NUTRITIONAL AND RHEOLOGICAL PROPERTIES OF COMPOSITE FLOURS OF WHEAT AND TWO YAMS *Colocasia esculenta* AND *Plectranthus rotundifolius* AND EVALUATION AS SUBSTITUTES TO WHEAT BREAD

Attanayake Mudiyanselage Vindana Chathuranga Attanayake, Katugampalage Don Prasanna Priyantha Gunathilake*, Nirmala Prasadi Vithana Pathirannehelage, Adikari Mudiyanselage Muthumali Uthpala Adikari
Department of Food Science & Technology, Faculty of Livestock, Fisheries, & Nutrition, Wayamba University of Sri Lanka, Makandura, Gonawila, Sri Lanka
*E-mail: kdppgunathilake@yahoo.com

Abstract
Colocasia esculenta (CE) and Plectranthus rotundifolius (PR) are two of the underutilized yams growing in Sri Lanka. The present study was to evaluate the potential of the flours obtained from these yams as wheat substituteS for bread making. The study consisted of flour preparation, proximate analysis, and evaluation of rheological properties, preparation of bread, &sensory evaluation at different substitution levels (10-30%). Flour preparation was done by drying and grinding of yamsusing published methods. A.O.A.C. approved methods were used for determining the proximate composition. Rheological properties were evaluated by Farinograph. Loaves of bread were prepared and were evaluated for sensory properties. According to proximate composition, the carbohydrate content of the flours of CE and PRwas 82.36±2.82% and 81.94±2.59%, .respectively. Protein, fat, moisture, ash and fibre of the flours werein the range of 1.27-1.80%, 1.92-2.32%, 10.42-11.43%, 1.75-2.03%, 1.56-1.79% respectively. Farinograms evaluation revealed that 10% incorporation of CE flour results in 67% of water absorption, 6 minutes of dough development time, 2 minutes of arrival time and 23.5 minutes of stability. As for PR, the respected values were 60%, 7.5 minutes, 1 minute, and 20 minutes respectively. It was found that, with the substitution levels of yams flour into wheat flour increases, declining in bread rise during the baking process. The results were agreed with the results of the rheological study. The sensory study revealed that both yams' flourup to 10% substitution level can formulate bread which is insignificant in overall acceptability with normal wheat bread. Thus, it was concluded that 10% was the most suitable level of substitution among selected when considering the rheological and sensory properties.

Keywords: *Colocasia esculenta, Plectranthus rotundifolius*, composite flour, bread, rheological properties

Received: 05.05.2020 Received in revised form: 03.09.2020 Accepted: 17.09.2020

1. INTRODUCTION

Due to the expensiveness, high demand, and geographical scarcity of wheat flour, there have been attempts on a suitable replacement. Especially regarding bread making numerous efforts have been made notably in tropical areas. Wheat favours the temperate zone; hence the tropical countries have to import wheat. The majority of the tropical countries are developing countries including Sri Lanka. However, the sole replacement has not shown positive results throughout the years. The concept of composite flour bread has given more remunerative results comparable. Substitute flours have been prepared mostly out of cereals, yams, and roots. Abundant crops in countries have been used regarding flour preparation. By adopting underutilized potential sources it is possible to cut off the high cost for wheat importation as well as fulfilling the demand for bread. Sri Lanka provides favour able growing conditions for CE, PR and *Xanthosoma sagittifolium* (Arrowleaf elephant ear) which have been identified as potential flour and bread-making sources.

Various studies have shown that the incorporation of non-wheat flour such as yam and other cereal flours in bread production. According to Cardenas et al. (1993), 30% of wheat flour can be replaced with sweet potato flour in bread and they found that there was no difference in sensory characteristics or protein quality of the sweet potato-wheat composite bread. Similarly, Ukpabia and Uchechukwu (2001) also have been investigated the potential use of Chinese yam (*Dioscorea esculenta*)flour in loaf bread making process and they have reported that at 30% level of substitution, the yam and wheat composite bread showed no any significant difference when compared with 100% wheat bread. Furthermore, Amandikwa et al. (2015) suggested that various underutilized yam varieties may be useful in food formulations because of their nutritional and physic-chemical characteristics and acceptable loaves of bread comparable to wheat bread can be made at 25% level of yam flour substitution. This kind of studies including adding values to these underutilized yams, therefore, recommends extensive cultivation and utilization of these yam varieties since they could serve as useful supplements for composite bread production and future food security. In some other studies, other crops such as sour maize and soy flour blends (Edema et al., 2005), coconut flour (Gunathilake et al., 2009) evaluated the production of bread with the substantial substitution to wheat flour. Product diversification with these yam crops currently has been minimal and also some of these yam varieties are not widely cultivated due toinadequate utilization. In terms of food security and saving foreign currency, there is,therefore, the need to investigatethe bread-making potentials of some of these yam varieties.Thus, the focus of this study is to check out the suitability of theses yam flours incorporation with wheat flour, in terms of bread making.

