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Improvement of Quality of Composite Bread by Incorporating Dual Modified Traditional Rice Flour

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***Abstract*— *Bakery industry is heavily depended on wheat flour due to its favorable properties. This dependency has proven disadvantageous for Bakery industry in countries where wheat cultivation is not possible. Rice flour with necessary modifications could be an ideal candidate to replace or used in combination with imported wheat flour in bakery industry. Traditional rice varieties suits best for obtaining flour since they nutritious and well adapted to the local setup. This study reports the impacts of physio-chemicals modifications of rice flour obtained from four traditional rice varieties grown in Sri Lanka in making of bread. Four traditional rice varieties namely Madatuwalu, Kaluhenati, Panchaperumal and Rathdal were selected and grains were soaked in 0.5M or 1M $NaHCO_3$ solution for one hour followed by dehydration at 100°C for one to two hours. Functional properties of the modified rice flour such as, Water Solubility, Swelling Power and Water Absorption Index were determined. The treatments tested were shown significant effects ($p < 0.05$) on functional properties of all four flour types. Dipping in 1M $NaHCO_3$ solution for one hour followed by dehydration for two hours at 100°C was the best treatment and Madathuwalu was the highest performing flour type for all the functional properties. Hence, Madathuwalu was selected after the application of best treatment to develop rice flour incorporated composite bread. The results showed that composite bread developed by substituting 40% wheat flour with modified rice flour resulted in the similar sensory attributes to bread developed with 100% commercial wheat flour.*

***Keywords*— composite bread, flour modification, functional properties, rice flour, traditional rice varieties.**

I. INTRODUCTION

Bread is the most popular bakery product in Sri Lanka and most parts of the world. The consumption rate of bread has seen a continuous increase in the past decades mainly due to fact that it provide a convenient food option for many in our sophisticated society (Seibel, 2006). However, the wheat flour needed for making bread had to be imported, since the local climatic and soil conditions in many tropical countries are unfavorable for growth of bread wheat (Abdelghaforet al., 2010). Due to the drop in production bread of wheat worldwide and the current production also being channeled for animal food and bio fuels, the future pricing of wheat flour-remain uncertain and increasing trends in prices have been forecasted. Consequently, Sri Lanka government has initiated programs to discourage the consumption of wheat based products while promoting rice flour in an attempt to save enormous foreign exchange used for importing wheat grains and flour (Mahalingam*et al*., 2014).

Traditional rice varieties are well adapted to the local climatic conditions and demonstrate considerable resistance to diseases, pest attacks, water stress and high salinity. Rice flour obtained from traditional varieties is found to be highly nutritious and contain higher amounts of glutamic acids and vitamins than commercial varieties (Wickramasinghe and Noda, 2008). Thus rice flour obtained from traditional varieties could provide an alternative for imported and expensive wheat flour in bakery industry.

However, utilization of rice flour in bakery industry is hampered due to the fact that it contains no glutens which is considered to be very important for maintaining the correct structure of bread dough (Owens, 2001). Absence of gluten often results in a watery batter rather than dough, and can result in bread with poor structure, colour and other post-baking quality defects. Functional properties of the rice flour could be upgraded using chemical, physical and enzymatic methods. Application of heat mist treatment of rice kernels has resulted in improved functional properties of flour derived from them. Modified rice flour has resulted in better paste, clarity, stability, resistance to retrogradation and increased freeze-thaw stability which in turn gave the desired body and texture to the products made out of flour (Perez et al., 2000).

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Functional properties of the rice flour can be upgraded using chemical, physical and enzymatic methods. Previous studies have been shown that application of simple physical treatment methods such as, heat moist treatments of rice kernels could improve functional properties of rice which in turn gives the desired body and texture to the products made out of flour from the treated kernels (Naivikul et al., 2012). Most of the starch modification studies reported thus far have focused on corn, wheat, tapioca, sago and potato starches compared t few reported studies for rice (Xiao et al., 2012).

This studyinvestigate theeffectsof physio-chemical treatments on the functional properties of rice flour of selected four different traditional rice varieties grown in Sri Lanka.The flour derived from treated rice kernels was evaluated for its suitability to produce bread singly or in combination with wheat flour. The study also focused on enhancing the sensory profile of bread within the preview of edible grade requirements to comply with the wants and needs of the bakery industry.

