pressure above atmospheric pressure during cooking thus cause physical damage to the gels. Fish cracker gels cooked at 115°C (10 psi) produced ~77 % perfect condition gels whereas only 36 % of the samples were in perfect condition after being subjected to cooking at 121°C (15 psi). It is believed that any further increase of the cooking temperature will cause more damage to the shape of the samples. Kyaw et al. [8] studied the effect of pressure cooking on the microstructure and expansion of fish crackers cooked up to 121°C, and highlighted the gradual increase of the tapioca and wheat starch swelling power with an increase in cooking temperature before the granules hydrated with a simultaneous loss of their polarization crosses and burst. In this study, observation was done only during the first RCC cycle because the gels were initially formed at this stage. It had been observed that no further physical damages happened to the products when subjected to subsequent cycle of RCC up to the fourth cycle.

CONCLUSION

The resistant starch content in fish cracker can be increased when subjecting the product to a higher cooking temperature up to 4 cycles of RCC although some product's physical damages such as cracks, burst and fragments were observed on the shape of the fish cracker gels. The treatment of higher cooking temperature in RCC also caused reduction in the linear expansion of the product after frying.

ACKNOWLEDGEMENT

The authors gratefully acknowledge financial support from Universiti Putra Malaysia.

REFERENCES

[1] Siaw, C. L., S. Y. Yu, and S. S. Chen (1979) Studies on malaysian fish crackers: effect on sago, tapioca and wheat flours on the acceptability. 2nd FAOB Symposium on Food and Nutritional Biochemistry in Asia and Ocenia. October 10-12, Hotel Merlin, Kuala Lumpur, Malaysia.

[2] Nor, M. Z. M., R. A. Talib, M. A. Noranizan, N. L. Chin, and K. Hashim (2012a) Increasing resistant starch content in fish crackers through repetitive cooking-chilling cycles. International Journal of Food Properties. (accepted for publication).

[3] Nor, M. Z. M., R. A. Talib, M. A. Noranizan, N. L. Chin, and K. Hashim (2012b) Resistant starch yield and linear expansion of lab-produced and selected commercial fish crackers. Universiti Malaysia Terengganu 11th International Annual Symposium on Sustainability Science and Management (UMTAS). July 9-11, Ri-Yaz Heritage Marina Resort & Spa, Kuala Terengganu, Malaysia.

[4] Berry, C. S. (1986) Resistant starch: Formation and measurement of starch that survives exhaustive digestion with amylolytic enzymes during the determination of dietary fibre. Journal of Cereal Science. 4: 301-314.

[5] Parchure, A. A., and P. R. Kulkarni (1997) Effect of food processing treatments on generation of resistant starch. International Journal of Food Sciences and Nutrition. 48: 257-260.

[6] Sievert, D., and Y. Pomeranz (1989) Enzyme-resistant starch I. Characterization and evaluation by enzymatic, thermoanalytical and microscopic methods. Cereal Chem. 66: 342-347.

[7] Siaw, C. L., Idrus. A. Z., and S. Y. Yu (1985) Intermediate technology for fish cracker (keropok) production. Journal of Food Technology. 20: 17-21.

[8] Kyaw, Z. Y., S. Y. Yu, C. S. Cheow, and M. H. Dzulkifly (2001a) The effect of pressure cooking on the microstructure and expansion of fish cracker 'keropok'. Journal of Food Quality. 24: 181-194.

[9] Yu, S. Y. (1991) Acceptability of fish crackers (keropok) made from different type of flour. Asean Food Journal 6: 114-116.

[10] Goñi, I., L. García-Diza, E. Mańas, and F. Saura-Calixto (1996) Analysis of previous resistant starch:A method for foods and food product. Food Chemistry. 56: 445-449.

[11] Yu, S. Y., J. R. Mitchell, and A. Abdullah (1981) Production and acceptability testing of fish crackers('keropok') prepared by the extrusion method. Journal of Food Technology. 16: 51-58.

[12] Shin-Kyung, L., M. Sae-Hun, and S. Mal-Shick (1997) Effect of heating conditions on the resistant starch formation. Agricultural Chemistry and Biotechnology. 40: 220-224.

[13] Mohd Adzahan, N., M. H. Dzulkifly, and A. R. Russly (2010) Effect of heat treatment on the phsysico-chemical properties of starch from different botanical sources. International Food Research Journal. 17: 127-135.

[14] Eerlingen, R. C., and J. A. Delcour (1995) Formation, analysis, structure and properties of type III enzyme resistant starch. Journal of Cereal Science. 22: 129-138.

[15] Jiranuntakul, W., C. Puttanlek, V. Rungsardthong, S. Puncha-arnon, and D. Uttapap (2012) Amylopectin structure of heat–moisture treated starches. Starch - Stärke. (in press)