2. MATERIALS AND METHODS

Materials

CE and PR yamswere collected from the Makandura area in Sri Lanka. All the chemicals used for the experiments were of analytical grade. All-purpose Wheat flour was (Prima brand)and otheringredients for bread were purchased from Keels Super Market, Dankotuwa, Sri Lanka.

Flour preparation

Five kilograms of each of the yams, CE and PR,were washed, hand peeled. The yams were dipped in 5% citric acid and then grated into thin slices(the thickness was around 5 mm). Thenthe yams slices were dried in a dehydrator at 70°C for 18 hrs. The dried yams were ground into powder using a laboratory-scale grinder and sieved through a 250 µm sieve. The sieved flour was packed separately in airtight containers to prevent moisture re-absorption. Three blends were made with eachyam. Wheat flour, used as control (100% white wheat flour) was progressively substituted with yams flour. Thus, CE flour/wheat flour blends and PR flour/wheat flour blends were prepared with, respectively, 10%, 20% and 30% of white wheat flour substitutions.

Proximate analysis

The moisture, crude protein, crude fat, crude fiber and ash contents of the flour blends were determined following the procedure outlined by AOAC (2000), while carbohydrate was calculated by difference.

Rheological properties

Rheological properties of composite flour blends at different substitution levels were assessed according to the method described by A.A.C.C, (2000). The water absorption, arrival time, dough stability, and dough development time of the dough were measured by the resulted farinograph ((Brabender, Duisburg-Germany). All rheological experiments were conducted in the Industrial Technology Institute in Sri Lanka (ITI).

Bread making

All ingredients, flour, butter, salt and yeast were initially dry mixed in a mixing machine and later water was mixed with the original dry mix to form a soft dough that can easily be handled. The straight dough method described in Giannou et al. (2003) was followed.

Sensory analysis

Sensory analysis was conducted using 30 semi-trained panelists. General appearance, crust colour, crumb grain, taste, and overall acceptability of formulated bread were evaluated based on the method described in Meilgaard et al.(1991).

Statistical Analysis

Data were obtained in triplicate (n=3) and the means and standard deviations (SD) were recorded. Sensoryevaluation data were analyzed using analysis of variance (ANOVA) and the Least Significant Difference (LSD) was used to ascertain differences between samples at $p < 0.05$.

3. RESULTS AND DISCUSSION

As well as in the whole world majority of wheat-based products such as buns, noodles, cakes, flat breads, biscuits, and bread are very popular in Sri Lanka. Among these food items, bread is the most prominent one Asian is consumed as a staple food. Even more than in Sri Lankan lifestyle, European and American regions see, bread is served at almost every meal (Kent, 2000). As mentioned earlier bread is consumed regardless of social status as well as regardless of the age class. According to the Central Bank report in 2014, the acceptance level for bread in the Sri Lankan diet is pretty high.Luxurious regions of European and North American continents may bear the root of wheat, however, that has not restricted developing countries from utilizing wheat. In most developing countries,it is seen that wheat bread playing a vital role in fulfilling the hunger of their nations. As long as they do not provide favourable conditions for wheat growth they have to import wheat especially from European and North American regions.In Sri Lanka, the expenditure on food has been increasing continuously to almost to a level of discomfort. Wheat is the most effective contributor in this regard bearing values that exceed LKR 357.2 USD millions per annum (CBSL, 2015). This is not a strange circumstance when considering parallel developing countries.