II. METHODOLOGY

2.1 Application of dual modification to rice grains

Dehusked polished rice grains of four selected traditional rice varieties (*Madathuwalu* G1, *Kaluhenati* G2, *Panchaperumal* G3 and *Ratdal* G4) were dipped separately in a solution of NaHCO3 with two different concentrations (0.5 M and 1 M) for one hour followed by through washing with distilled water. Next all samples were placed in an oven at 100 ºC for two different time durations (1 and 2 hours) separately for dehydration. Three replications were maintained for each treatment.

Treatment combinations given for the rice were as follows.

T1 - 0.5 M $NaHCO_3$ dipping one hour followed by 100ºC dehydration for 1 hour

T2 - 1 M $NaHCO_3$ dipping one hour followed by 100ºC dehydration for 1 hour

T3 - 0.5 M $NaHCO_3$ dipping one hour followed by 100ºC dehydration for 2 hours

T4 - 1 M $NaHCO_3$ dipping one hour followed by 100ºC dehydration for 2 hours

Rice flour was obtained from rice grains before and after the application oftreatments. Both modified rice grains and native rice grains went through the same grinding process followed by sieving with a 160 µm sieve to obtain fine rice flour with uniform particle size. After that sieved rice flour were analyzed separately to determine for their functional properties such as, water absorption index (WAI), water solubility (WS) and swelling ability (SP)according to the standard methods respectivelyThumrongchote et al., 2012. Statistical analysis was carried out between modified and native rice flour derived from all four traditional rice varieties. The most effective treatment combination was identified based on the functional properties of each flour type analyzed. All data were analyzed using Minitab 16 software and most effective modification method and the treatment/s were determined based on general linear model. Three replicates were maintained for each and every treatment. Tukey multiple comparison test was used to compare the significant difference at $p \leq 0.05$.

2.2Development of flour blend for the fortification of bread

Flour with the best functional properties was obtained with modified rice flour (1M $NaHCO_3$ dipping for one hour followed by 2 hours dehydration at 100ºC) obtained from *Madathuwalu* (F1) and used to produce bread singly and in combination with wheat flour in various proportions Table 2.1). 100% wheat flour served as the control.

Table.2.1: Composition of Flour Blends

Treatments	Modified Rice Flour (%)	Wheat Flour (%)
A (Control)	-	100
B	20	80
C	40	60
D	50	50
E	60	40
F	80	20
G	100	-

2.3Determination of Leavening Index of bread dough

Different bread dough combinations were prepared using blends in Table 1 with modified rice flour to measure the leavening index. Initial volume of the flatten dough was recorded and volume increment due to the leavening action was recorded in every half an hour interval until the volume of the dough increased by two-fold after the method described by Navarathne, (2007).

$$\text{Leavening Index} = \frac{\text{Increased Volume (ml)}}{\text{Initial volume (ml)}}$$

2.4Development of bread using different flour blends

Composite breads were prepared according to the methods described in (AACC, 2000). All the conditions were maintained at constant level except for the modified rice flour- wheat flour blends (Table 1). Different types of breads were produced using 100 g of flour was incorporated with 2 g salt, 2 g fat (shortening agent), 6g sugar, 2 g yeast (leavening agent) and 58 ml of water. All ingredients were mixed in a food grade stainless steel bowl for 2 min and kneaded for 10 min manually until the dough was well developed. After mixing, dough was covered with a wet clean muslin cloth allowed to ferment for 45 min at room temperature (25 ±0.5°C). After the first fermentation, the dough was divided into 50 g portions, rounded up, placed in pre oiled baking pans, and proofed for another 45 min. Subsequently, the proofed dough was subjected to baking in an oven pre-heated to 220°C for 30 min. Thereafter, the bread was cooled for 60 min at ambient temperature.

2.5Selection of the most preferable composite bread based on the sensory analysis

Composite bread samples were subjected to a sensory evaluation within 3 hours after baking. Sensory evaluation was conductedat a sensory lab with an untrained panel of 30. Sensory attributes such as, taste, aroma, texture, crust appearance, crust colour, crumb appearance, crumb colour and overall acceptability were assessed for all composite bread samples developed using different flour combinations (T1 to T5 as given in table 1)using five point hedonic scale.

