Development of *Syzygium caryophyllatum* Fruit Pulp Incorporated Rice Flakes

I.G.G. Kasunmala*, S.B. Navaratne and I. Wickramasinghe

Department of Food Science and Technology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

Date Received: 10-09-2020 Date Accepted: 12-11-2020

Abstract

Nutritional quality of rice flakes was enhanced by incorporating *Syzygium caryophyllatum* fruit pulp while binding it with rice flour by *Neolitsea cassia* mucilage. Four rice flakes formulations were prepared by altering two variables namely adding with and without leavening agent (Sodium bicarbonate) into the dough and extruded dough flaxes subjected to with and without roller milling manually. According to the results, physical properties, sensorial properties and texture profile analysis of rice flakes prepared from four treatment combinations were significantly difference to each other ($p<0.05$) except nutritional and antioxidant activities. SC fruit pulp added rice flakes with the leavening agent and subjected to roller milling (F4) was selected as the best rice flake formulation in terms of physical, sensorial and textural properties. Further, TPC, DPPH radical scavenging activity % and FRAP value of this (F4) formulation were 7.86 GAE/100 g, 37.21 and 36.32 TE/100 g respectively.

Keywords: antioxidant activity, Neolitsea cassia mucilage, rice flakes, Syzygium caryophyllatum fruit pulp, textural improvements

1. Introduction

Breakfast cereals are considered as the most important part of breakfast practices as it makes up the substantial amount of energy intake of western world (Joye et al., 2011). Generally, ready-to-eat (RTE) cereals are becoming most common application in breakfast cereals as they do not required any further processing, convenient, affordable, nutrient dense and large verity of products including rolled, extruded, and puffed cereals (Faller et al., 2000; Medina et al., 2011; Oliveira et al., 2015). The process of making RTE cereals is dictated by the type of cereals, but most processes involve similar techniques of mixing, cooking, cooling, shaping, toasting, coating, and drying (Caldwell et al., 2000). Most of the breakfast cereals made out with wheat and maize as the major raw material (Oliveira et al., 2015). Rice is the most common staple food in Asian region. Therefore, introducing rice flour into breakfast cereals may help to popularise breakfast cereals in Asian region and make it as economical and health-promoting ingredient to improve the nutritional quality of low income population. However, the lack of gluten protein in rice makes harder to use rice flour as to dough preparation in bakery industry. Gluten protein is the major component which is responsible for the formation of basic structure of wheat dough preparation (Kasunmala et al., 2020). Textural attributes such as crunchiness or crispness define the best quality attribute in RTE cereals (Sacchetti et al., 2003). Most of the time consumers prefer to consume RTE cereals after being submerged in milk (Luckett and Wang, 2012). The time a cereal can retain its desired crispness after being added to milk is known as the "bowl life" (Luckett and Wang, 2012). Therefore, it is important to retain the crispiness of RTE cereal in milk to attract the consumer acceptance. Hence, the texture will be the driving factor in formulating a new RTE cereal.

*Correspondence: kasunmala@sci.sjp.ac.lk
Tel:+94 714309014

Extrusion cooking is a versatile, low-cost and very efficient technology which used in food processing; of that raw materials are cooked by using several mechanisms such as moisture, pressure, temperature and mechanical shear that result in plasticised mass with molecular transformations and chemical reactions (Oliveira et al., 2015). As a result of the extrusion cooking molecular transformation such as break down of covalent bonds in biopolymers, structural disruption and mixing may take place while texturising and modifying the functional properties of raw materials (Oliveira et al., 2015). Further chemical changes such as starch gelatinisation, complex formation between amylose and lipids, protein denaturation, and degradation reactions of vitamins and pigments are taking place during the extrusion cooking (Oliveira et al., 2015). However, those effects are govern by extrusion conditions such as extrusion temperature, screw speed and configuration, feed moisture content etc. as well as characteristics of raw materials such as particle size, composition etc. (Oliveira et al., 2015). Further, leavening agent and roller milling were used as to improve the texture of formulated extruded RTE cereal.

S. caryophyllatum is an evergreen tree belongs to Myrtaceae family, which bears blackish purple colour fruits which have delicate but characteristic flavor combination of mild sweet, sour (Shilpa and Krishnakumar, 2015). *S. caryophyllatum* fruit pulp was incorporated into RTE cereal as a functional ingredient to boost as antioxidant vigor. Also mucilage extracted from *N. cassia* leaves was incorporated into the rice dough as a binding agent to make better contact of rice flour with *S. caryophyllatum* fruit pulp as cohesive dough.

The objective of this study was to identify the effects of leavening agent and roller milling to improve textural quality of ready-to-eat breakfast cereals formulated by using rice flour, *S. caryophyllatum* fruit pulp and *N. cassia* mucilage extract while employing extrusion technology.