The plus point of all these countries is that they have staples other than wheat that have potential in bread making. Yams are one of the categories that have the potential to be used bakery ingredients. CE and PR are some of the underutilized yams available in Sri Lanka and in this present study evaluate the potential of these yams flour for bread making. Proximate composition of flours, rheological properties of the composite blends and acceptability of the breads prepared from these flours evaluated.

Proximate analysis

The proximate composition of the CE and PR flours is shown in Table 1.The moisture content of studied flours was varied among sources and it is ranged from 10.4-11.0%. The protein contents in yams flours were lower(1.44-1.80%). Similar levels of proteins were also mentioned in flours of *Dioscorea rotundata* and *Dioscorea alata* in Obadina et al (2014).However, CE flour contains significantly higher protein content than PR flour. The protein content of these flours was lower when compared with all-purpose wheat flour. Normally wheat flour contains nearly about 10% protein.Comparatively higher fiber content was observed in CE flour than PR flour. Mineral and fat content were higher in PR flour than CE flour.

Rheological properties

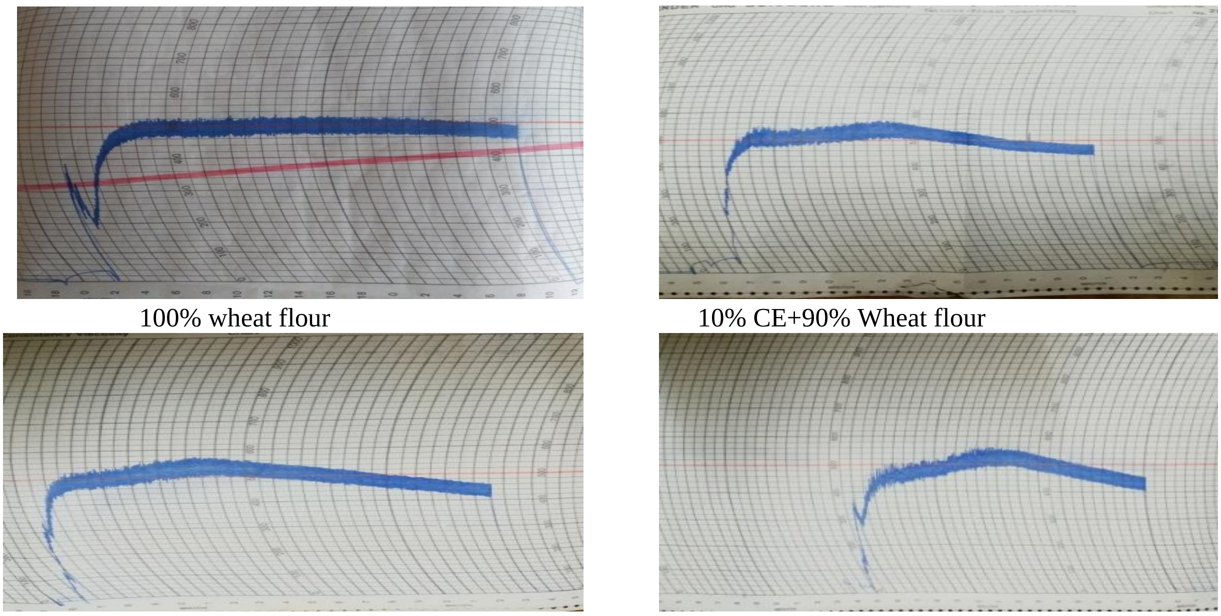
Generally, mixing, fermentation and baking are the three basic operations involve in the bread-making process.

Table 1. Amounts of nutritional compounds about CE and PRflour

Constituents	CE flour	PR flour
Carbohydrate	82.36±0.7	81.93±3.7
Moisture	10.41±0.4	11.01±0.6
Ash	1.74±0.1	2.00±0.1
Fat	1.91±0.1	2.04±0.2
Protein	1.80±0.2	1.44±0.2
Fiber	1.75±0.3	1.56±0.1

During the mixing process, the flour and water mixture transforms into the cohesive viscoelastic dough. In the mixing process, atmospheric air incorporates into the dough and this incorporated air provided the gas cells into which the carbon dioxide produced by the yeast cells diffuses during the fermentation process (Bakare et al., 2015). The development of dough occurs due to interactions among flour constituents and the ingredients used during the mixing operation. According to Bakare et al. (2015), these interactions in the dough are more complex than what was observed during the farinograph test which is mostly used in measuring the dough rheological tests. However, with the use of a farinograph can derive an empirically verifiable insight into what may be at play during the actual process of dough development (Bakare et al., 2015). Furthermore, the main objective of the mixing of dough is to bring about changes in the physical properties of the dough that would improve the ability of the dough to retain the carbon dioxide gas producing from yeast during the fermentation process and some of the physical properties of the dough which are critical for control in bread making processare resistance to deformation, extensibility, elasticity, and stickiness (Bakare et al., 2015).