2.6Analysis of physical, chemical and microbiological properties of selected composite flour blend against 100% wheat flour.

2.6.1 Loaf weight, Loaf volume and Loaf specific volume

Bread loaves were weighed using an electronic top loading balance after 20 min from baking. Loaf volume was determined according to the rape seed displacement method (AACC, 2000, Standard 10-05).Specific volume of the loaf was determined after one hour from baking according to the method by López et al. (2004).

$$\text{Specific volume } (cm^3/g) = \frac{\text{Volume } (cm^3)}{\text{Weight } (g)}$$

2.6.2 Proximate analysis

Proximate parameters such as moisture content, crude protein, crude fat, crude ash content, crude fiber content and carbohydrate content were analyzed for the selected bread which was developed from the composite flour mixture (modified rice flour 40% + wheat flour 60%) and the bread developed from 100% wheat flour according to the methods described in AOAC, (2000).

2.6.3 Microbial analysis

One gram of the selected bread sample was weighed using electronic balance and homogenized with distilled water and then shaken to obtain a solution. An liquate of 1 ml of the solution was serially diluted in a set of 5 test tubes containing 9 ml of sterile, distilled water as the diluent and aseptically 0.1 ml of appropriate dilution was spread plated on to nutrient agar (NA) and potato dextrose agar (PDA) plates for the enumeration of aerobic viable bacteria and fungi, respectively. The NA culture plates were incubated at 37°C for one week while PDA plates were incubated at room temperature (28 ± 2°C) for one week. Number of colonies formed on culture plates were recorded in every 24 hours until six days from culture initiation and expressed as colony forming units per gram (cfu/g) of samples. All counts were done in duplicate using the colony counter following the method by Daniyan and Nwokwu, (2011).

2.6.4 Staling effect of bread in terms of elasticity

A bread sample was developed from the selected composite flour mixture (modified rice flour 40% + wheat flour 60%) and the crust of the bread was removed using a sharp knife. Then the crumb of the bread was taken and cut into a rectangular shape (1.0 x1.0 x 4.0 cm3) pieces to obtain bread fingers. The cut bread fingers, numbering about 80 were temporary stored in a pet-bottle with a tightly closed lid for subsequent use. One bread finger was taken from the pet- bottle and one end was clipped off about 1.0 cm apart and placed over a ruler. The clipped was fixed to a stationary wooden surface. The other end of the bread piece was also clipped 1.0 cm apart from the end and left free. A strong thread was attached to the clip of free end and dragged gently over the slide ruler until breaking of the bread finger was reached. The maximum elongation length was recorded. The same procedure was adapted to measure elasticity of bread crumbs 12, 24, 36, 48, 60, and 72 hours after backing. A graph was plotted with elongation length against the age of composite bread. Mean value of 10 bread fingers were taken as the elongation length. Same procedure was repeated for wheat bread as the method described by Navaratne, (2007).

2.6.5 Cost analysis

Cost analysis was done for the selected composite bread produced using modified traditional rice flour against the bred containing 100% wheat flour.

III. RESULTS AND DISCUSSION

3.1Water Absorption Index (WAI), Water Solubility (WS) and Swelling Power (SP)

All treatments for all flour types showed significantly higher ($p < 0.05$) WAI values compared to the control in modification 4 (Table 2). Out of all the flour types, F1 showed the highest WAI value after applying treatment T4 in modification 4. Furthermore, out of all the treatments, T4 showed the highest WAI values for all the flour types except F2. The WAI values were more than 5 in all flour types after applying treatments T3 and T4. All

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treatments showed a higher WS values for all flour types than that of the control in modification 4 (Table 2).