2. Materials and Methods

2.1 Materials

S caryophyllatum fruits and *N. cassia* leaves were collected from Galle Southern province, Sri Lanka (80°13$^{/}$15$^{//}$E 6°3$^{/}$12$^{//}$N). White rice flour (150 μm) was purchased from a registered supplier, MDK Food products (Pvt) Ltd. Horana, Sri Lanka.

Analytical grade of citric acid, disodium monohydrogen orthophosphate, ferric chloride, folin-ciocalteu reagent, gallic acid, glacial acetic acid, methanol, monosodium dihydrogen orthophosphate, sodium acetate tetrahydrate, sodium carbonate, sodium fluorescein, 6-hydroxy-2-5-7-8-tetramethylchroman-2-carboxylic acid (Trolox), 2,2-diphenyl-2-picryl-hydrazyl (DPPH), 2,2-azobis(2-amidinopropane) dihydrochloride (AAPH), 2,4,6-tripyridyl-s-triazine (TPTZ) and dimethyl sulfoxide (DMSO) were purchased from Sigma-Aldrich (USA).

2.2 Preparation of raw materials

Well-ripen blackish purple colour *S. caryophyllatum* fruits were manually picked, cleaned, washed and air dried at 25° C. Thereafter, edible portion of the fruits was extracted and fruit pulp was prepared with 10:1 ratio of fruit pulp and water using a juice extractor (Joyong Electric Appliance Co., Shandong, China). Prepared fruit pulp was hot water blanched at 70° C for 3 minutes. *N. cassia* mucilage was extracted by using method described by Kasunmala et al. (2017).

2.3 Preparation of rice flakes

About 500 g of rice flour was mechanically kneaded using a dough mixer with 50 g of sugar, 2.25 g of salt, 125 g of lilly pilly (*S. caryophyllatum*) fruit pulp and 350 mL of *N. cassia* mucilage for 15 minutes to form a dough with suitable consistency. Mucilage of *N. cassia* leaves was used as a substitute for water during kneading the dough. The prepared dough was introduced into an extruder fitted with a die of 10.0×0.5 mm orifice and extruded at 75° C to get the rice strips and they were allowed to rest for five minutes and cut into small pieces (approximately 1.5 cm). Finally, they were dried in a preheated hot air oven at 120° C for 10 minutes until moisture content reached to 10%. Thereafter rice flakes were removed from the dryer and packed in double laminate (LLDPE:PET) pouches and stored at ambient conditions (27±2° C, RH=74%) for the subsequent use of the study.

Further, four rice flake formulations were developed by incorporating with and without Sodium bicarbonate (0.5%) into the rice dough as well as extruded dough flaxes subjected to with and without roller milling manually given as F1=Rice flakes without Sodium bicarbonate (rising agent) and without subjected to roller milling; F2=Rice flakes with the rising agent and without subjected to roller milling; F3=Rice flakes without rising agent and subjected to roller milling; F4=Rice flakes with rising agent and subjected to roller milling.

2.4 Sensory evaluation of formulated rice flakes

Sensory evaluation of prepared rice flakes was carried out by resorting 15 numbers of trained panelists and they were properly instructed beforehand. Four types of rice flake samples were served separately in the ceramic bowls which were randomly labeled with three digits, as five gram (5 g) flakes with 30 mL of UHT semi-skimmed milk (1.6% w/v fat), a fork, cup of water and a ballet paper were served to the panelists before the evaluation and respondents were asked to evaluate five sensory stimuli such as colour, aroma, chewiness, taste, mouth feel, palatability and overall acceptability against seven point hedonic scales. The lower the score given for a sensory stimulus attributed to the lower satisfaction of the respondent.

2.5 Physical and nutritional properties of formulated rice flakes

(a) Specific weight of flakes

The specific weight of flakes was determined according to the method described by Gates et al. (2008) by tipping flakes into a known volume of a container. Flakes were filled into a pre-weighed 120 mL beaker by tapping the beaker rotating lateral direction and the surface was flattened by using the edge of a wooden ruler. The weight of the flakes was measured by using an analytical balance.

(b) Determination of milk absorption by the flakes

Milk absorption was measured according to the method of Anderson et al. (2003) with few modifications. Approximately four grams of flakes were placed in 30 mL of milk at 8±1° C for 3 minutes, and then the flakes were removed from the milk and drained off on a stainless-steel mesh for 30 seconds. The milk absorption was calculated as using equation 1.

$$\text{Milk absorption\%} = \frac{\text{Weight of drained flakes-Weight of dry flakes}}{\text{Weight of dry flakes}} \quad (1)$$

(c) Colour analysis of flakes

Colour of prepared flake formulations was measured with a Chroma meter (Ramsey, NJ, USA). Instrument was calibrated using a white tile and the colour was expressed in Hunter-Lab scale. Brightness of flakes represented by (L*) value, where 0=black and 100=white. The a* value is indicated the red-green difference where positive value expressed redness and negative greenness. Yellow-blue difference represented by b* where positive value indicates yellowness and negative blueness. Each data represents the mean of ten replicates.