Measurements of water absorption, dough development time, arrival time, dough stability, and degree of softening were made by using a farinograph. Water absorption is the amount of water that the flour can absorb until the dough consistency reaches 500 BU and the dough development time is the time required for the curve to reach its maximum height (i.e. 500 BU). Dough stability is the time needed before the dough consistency starts to decline from 500 BU line. Dough weakening is the reduction in the dough consistency from 500 BU line after 5 min. Departure time (DT) was the time required for the curve to drop below the 500 BU consistency line. Dough Stability Time describes how much tolerance the flour has to over or under mixing and all the composite flours blends showed significantly lower dough stability vales when compared with only wheat dough (100% wheat). However, 10% yams flour containing dough, both 10% CE and 10% PR showed significant stable dough compared with 20% and 30% yam flours incorporated dough. The farinograph records how far the dough stretches before breaking (Hallén et al, 2004). Figure 1 and 2 shows the Farinograms for different blend levels of CE and PR flour with wheat flour. Table 2 shows the mixing behaviour of two flours at different substitution levels.



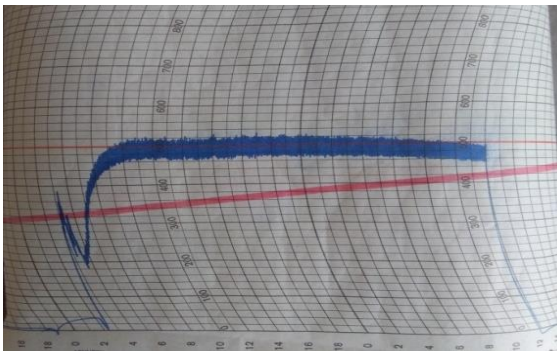
100% wheat flour

10% CE+90% Wheat flour

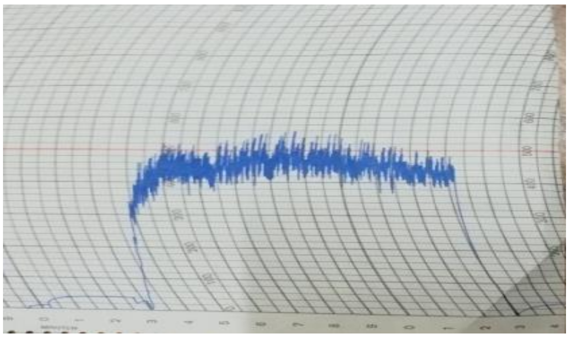
20% CE+ 80% wheat flour

30% CE+ 70% wheat flour

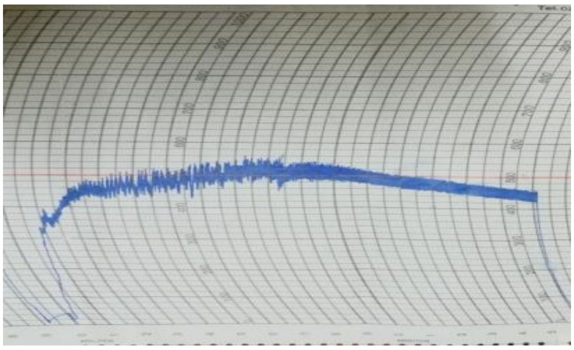
Figure 1: Farinograms of different blend levels of CE flour with wheat flour.