Table.3.1: Water Absorption Index (WAI), Water Solubility (WS) and Swelling Power (SP) of selected flour types after the application of different treatments

	Flour Type	WAI	WS%	SP
C				
	F1	1.2±0.01^{h}	1.18±0.05^{h}	1.37±0.05^{h}
	F2	1.22±0.01^{h}	1.34±0.03^{gh}	1.42±0.01^{h}
	F3	0.68 ±0.03^{h}	0.08±0.01^{i}	0.72±0.02^{i}
	F4	1.21±0.01^{h}	1.2±0.04^{h}	1.37±0.05^{h}
T1	F1	5.22± 0.29^{efg}	2.35±0.19^{defg}	5.34±0.3^{efg}
	F2	5.55± 0.16^{cdef}	3.09±0.17^{cdef}	5.73±0.17^{def}
	F3	5.02± 0.12^{fg}	1.81±0.37^{fgh}	5.12±0.11^{fg}
	F4	4.82± 0.02^{g}	2.92±0.37^{efg}	4.96±0.03^{g}
T2	F1	5.39±0.07^{defg}	2.52±0.25^{cdef}	5.53±0.06^{def}
	F2	5.58±0.04^{cdef}	2.22±0.36^{cdef}	5.71±0.03^{cde}
	F3	5.24±0.04^{defg}	1.91±0.32^{cdef}	5.34±0.02^{efg}
	F4	5.11±0.03^{fg}	1.49±0.23^{cdef}	5.19±0.02^{fg}
T3	F1	6.30±0.22^{b}	2.55±0.13^{bcd}	6.47±0.22^{b}
	F2	5.59±0.1^{cdef}	2.59±0.24^{cdef}	5.74±0.11^{cde}
	F3	5.81±0.12^{bcde}	1.64±0.33^{cde}	5.91±0.10^{bcd}
	F4	5.74±0.2^{bcde}	2.22±0.21^{cde}	5.87±0.2^{bcd}
T4	F1	6.816±0.24^{a}	4.44±0.22^{a}	7.13±0.24^{a}
	F2	5.86±0.11^{bcd}	3.02±0.19^{bc}	6.04±0.1^{bcd}
	F3	6.12±0.48^{bc}	3.51±0.2^{b}	6.34±0.4^{bc}
	F4	6.01±0.22^{bc}	4.30±0.14^{a}	6.29±0.22^{bc}

Note: (Modification of rice flour using sodium bicarbonate solution and dehydration) verses native rice flour. T1 - 0.5 M $NaHCO_3$ dipping one hour followed by 100°C dehydration for 1 hour, T2 - 1 M $NaHCO_3$ dipping one hour followed by 100°C dehydration for 1 hour, T3 - 0.5 M $NaHCO_3$ dipping one hour followed by 100°C dehydration for 2 hours, T4 - 1 M $NaHCO_3$ dipping one hour followed by 100°C dehydration for 2 hours, *Madatuwalu* -F1, *Kaluhenati* – F2, *Pachaperumal* – F3, *Ratdal*- F4.

Out of all treatments, treatment T4 showed a significantly higher ($p< 0.05$) WS value for all flour types compared to the control. The highest WS value was shown by the flour type F1 after the treatment T4 in modification 4. All the treatments in modification 4 showed significantly higher ($P < 0.05$) SP values (more than 5) for all flour types obtained from all selected traditional rice varieties compared to the control (Table 3.1). The highest SP value was obtained for F1 flour type for treatment T4.

Water absorption capacity is an important functional characteristic in the development of a ready-to-eat food for cereal grains. A high water absorption capacity could result product cohesiveness where all modified flour can form more viscous or thicker batter due to its ability to retain more water into its molecular structure (Tharise et al., 2014). Moreover, it was confirmed that WS values increased with different modification methods due to the leaching of amylose (Jimoh et al., 2009). Further, eating quality is often associated with retention of water in the swollen starch granules. High swelling power is an important criterion for good quality flour (Ocloo et al., 2010). According to David et al., (2015), increase in water absorption capacity resulted in an increased swelling power leading to improved solubility.

Statistical analysis, have shown significant differences ($p<0.05$) in all selected rice varieties and treatments on Water Absorption Index (WAI), Swelling Power (SP) and Water Solubility (WS). Treatment T4 (dipping in 1 M NaHCO3 for 1 hour followed by dehydration at 100°C for 2 hours) showed the highest WAI, SP and WS for F1 (*Madatuwalu*) flour type. Therefore, flour type F1 was selected as the most responsive flour type and treatment T4 was selected as the most effective treatment to enhance the functional properties for the fortification of bakery products

3.2Leavening index

Previous studies reports that the desirable leavening index for bread is approximately 2.0 (Nawarathne, 2007). According to the Table 3.2, dough obtained from 100% wheat flour showed desirable LI value within 150 min. All modified rice flour (F1) combinations were taken more than 150 min to achieve the desirable LI value. T1 and T2 flour combinations showed the lowest time duration (3 hours) to achieve the desirable LI value except control. Leavening action was not observed from T6 since it contained 100% modified rice flour. Further, combinations with modified rice flour were highly leavened compared to the respective combinations with unmodified rice flour.