(d)Texture profile analysis of flakes

Texture profile analysis was performed by using a Texture Analyser, TA.XT2 plus (Stable Micro Systems, Surrey, England). Rice flakes from each formulation was securely fastened to the smooth platform (Base TA-90) and subjected to 75% deformation in a compression mode in TPA cycle using a cylindrical probe (38 mm) at a speed of 1.0 mm/sec. From the TPA curve, hardness, gumminess, springiness, and chewiness were recorded. A total of eight repeated measurements were taken from rice flakes formulation.

Flake size was measured by using Venire caliper. Moisture, ash, and protein content were determined according to AOAC official method 920.151, 923.03, 923.04 respectively (AOAC, 1999).

2.6 TPC and antioxidant analysis of formulated rice flakes

Four stock solutions (5,000 ppm) were prepared by using accurately weighing 5.0 mg of powdered rice flakes dissolved in 1,000 µL of corresponding solvent of each assay. Solutions were centrifuged (Durafuge 300, Precision Scientific) at 5,000 rpm for 15 minutes to get the clear supernatant solution. All the bio-assays were carried out using high throughput 96-well micro-plate reader (Spectra Max Plus384, Molecular Devices, USA). Each data represents the mean of six replicates.

(a) Total Polyphenolic content (TPC) of rice flakes

TPC of rice flakes formulations was measured according to the modified Folin-Ciocalteu method of Singleton et al. (1999). A mixture of 20 µL of stock solution (powdered rice flakes dissolved in distilled water) and 110 µL of ten times dilute folin-ciocalteu reagent was incubated with 70 µL sodium carbonate solution for 30 minutes at room temperature (25±2 °C) and the absorbance was recorded at 765 nm. Results were expressed as mg Gallic acid equivalents (GAE)/g of rice flakes using the calibration curve of Gallic acid standard (y=0.000432x+0.02436, R^2=99.8%).

(b) 2,2-diphenyl-2-picryl-hydrazyl (DPPH) free radical scavenging activity of rice flakes

The DPPH free radical scavenging activity of rice flakes was determined according to the method of Blois (1958) with few modifications. A mixture of 150 µL of DPPH solution (absorbance of 0.75±0.05 at 517 nm) and 50 µL of rice flakes dissolved in methanol at room temperature (25±2° C) was incubated in dark for 10 minutes. The absorbance of the mixture was recorded at 517 nm. DPPH radical scavenging activity percentage was calculated using the following equation.

$$Scavenging\ activity(\%)=\frac{(A\ control\text{-}A\ sample)}{A\ control}\times 100\% \quad (2)$$

A=Absorbance reading

(c) Ferric reducing antioxidant power (FRAP) value of rice flakes

The FRAP value was determined according to the method described by Benzie and Szeto (1991). Fresh FRAP reagent was made by mixing 300 mM acetate buffer (pH 3.6), 10 mM TPTZ solution, and 20 mM ferric chloride hexahydrate solution (10:1:1, v/v/v) and incubated at 37° C for 10 minutes. Exact 20 µL of stock solution (powdered rice flakes dissolved in acetate buffer) were incubated with 30 µL of acetate buffer and 150 µL FRAP solution at room temperature (25±2° C) for 8 minutes. The absorbance of the ferrous-TPTZ complex was recorded at 593 nm. Results were expressed as mg Trolox equivalents (TE)/ g of rice flakes using a calibration curve of Trolox (y=0.0462x+0.0733, R^2=99.94%).

2.7 Shelf life analysis of formulated rice flakes

For the shelf life analysis, the best rice flake formulation (F4) which was packed in double laminate (LLDPE: PET) pouches were stored in a storage box at room temperature. The sample was analysed concerning the test parameters such as moisture content, colour, texture (hardness), total plate count (TPC, SLS:516: Part 1:1991) and viable yeasts and mould count (Y and M, SLS 516:part 2:1991) for a period of 6 months while drawing samples for the analysis monthly. All the tests were triplicated for each parameter.

2.8 Statistical analysis

The results were expressed as mean ± standard error (SE) by comparing the means using one-way ANOVA using IBM SPSS Statistics 22.0 package. Turkey's multiple range tests was used for mean separation when ANOVA was significant ($p<0.05$).

3. Results and Discussion

As a breakfast cereal, rice flakes were developed by using *S. caryophyllatum* fruit pulp to enhance the antioxidant activity of them with some textural improvements. Textural improvements were achieved by adding a leavening agent (Sodium bicarbonate) and adopting a roller milling process. Four types of flake formulations were prepared and the appearance of formulated rice flakes samples (F1, F2, F3, and F4) are illustrated in Figure 1.