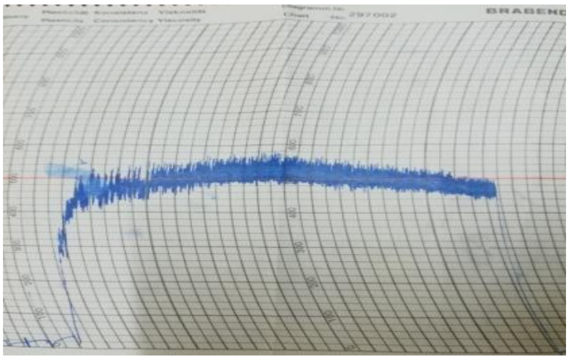
100% Wheat flour



10% PR+90% wheat



20%PR+wheat flour



30% PR+wheat flour

Figure 2: Farinograms of different blend levels of PR flour with wheat flour.

Table 2: Mixing behaviors of flour blends

	Level of yam flour substitution (%)	Water absorption (%)	Dough development time (min)	Arrival time (min)	Stability (min)
CE flour	10	67.0	6	2	11.5
	20	71.0	7.5	3	9
	30	74.5	8.5	3.5	8
PR flour	10	60.0	7.5	1	12
	20	60.5	8.5	2	12.5
	30	59.5	5.5	2	6

Water in the mixture is responsible for hydrating the protein molecules and that will facilitate the interactions between the proteins cross-links with the disulfide bonds during the dough mixing process (Bakare et al., 2015). For the bread making, the optimum amount of water is essential to develop cohesive, viscoelastic dough with optimum gluten strength and however, this differs from flour to flour. The amount of water is depending on the quantity of protein mainly. Therefore, protein content has been known as an important determinant of the extent to which flour blends would absorb water during mixing (Sliwinski et al. 2004). As the protein content is low in both CE and PR flours compared with the wheat flour, when the incorporation level increase, the amount of water which absorbs by the flour blends decreased.

Farinograms evaluation revealed that 10% incorporation of CE flour results in 67% of water absorption, 6 minutes of dough development time, 2 minutes of arrival time and 23.5 minutes of stability. As for PR flour, the respected values were 60%, 7.5 minutes, 1 minute, and 20 minutes. It was found that, with the substitution levels of yams flour into wheat flour increases, declining in bread rise during the baking process. The results were agreed with the results of the rheological study. This could be probably due to variation in dough development characteristics upon addition of more than 10% yam's flour, which may have contributed to over dilution of gluten forming protein resulting in weakening of the dough. Similar studies have been done for the determination of supplementation of wheat flour with cowpea flour by Sharma, et al (1999) and they described that the changes in hydrating properties of two proteins may be another reason for differences in dough characteristics.

Bread development

Figures 3 and 4 show the front and cross-section views of bread prepared from different composite floursofCEand PR.The results showing that the addition of both yams flour decreased the volume of the bread produced. The addition of both yam flours may change the bulk density of the bread produced. The lowest volume was obtained for samples with the highest yam's flour percentage. According to Mamat et al. (20140, two factors are contributing these volume changes with increasing substitution levels: the ability of hydrocolloids to absorb more water, which could suppress the amount of steam generated, resulting in a reduced volume of loaf; and the addition of yam's flour, which could also disrupt the gluten network that contributed to the low expansion of the loaf.

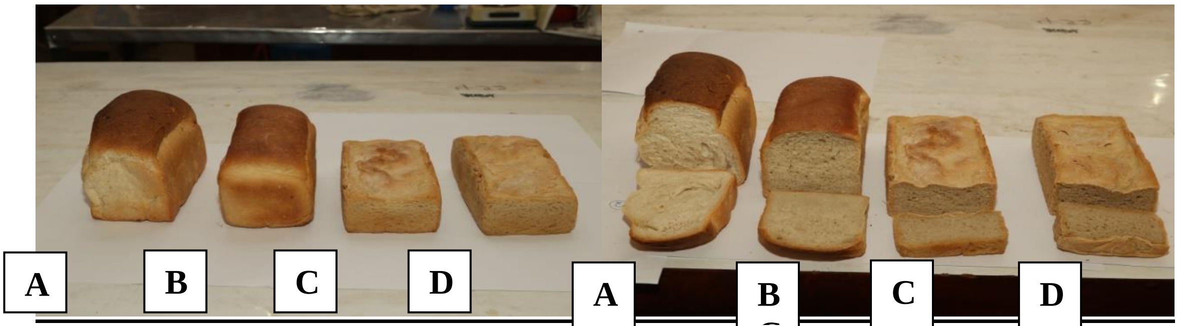


Figure 3: Front views and cross-section views of CE flour incorporated wheat flour bread. *(A: 100% Wheat flour, B: 10% CE flour+ 90% Wheat flour, C: 20% CE flour+ 80% Wheat flour, D: 30% CE flour+ 70% Wheat flour)*