Table 3.2. Leavening Index of different flour combinations

Time Duration	Leavening Index (LI)						
	A	B	C	D	E	F	G
30 min	0.53	0.4	0.38	0.36	0.28	0.16	0
60 min	1.1	0.66	0.56	0.56	0.3	0.18	0

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90 min	1.48	1.42	0.65	0.67	0.32	0.2	0
120 min	1.85	1.73	1.32	1.3	0.35	0.21	0
150 min	2.14	1.88	1.75	1.38	0.38	0.22	0
180 min		2.08	2.01	1.68	0.44	0.22	0
210 min				1.75	0.45	0.22	0
240 min				1.88	0.45	0.22	0

3.3 Morphological appearances of developed breads

Fig.3.1: appearance of developed breads using different proportions of wheat flour and modified rice flour (a- 100% wheat flour, b– 80% wheat flour + 20% modified rice flour + 60% modified rice flour, c- 60% wheat flour + 40% modified rice flour, d- 50% wheat flour + 50%, e- 40% wheat flour + 60% modified rice flour, f– 20% wheat flour + 80% modified rice flour)

Morphological features of developed composite breads were shown in Fig. 3.1 It was observed that B and C composite breads produced with rice flour and wheat flour showed golden color crust appearance compared to the control (A) bread sample. Further, satisfactory appearance in terms of structure and volume was observed in B and C composite bread samples including the control compared to the other composite bread samples.

Composite bread structure became more compact and dense with the increment in the proportion of modified rice flour content. Cracks appeared on the crust of the bread samples with high proportion of modified rice flour (E and F). Moreover, the crust color (golden color) reduced in D, E and F bread samples compared to B and C bread samples including the control.

3.4 Sensory analysis of developed breads

Fig. 3.2 shows the sensory characteristics of different composite bread samples developed with different levels of rice flour supplementations. All the samples were shown significantly different effect ($p < 0.05$) on all the sensory attributes (crust appearance, crumb appearance, crust colour, crumb colour, taste, aroma, crumb texture and overall acceptancy). Sample A was given high rates ($p< 0.05$) for all sensory attributes by the panelists compared to other composite samples..

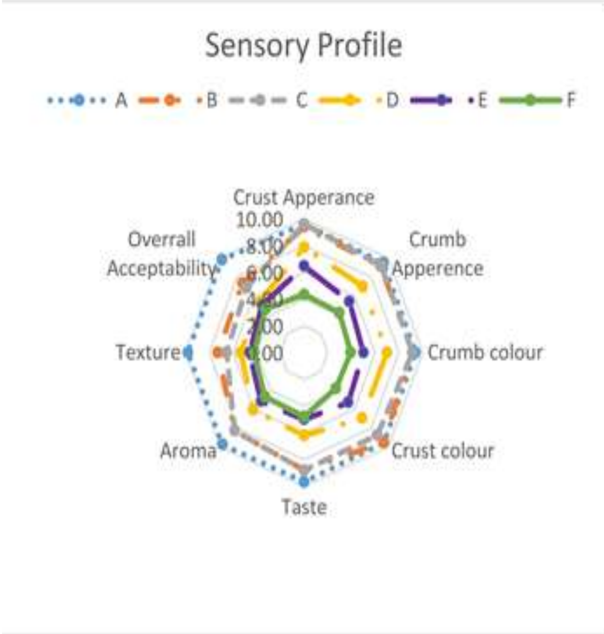

Fig.3.2: Sensory profile for developed breads using different proportions of wheat flour and modified rice flour (A- 100% wheat flour, B– 80% wheat flour + 20% modified rice flour, C- 60% wheat flour + 40% modified rice flour, D- 50% wheat flour + 50% modified rice flour, E- 40% wheat flour + 60% modified rice flour, F– 20% wheat flour + 80% modified rice flour)