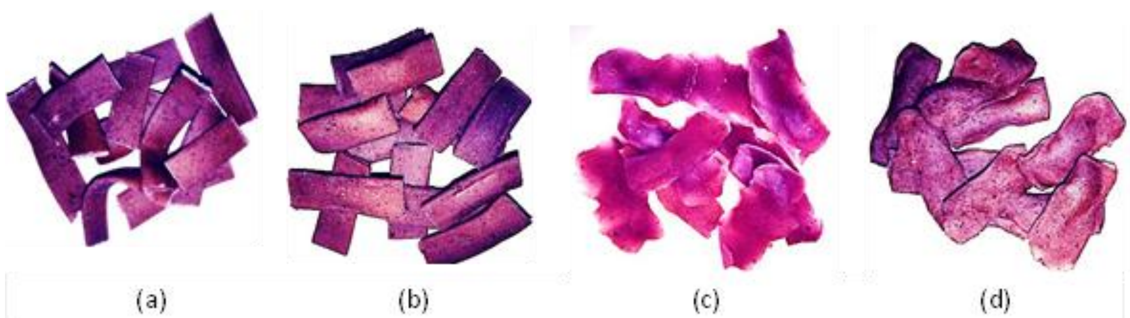

Figure 1. Appearance of prepared *S. caryophyllatum* fruit pulp incorporated rice flakes samples (a) Rice flakes without a leavening agent and without subjected to roller milling-F1; (b) Rice flakes with a leavening agent-F2; (c) Rice flakes subjected to roller milling-F3 (d); Rice flakes with a leavening agent and subjected to roller milling-F4.

3.1 Physical and nutritional properties of prepared flake formulations

Physical properties of prepared four types of *S. caryophyllatum* pulp incorporated rice flakes were evaluated in terms of thickness, bulk density, milk absorption capacity, colour, and nutritional values, and results are tabulated in Table 1.

According to the results given in Table 1, the thickness of four rice flakes formulations was significantly difference ($p<0.05$) from each other. Highest thickness was observed in F2 (rice flakes with a leavening agent and without subjected to a roller milling) and the lowest thickness was observed in F3 rice flakes, which subjected to roller milling and without adding the leavening agent. The thickness of F1 and F2 formulations was comparatively higher than that of F3 and F4, because F3 and F4 flakes samples were subjected to roller milling. In comparison with the addition of leavening agent, the leavening agent added flakes were thicker than that of without leavening agent because the leavening agent improved the porous structure during raising the dough. Gates et al. (2008) also reported that best quality oat flakes having a thickness range of 0.54-1.13 mm with roller milling which was compatible with the thickness of F3 and F4 formulations.

Table 1: Physical properties of prepared *S. caryophyllatum* pulp incorporated rice flakes.

Parameters		F1	F2	F3	F4
Thickness (mm)		1.26±0.45[b]	2.12±0.67[a]	0.55±0.02[d]	0.85±0.01[c]
Specific weight (g)		365.42±1.28[c]	342.12±2.74[d]	486.67±3.24[a]	422.56±4.62[b]
Milk absorption (g/g)		1.38±0.42[d]	1.77±0.17[b]	1.56±0.32[c]	2.17±0.11[a]
Colour	L*	12.91±1.56[d]	27.76±0.49[a,b]	28.20±2.73[a]	21.26±0.72[c]
	a*	20.12±2.16[d]	40.28±0.88[b]	51.55±2.68[a]	34.54±1.39[c]
	b*	-16.14±1.81[c]	-18.39±2.62[d]	-14.93±1.84[b]	-9.28±0.61[a]
Moisture content %		7.21±0.35[a]	6.56±0.54[b]	5.28±0.38[c]	6.45±0.42[b]
Ash content %		2.57±0.32[a]	2.35±0.12[a]	2.49±0.43[a]	2.52±0.28[a]
Protein content %		10.36±0.05[a]	10.27±0.32[a]	10.28±0.64[a]	10.42±0.51[a]

Note: Data represented as mean±standard deviation (n=6). Mean values in rows superscripted by different letters are significantly different at $p<0.05$ according to Turkey's multiple range tests. Nutritional quality results are presented on a dry weight basis. L*=brightness, a*=red-green difference b*=yellow-blue difference. F1-Rice flakes without a leavening agent and without subjected to roller milling; F2-Rice flakes with a leavening agent; F3-Rice flakes subjected to roller milling, F4-Rice flakes with a leavening agent and subjected to roller milling.