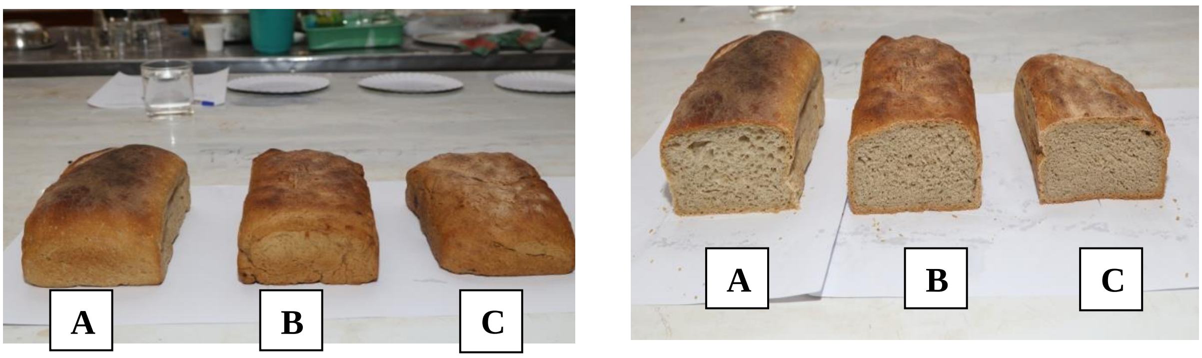


Figure 4: Front views and cross-section views of PR incorporated wheat flour bread. *(A: 10% PR flour+ 90% Wheat flour, B: 20% PR flour+ 80% Wheat flour, C: 30% PR flour+ 70% Wheat flour)*

Furthermore, according to Okaka (2005), the low oven spring in the baking process recorded by the composite bread samples is attributed to low gluten content and this has a direct contribution to the viscoelastic properties of the bread dough. It was observed that the weight of the loaves increased with an increase in yam flour and this may be due to higher water absorption observed in the yam based bread samples during the dough mixing process. Higher water absorption may not related to the protein content of the yams flour, however, due to starches present in these yam's flours.

Sensory evaluation

The sensory study revealed that both yams' flour up to 10% substitution level can develop bread which is insignificant in overall acceptability with normal wheat bread. Tables 3 and 4 show the sensory evaluation scores of bread samples at different levels of CE and PR flours incorporation respectively. It is evident from the results that the scores for each sensory parameter decreased significantly with the increase in yam's flour. Theresultofthis study highlighting that both yam flours, CE and PR, could be used in composite bread production at a 10% level of substitution level and however, beyond more than 10% substitution levels .most of the bread characteristics may be affected. Similarly, the results of this study showed that as the amount of yam flour increased to 30%, bread was less acceptable. Thus, these results show that up to 10% substitution is possible to produce bread with acceptable qualities.

4. CONCLUSIONS

From the overall results of the study, it could be concluded that the additionof flours of *Colocasia esculenta* and *Plectranthus rotundifolius*yams to wheat flour modifies to a lesser or greater extent, rheological properties of the dough, depending on the nature of the source of a wheat substitute and the level of wheat flour substitution. Based on sensory acceptance of resulted bread, the bread of acceptable sensory attributes was produced with up to 10 % incorporation of *Colocasia esculenta* and*Plectranthus rotundifolius* yam flour into wheat flour. This would be of economic importance in many developing countries such as Sri Lanka as a whole in promoting the use, utilization and processing of locally available food crops.