However, mean scores for sample A (100 % wheat flour) was not significantly different ($p > 0.05$) with the mean scores for sample B (80 % wheat flour: 20% modified rice flour) and sample C (60 wheat flour: 40 modified rice flour) on crust colour, crumb colour, crust appearance and crumb appearance. Further, sample B and sample C showed significantly higher scores ($p <0.05$) for all sensory parameters among the composite samples

3.5 Loaf weight, Loaf volume and Specific volume of bread

Table 3.3: Loaf weight, loaf volume and specific volume of selected composite bread sample (60% wheat flour + 40% modified rice flour) against wheat flour bread

Parameter	Selected composite bread	100% wheat flour bread
Loaf weight (g)	144.82 $\pm$ 1.79^b	156.22 $\pm$ 1.55^a
Loaf volume (cm^3)	173.68$\pm$ 1.18^b	245.58$\pm$ 2.26^a
Specific volume (cm^3/g)	1.20$\pm$ 0.01^b	1.57 $\pm$ 0.02^a

All values are means of triplicate determination + SD

According to the Table 3.3. Loaf weight, loaf volume and specific volume high in bread developed by 100% wheat flour compared to selected modified rice flour containing composite bread. It has been reported that the reduction of loaf volume and specific volume of composite breads is due to the dilution effects of gluten with the addition of rice flour. Therefore, dough cannot properly stretch by carbon dioxide (CO_2) gas during fermentation and the proofing time (Oladunmoye*et al.*, 2010).

3.6 Proximate composition of bread

Table.3.4: Proximate analysis of selected composite bread sample (60% wheat flour + 40% modified rice flour) against wheat flour bread

Constituent	Composite Bread (60% wheat flour + 40%	100% Wheat flour Bread
Moisture	33.33 ± 0.859[b]	37.33 ± 0.647[a]
Crude Fiber	0.85 ± 0.010[a]	0.75 ± 0.01[b]
Crude Ash	1.75 ± 0.008[a]	1.55± 0.02[b]
Crude Protein	7.47± 0.100[a]	7.55± 0.105[a]
Crude Fat	1.1± 0.01[b]	1.45± 0.02[a]
Carbohydrates	55.47± 0.832[a]	51.35± 0.520[b]

% db - % dry basis, All values are means of triplicate determination ± SD

Moisture content of the composite bread was lower than that of the bread developed using 100% wheat flour (Table 3.4). Low moisture content observed in the composite bread is considered as a good indicator since it enhance the shelf life of the bread (Madukwe et al., 2013). Crude fiber and crude ash content were higher in composite bread than that of the bread developed using 100% wheat flour. However, crude fat and crude protein content of the composite bread were lower than that of the bread developed using 100% wheat flour.

3.7 Microbial Analysis of bread

Bacterial and yeast mold colonies were not observed in both 100% wheat flour bread and composite bread samples (60% wheat flour + 40% modified rice flour) within the first three days of storage (Fig. 3.3 and Fig. 3.4). Bacterial colonies were observed on the culture plates which were prepared using four days old 100% wheat flour bread sample. However, bacterial colonies were not observed from four days old composite bread samples. The number of bacterial colonies were high in bread samples prepared using 100% wheat flour compared to the composite bread samples. Further, yeast and mold colonies were observed in both bread samples after third storage day. Yeast and mold count was high in bread samples prepared using 100% wheat flour compared to composite bread samples. According to the proximate analysis of two bread samples, moisture content was lower in composite bread than that of the wheat flour bread. This might be the reason for reduction of growth and proliferation of bacteria, yeast and mold in composite bread sample compared to wheat flour bread sample.