The specific weight of rice flakes was also significantly different ($p<0.05$) in each formulation. While the highest specific weight was observed in F3 and the lowest was in F2. Specific weight is a measurement of bulk density indicating the extent of packing in compact. This may be also a consequence of the textural improvements done to rice flakes. Gates et al. (2008) also reported that flake thickness was closely related to the specific weight. When rice flakes were more flattened, can be packed well. This phenomenon was compatible with our results, as F3 showed the highest specific weight which had the lowest thickness.

According to Table 1, milk absorption was significantly different ($p<0.05$) for each formulation. The highest milk absorption was observed in F4 and lowest in F1. Rice flakes with improved porous structure had the highest milk absorption capacity than that of other flake formulations.

Colour of the *S. caryophyllatum* fruit pulp incorporated rice flakes formulations were significantly different from each other ($p<0.5$). Both lightness (L*) and redness (a*) values of all flake formulations were showed a similar pattern, while F3 formulation was observed highest L* and a* values lowest were in F1. When considering the yellowness (b*) of the flake formulations, all samples had negative values that indicate the values towards blueness, and the highest blueness was observed in F2 and lowest was in F4. Colour values of the flakes did not show any relationship to the structural improvements of rice flakes as L*, a*, and b* values did not indicate any compatibility with the textural modifications. Colour of the flakes directly related to the addition of *S. caryophyllatum* fruit pulp and dark colour of flakes due to the dark purple colour of *S. caryophyllatum* pulp. Wanyo et al. (2009) also reported that the darkness of rice flakes was increased by the addition of rice bran powder and further stated that L* value was decreased while increasing a* and b* values by addition of rice bran powder.

According to the results given in Table 1, moisture content of four formulations of *S. caryophyllatum* fruit pulp incorporated flakes significantly varied for each other, but all the values were low which indicate that the hydrophilic nature of *S. caryophyllatum* fruit pulp incorporated flakes. The highest moisture content was observed in F1 and the lowest was in F3. Gates et al. (2008) reported that moisture content of oat flakes varied from 6.0 to 8.7%, and also weak positive correlation was observed between moisture content and flake thickness. Further, ash and protein content of four formulations were not significantly different (p>0.05). This may be due to the same dough composition used for each formulation. Wanyo et al. (2009) also reported that protein content and an ash content of rice bran incorporated rice flakes were 8.62-12.15% and 5.02-11.92% respectively. Because rice bran considered as a rich source of protein and *S. caryophyllatum* pulp incorporated rice flakes also contained a similar range of protein content as rice bran incorporated rice flakes. However, the ash content of rice bran incorporated rice flakes was much higher than that of *S. caryophyllatum* pulp incorporated rice flakes, because rice is more fibrous than *S. caryophyllatum* fruit pulp. Medina et al. (2011) also reported that ash content of corn and quinoa breakfast flakes was 2.09 and 1.99 which was compatible with *S. caryophyllatum* pulp incorporated rice flakes.

Considering all physical and nutritional parameters F4 formulation with *S. caryophyllatum* fruit pulp incorporated flakes was selected as the best formulation.

3.2 Texture profile analysis of prepared flakes formulations

Since one of the objectives of this study was to improve the texture of rice flakes by incorporating *S. caryophyllatum* fruit pulp, four formulations were subjected to texture profile analysis (TPA) and results pertaining to the analysis are tabulated in Table 2.

Table 2: Texture profile analysis of prepared *S. caryophyllatum* pulp incorporated rice flakes.

Parameters	F1	F2	F3	F4
Hardness (g)	207.73±2.34^{a}	156.43±1.54^{b}	84.62±1.74^{d}	118.28±2.32^{c}
Adhesiveness (mJ)	0.64±0.06^{b}	0.38±0.27^{c}	0.85±0.12^{a}	0.15±0.00^{d}
Resilience	0.46±0.01^{b}	0.52±0.01^{a}	0.25±0.07^{c}	0.55±0.02^{a}
Fracturability (g)	226.48±4.42^{a}	184.54±1.72^{b}	115.20±1.18^{d}	138.28±2.56^{c}
Cohesiveness	0.56±0.05^{a}	0.54±0.02^{a}	0.44±0.01^{b}	0.52±0.01^{a,b}
Gumminess g	-272.74±22.1^{a}	-384.17±4.52^{b}	-572.91±22.47^{d}	-416.36±13.15^{c}

Note: Data represented as mean±standard deviation (n=6). Mean values in rows superscripted by different letters are significantly different at p<0.05 according to Turkey's multiple range tests. F1-Rice flakes without a leavening agent and without subjected to roller milling; F2-Rice flakes with a leavening agent; F3-Rice flakes subjected to roller milling; F4-Rice flakes with a leavening agent and subjected to roller milling.