Table 3. Sensory properties of CE flour incorporated bread from different flour blends

Percentage of CE flour incorporation	Sensory attribute					
	General appearance	Crust color	Crumb grain	Texture	Taste	Overall acceptability
0%	21.2±2.9	8.8±1.1	17.1±3.0	16.1±2.4	20.8±3.0	86.0
10%	21.0±2.6	7.2±1.2	15.1±3.0	15.6±1.9	20.8±2.7	80.2
20%	20.6±3.2	7.4±1.3	15.3±2.4	15.2±2.0	20.5±3.2	62.3
30%	13.2±3.9	5.3±1.6	7.9±3.2	9.9±1.9	18.7±3.2	55.9

Table 4. Sensory properties of PR flour incorporated bread from different flour blends

Percentage of PR flour incorporation	Sensory attribute					
	General appearance	Crust color	Crumb grain	Texture	Taste	Overall acceptability
0%	20.2±2.7	8.8±1.1	18.1±3.0	17.1±2.4	20.8±3.0	87.2
10%	14.0±1.9	8.2±1.2	14.1±3.0	16.6±1.9	20.8±2.7	78.2
20%	10.6±3.2	4.4±1.3	10.3±2.4	11.2±2.0	17.0±3.2	47.3
30%	9.2±3.3	3.3±1.6	9.4±3.2	11.6±1.9	18.4±3.2	44.9

5. ACKNOWLEDGEMENTS

We greatly acknowledge the financial support provided by the Wayamba University Research Grant (SRHDC/RP/04/16-12).

6. REFERENCES

[1]. Amandikwa, C., Iwe, M.O., Uzomah, A. and Olawuni, A.I., 2015. Physico-chemical properties of wheat-yam flour composite bread. *Nigerian Food Journal*, *33*(1), pp.12-17.

[2]. Approved methods of the American Association of cereal chemists. (2000). 10th ed., methods 38-10, 54-10, 54-21, 56-81B. USA: AACC.

[3]. AOAC. 2000. Official Methods of Analysis, AOAC Int'l 17th Ed., AOAC INTERNATIONAL, Gaithersburg, MD, USA.

[4]. Giannou .V, Kessoglou .V,andTzia .C.,2003, Quality and safetycharacteristicsofbread made fromfrozen dough", Trends in Food Science & Technology 14 (2003) 99–108

[5]. Cardenas, H., Kalinowski, J., Huaman, Z. and Scott, G., 1993. Nutritional evaluation of sweet potato cultivars Ipomea batata (L.) Lam used bread as a partial substitute of wheat flour. *Archivos latinoamericanos de nutrition*, *43*(4), pp.304-309.

[6]. Edema, M.O., Sanni, L.O. and Sanni, A.I., 2005. Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *African Journal of Biotechnology*, *4*(9).

[7]. Gunathilake, K.D.P.P., Yalegama, C. and Kumara, A.A.N., 2009. Use of coconut flour as a source of protein and dietary fibre in wheat bread. *Asian Journal of Food and Agro-Industry*, *2*(3), pp.382-391.

[8]. Hallén, E., İbanoğlu, Ş. and Ainsworth, P., 2004. Effect of fermented/germinated cowpea flour addition on the rheological and baking properties of wheat flour. *Journal of food engineering*, *63*(2), pp.177-184.

[9]. Mamat, H., Matanjun, P., Ibrahim, S., Amin, S.F.M., Hamid, M.A. and Rameli, A.S., 2014. The effect of seaweed composite flour on the textural properties of dough and bread. *Journal of applied phycology*, *26*(2), pp.1057-1062.

[10]. Meilgaard, M., Civille, G. V., & Carr, B. (1991). Sensory evaluation techniques (2nd ed.).Boca Raton, Florida, USA: CRC Press LLC.

[11]. Obadina, A.O., Babatunde, B.O. and Olotu, I., 2014. Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. *Food science & nutrition*, *2*(6), pp.676-681.

[12]. Sharma, S., Bajwa, U. and Nagi, H.P.S. (1999). Rheological and baking properties of cowpea and wheat flour blends. Journal of the Science of Food and Agriculture, 79:657- 662.

[13]. Sliwinski, E. L., P. Kolster, and T. Van Vliet. 2004. On the relationship between large-deformation properties of wheat flour dough and baking quality. J. Cereal Sci. 39:231–245

[14]. Ukpabia, U.J., Uchechukwu, N., 2001. Potentials of Chinese yam (*Dioscorea esculenta*) flour in bread. In: Proceedings of the Eighth Triennial Symposium of the International Society for Tropical Root Crops, African Branch(ISTRC-AB)12–16th Nov. Ibadan Nigeria. pp. 219–221.