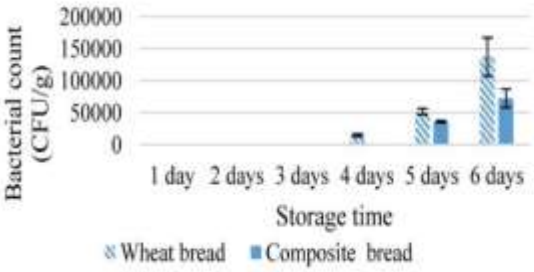

Fig. 3.3: Bacterial count of composite bread and wheat bread with the storage time. Vertical bars show standard deviations

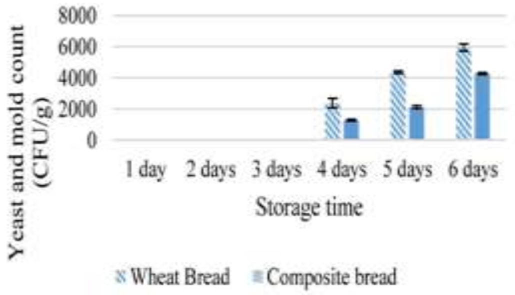

Fig.3.4: Yeast and mold count of the composite bread and wheat bread with the storage time. Vertical bars show standard deviations.

The results showed that the bacterial count was increased after 4th day and yeast and mold count was increased after the 3rd day in composite bread. Therefore, developed composite bread can be stored three days within the original package at room temperature without any microbial growth.

3.8 Stalling effect of bread

A significant difference was not observed between the bread developed using 100% wheat flour and the composite bread sample in terms of elongation length pattern with storage time (Fig. 3.5). Both composite bread and 100% wheat flour bread caused noticeable decrement in elongation length values from 24 to 72 hour storage. Elongation length of composite bread was lesser than that of the bread developed with 100% wheat flour. This could

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be associated with the difference in quantitative distribution of protein fractions and physicochemical properties of wheat and rice starch (Navarathne, 2007).

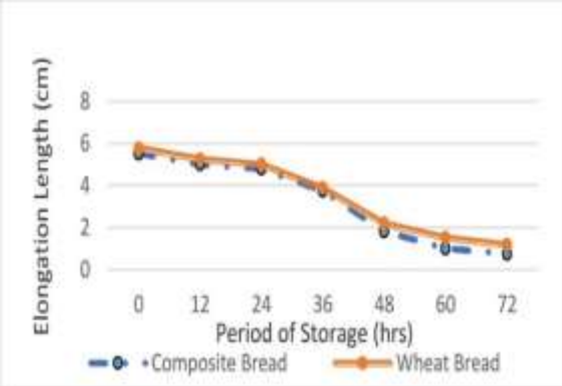

Fig.3.5: Elongation length of composite bread and wheat bread with the storage time

3.9 Cost Analysis of bread

Table.3.5: Cost analysis of selected composite bread and wheat flour bread

Composite bread (60% wheat flour + 40% modified flour) (450 g)			**100% Wheat flour bread (450 g)**		
Ingredient	**Amount**	**Cost Rs.**	**Ingredient**	**Amount**	**Cost Rs.**
Wheat flour	270 g	10.00	Wheat flour	450 g	20.00
Modified rice flour (Processing cost included)	180 g	15.00	-	-	
Yeast	9 g	10.00	Yeast	9 g	10.00
Salt	9 g	5.00	Salt	9 g	5.00
Sugar	27 g	2.50	Sugar	27 g	2.50
Margarine	9 g	5.00	Margarine	9 g	5.00
Other cost (baking and packaging)		5.00	Other cost (baking and packaging)		5.00
Total		**52.50**	**Total**		**47.50**

Table 3.5 shows that the total costs for the production of composite bread (60% wheat flour + 40% modified rice flour) was marginally higher than that of the wheat flour bread. The reason was due to the high cost of raw materials for the preparation of composite bread compared to wheat flour bread. Further, extra processing cost is required to make the rice flour suitable for the fortification of bread. However, having concern the overall benefits of promoting rice based bread in Sri Lanka, the higher price margin can be neglected.

IV. CONCLUSIONS

This study investigated the potential of developing rice bread using modified rice flour according to chemical and physical dual modification method (Dipping $NaHCO_3$ solution and dehydration). Incorporation of modified rice flour to commercial wheat flour caused significant changes to bread volume and textural attributes. The composite bread developed using 40 % modified rice flour and 60% wheat flour was considered as the best composite flour for bread. Composite bread developed with 40% modified rice flour and 60% commercial wheat flour resulted in similar sensory attributes to the bread developed with 100% wheat flour. This finding opens a new avenue for bakery industry in Sri Lanka which could eventually leads to reduce the total dependency on wheat flour.

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