According to the results given in Table 2, the hardness of four formulations of *S. caryophyllatum* pulp incorporated rice flakes was significantly different (p<0.05) to each other. Flakes prepared out of roller milling process (two formulations) had the lowest hardness compared to the other two formulations. Further, the leavening agent usually improves the porous texture of rice flakes and leavening agent added flakes had a lower hardness than the no comparatively none leavening agent incorporated rice flakes. The texture of rice flakes should be firm enough for easy chewing however should have an adequate strength to bear the external pressure during packaging and transportation. Wanyo et al. (2009) reported that the addition of rice bran powder reduced the hardness of rice flakes. Wanyo et al. (2009) also stated that hardness of rice flakes (wheat flour: rice flour, 1:1) was 115.6 g and it was compatible with the F4 *S. caryophyllatum* pulp incorporated rice flake formulation.

Adhesiveness between four formulations of *S. caryophyllatum* pulp incorporated rice flakes was also significantly different (p<0.05) to each other. The highest adhesiveness was observed in F3 formulation and the lowest was in F4. Adhesiveness indicates the stickiness of the rice flakes and low stickiness was preferred for rice flakes. Hence, rice flakes out of F4 formulation was selected as the best formulation in terms of adhesiveness. Resilience is a measurement of elasticity of rice flakes. F2 and F4 formulations were showed comparatively high resilience and F3 formulation had the lowest. Rice flakes with lowest thickness and hardness exhibited the lowest resilience as well. Fracturability measured the tendency of breakability and it is running in hand in hand pattern with the hardness of rice flakes. While the highest fracturability was given by the F1 formulation and the lowest value was indicated by F3. Hence, thinner the rice flakes it imparts the lowest Fracturability. The strength of internal bonds within the sample was measured by the cohesiveness of rice flakes. There was no significant difference ($p>0.05$) in cohesiveness between F1, F2, and F4 rice flakes; however, F3 had a significantly low cohesiveness ($p<0.05$) than the other three formulations.

Gumminess described the mouth feel sensation during chewing the rice flakes. Gumminess of all flake formulations was significantly different ($p<0.05$) to each other and the highest gumminess was observed in F1 and lowest was in F2. On the other hand, when the hardness of rice flakes increases, the gumminess is also concurrently elevated. Further, TPA parameters indicated that the most favourable formulation was F4, and F3 flakes sample had noteworthy changed because it had a thin, breakable texture comparatively all other samples.

3.3 Sensory evaluation of fruit pulp incorporated flakes

Sensory evaluation for four types of rice flakes formulations was performed by serving rice flakes with 30 mL of UHT semi-skimmed milk (1.6% w/v fat) and results obtained from it were used to draw the sensory profile of each product and which is showing in Figure 2.

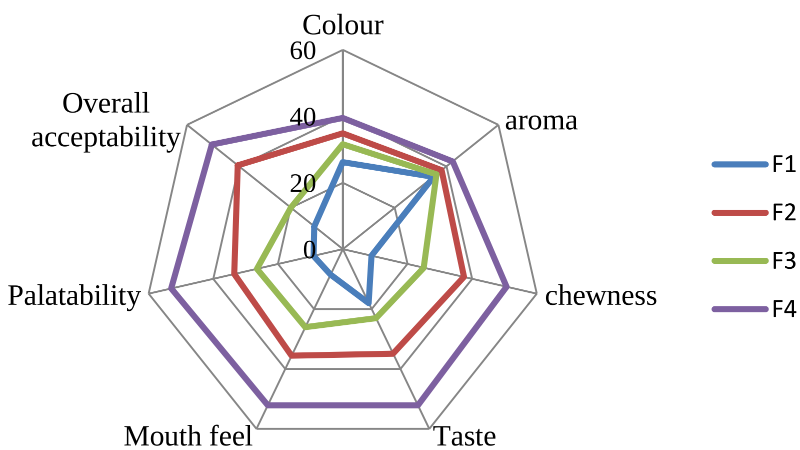

Figure 2. Sensory attributes of *S. caryophyllatum* fruit pulp incorporated rice flakes formulations. F1-Rice flakes without a leavening agent and without subjected to roller milling; F2-Rice flakes with a leavening agent; F3-Rice flakes subjected to roller milling; F4-Rice flakes with a leavening agent and subjected to roller milling.

According to Figure 2, all the sensory attributes except aroma were significantly ($p<0.05$) difference to each flake samples. The highest sensory ratings for all sensory stimuli were secured by the F4 flakes formulation and the least ratings were recorded by the F1. F4 formulation had both textural improvements, due to incorporation of the leavening agent along with the roller milling process, and the rice flakes out of F1 formulation did not have both textural improvement methods. Hence, this study revealed that both textural improvement methods (incorporation of $NaHCO_3$ and roller milling process) remarkably contributed to improve the sensory characteristics of *S. caryophyllatum* fruit pulp incorporated rice flakes. F2 and F3 also exhibited significantly higher sensorial characteristics compared to the flake out of F1 formulation.

High aromatic fragrance and colour of the *S. caryophyllatum* fruit pulp were positively contributed to the sensory profile of the flakes as colour and aroma of all four formulations were showed somewhat higher ratings. Addition of *S. caryophyllatum* fruit pulp did not affect the taste of rice flakes samples and most of the panelists like the taste of *S. caryophyllatum* fruits. Therefore, the sensory analysis revealed that F4 flakes formulation had the highest sensory rating and it was select as the best flakes formulation in terms of all sensory attributes. Wanyo et al. (2009) also reported that the incorporation of rice bran powder improved the sensory characteristics of rice flakes.

3.4 TPC and antioxidant analysis of prepared flakes formulations

Anthocyanin rich *S. caryophyllatum* fruit pulp was incorporated into rice flakes to improve the antioxidant activity. Results of the TPC and antioxidant analyses pertaining to the four *S. caryophyllatum* fruit pulp incorporated rice flakes formulations are tabulated in Table 3.

Table 3: Result of the antioxidant analyses of four *S. caryophyllatum* fruit pulp incorporated rice flakes formulations.

Antioxidant assay	F1	F2	F3	F4
TPC	$7.59 \pm 0.73^{a,b}$	$7.52 \pm 0.41^{a,b}$	7.90 ± 0.27^{a}	7.86 ± 0.58^{a}
DPPH	39.84 ± 0.56^{a}	$36.72 \pm 0.24^{a,b}$	$37.12 \pm 0.45^{a,b}$	$37.21 \pm 0.32^{a,b}$
FRAP	$34.24 \pm 0.16^{a,b}$	36.49 ± 0.12^{a}	$35.43 \pm 0.42^{a,b}$	36.32 ± 0.05^{a}

Data represented as mean±standard deviation (n=6). Mean values in a row superscripted by different letters are significantly different at $p<0.05$ according to Turkey's multiple range tests. Results are presented on a dry weight basis. TPC=mg Gallic acid equivalents/100 g of dry rice flakes powder; DPPH=scavenging activity% (correspond to well concentration 500 ppm); FRAP=mg Trolox equivalents /100 g of dry rice flakes powder; F1=Rice flakes without a leavening agent and without subjected to roller milling; F2=Rice flakes with a leavening agent; F3=Rice flakes subjected to roller milling; F4=Rice flakes with a leavening agent and subjected to roller milling.

According to the results given in Table 3, there was no significantly different ($p>0.05$) between four formulations of *S. caryophyllatum* incorporated rice flakes in polyphenol content, DPPH radical scavenging activity%, and FRAP value. TPC values obtained from this study were ranging from 7.52 to 7.90 mg GAE/100 g dry rice flakes. DPPH radical scavenging activity percentages of formulated *S. caryophyllatum* pulp incorporated rice flake samples were ranging from 36.72 to 39.84%. FRAP values of four formulations were also in the range of 34.24 to 36.49 mg TE/100 g dry rice flakes. Antioxidant capacity of prepared all four formulations as same as to each other because an equal level of *S. caryophyllatum* fruit pulp was incorporated into each type of flake. Moreover, according to the results, textural modifications of rice flakes do not affect the antioxidant activity of each formulation. Wanyo et al. (2009) reported that the incorporation of rice bran increased the antioxidant activity of rice flakes and rice bran incorporated flakes showed the DPPH radical scavenging activity percentage and FRAP value as 27.74 % and 11.94 mM $FeSO_4$/g sample respectively.

3.5 Shelf life analysis of S. caryophyllatum pulp incorporated rice flakes

According to the physical properties and texture profile analysis of rice flakes, F4 (*S. caryophyllatum* fruit pulp added rice flakes with the leavening agent and subjected to roller milling) was selected as the best formulation. Hence, storage studies were conducted based on the F4 formulation. Shelf life study was conducted for a period of six months at ambient conditions (27±2° C, RH=74%).

All the designated shelf life parameters were slightly changed during the period of six month of storage. The moisture content of the flakes was slightly increased during storage (6.45-7.15%) but increment was not significant (p>0.05). The colour of *S. caryophyllatum* fruit pulp incorporated rice flakes had a scant increment. Thus L* value had a slight increment (21.26-22.19). In the case of a* and b* values which were slightly decreased however the decrement was not significantly different (p>0.05) (a*=34.54-32.93; b*=(-)9.28-(-)9.03) for six months. The hardness of the *S. caryophyllatum* pulp incorporated rice flakes also slightly decreased (118.28-105.16) during the period of six months of storage and the reduction was not significant (p>0.05). According to the microbial analysis, total plate content and viable yeast and mold count were much lower value than that of the standard values (TPC; $<1\times10^4$:Y and M; $<1\times10^2$); therefore, *S. caryophyllatum* pulp incorporated rice flakes were microbiologically safe during the period of six months storage.

4. Conclusion

Rice flakes were prepared by incorporating *S. caryophyllatum* fruit pulp which contained high antioxidant activity with the mucilage extracted from *N. cassia* had better physical, chemical and organoleptic properties. The texture of the rice flakes can be improved by adding a leavening agent (Sodium bicarbonate) as well as flakes subjected to the roller milling. According to this study, four types of rice flakes out of four formulations were prepared and F4 formulation (*S. caryophyllatum* fruit pulp added rice flakes with the leavening agent and subjected to roller milling) had the better physical and sensorial properties along with the textural properties. Hence, F4 formulation was selected as the best treatment in making rice flakes out of *S. caryophyllatum* pulp and *N. cassia* mucilage. TPC, DPPH radical scavenging activity % and FRAP value of F4 formulation were 7.86 GAE/100 g, 37.21 and 36.32 TE/100 g respectively.

Acknowledgement

This work was supported by the university grants, University of Sri Jayewardenepura (Grant No: ASP/01/RE/SCI/2016/19).

Conflict of interest

There are none to declare regarding the present study.

References

Anderson, B.A., Singh, R.P. and Rovedo, C., 2003. Use of phytoglycogen extracted from corn to increase the bowl-life of breakfast cereal. *Journal of Food Process Engineering*, 26:315-322.

Association of Official Analytical Chemists (AOAC), 1999. Official Methods of Analysis, (16th ed). Gaithersburg, MD, USA.

Benzie, I.F.F. and Szeto, Y.T., 1991. Total antioxidant capacity of teas by the ferric reducing antioxidant power assay. *Journal of Agricultural and Food Chemistry*, 47:633-636.

Blois, M.S., 1958. Antioxidant determination by the use of stable free radical. Nature. 181:1199-1200.

Gates, F.K., Sontag-Strohm, T., Stoddard, F.L., Dobraszczyk, B.J. and Salovaara, H., 2008. Interaction of heat-moisture conditions and physical properties in oat processing: II. Flake quality, *Journal of Cereal Science*, 48:288-293.

Faller, J.F., Faller, J.Y. and Klein, B.P., 2000. Physical and sensory characteristics of extruded corn/soy breakfast cereals. *Journal of Food Quality*, 23:87-102.

Joye, I.J., Lamberts, L. and Delcour, K.B.J.A., 2011. In situ production γ-aminobutyric acid in breakfast cereals. *Food Chemistry*, 129:395-401.

Kasunmala, I.G.G., Navarathne, S.B. and Wickramasinghe, I., 2020. Effect of process modifications and binding materials on textural properties of rice noodles. *International Journal of Gastronomy and Food Science*, 21:100217.

Luckett, C.R. and Wang, Y., 2012. Application of Enzyme-Treated Corn Starches in Breakfast Cereal Coating. *Journal of Food Science*, 1750-3841.

Medina, W.T., de la Llera, A.A., Condori, J.L. and Aguilera, J.M., 2011. Physical properties and microstructural changes during soaking of individual corn and quinoa breakfast flakes. *Journal of Food Science*, 76:254-265.

Oliveira, L.C., Rosell, C.M. and Steel, C.J., 2015. Effect of the addition of whole-grain wheat flour and of extrusion process parameters on dietary fibre content, starch transformation and mechanical properties of a ready-to-eat breakfast cereal. *International Journal of Food Science and Technology*, 50:1504-1514.

Sacchetti, G., Pittia, P., Biserni, M., Pinnavaia, G.G. and Rosa, M.D., 2003. Kinetic modelling of textural changes in ready-to-eat breakfast cereals during soaking in semi-skimmed milk. *International Journal of Food Science and Technology*, 38:135-143.

Shilpa, K.J. and Krishnakumar, G., 2015. Nutritional, fermentation and pharmacological studies of *Syzygium caryophllatum* (L.) Alston and *Syzygium zeylanicum* (L.) DC fruits. *Cogent Food and Agriculture*, 1:1018694.

Singleton, V.L., Orthofer, R. and Lamuela-Raventos, R.M., 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocaltue reagent. *Methods Enzymol*, 299:152-178.

Sri Lankan Standards (SLS) 516: part 1. 1991. General guide line for enumeration of micro-organisms colony count techniques at 30 °C. Sri Lankan Standards Institution, Colombo 08.

Wanyo, P., Chomnawang, C. and Siriamornpun, S., 2009. Substitution of Wheat Flour with Rice Flour and Rice Bran in Flake Products: Effects on Chemical, Physical and Antioxidant Properties. *World Applied Sciences Journal*, 7:49-56.