Chemical composition, functional and sensory characteristics of wheat-taro composite flours and biscuits

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Abstract The physicochemical, alveographic and sensory characteristics of precooked taro-wheat composite flours and their biscuits were investigated. A 2x7 factorial design consisting of two varieties of taro flour (*Red Ibo Ngaoundere*, *RIN*, and *egg-like varieties*) and 7 levels of wheat substitutions (0, 5, 10, 15, 20, 25 and 30 %) was used for this purpose. It was observed that water absorption capacity (range 95–152 g/100 g), water solubility index (range 18.8–29.5 g/100 g) and swelling capacity (range 125.4–204.6 mL/100 g) of composite flours significantly ($p<0.05$) increased with increase in taro level. Conversely the dough elasticity index (range 59.8–0 %), extensibility (78–22 mm) and

strength (range 281–139×10⁻⁴ joules) significantly ($p<0.05$) diminished with increase in wheat substitution. Up to 10 % substitution with *RIN* taro flour and 15 % with egg-like taro flour, the composite taro-wheat dough exhibited elasticity indices acceptable for the production of baking products, whereas at all levels of taro substitution, the composite biscuits samples were either acceptable as or better (5–10 % substitution with *RIN* flour) than 100 % wheat biscuit.

Keywords Taro · Wheat · Composite biscuits · Sensory · Functional properties

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Introduction

Taro is a tropical root crop belonging to the monocotyledonous family Araceae. Taro (*Colocasia* spp) is widely cultivated in tropical areas of the world such as South East Asia, the Pacific Islands, the Mediterranean, Africa and the United States of America (Nip 1997). The world production of taro is about 10.3 million tons with Africa producing 9.5 million tons representing 92.2 % (FAO 2008). The most important producers are Nigeria (58 %), Ghana (17 %) and Cameroon (11 %). The corms are low in fat (0.5–1.2 %), proteins (2.9–4.6 %) and vitamins, but are a good source of carbohydrates (90.8–95.5 %) and minerals (1.6–5.5 %) especially magnesium (32.9–382 mg/100 g), calcium (25.4–192 mg/100 g) and potassium (3.5–59.7 mg/100 g) (Aboubakar et al. 2008; Kaur et al. 2011; Njintang et al. 2011). In some areas of the world taro constitutes the main food source; for instance in Palao, Micronesia, taro contributes to about 16 % of the caloric intake (Nip 1997). Taro starch is highly digestible and has been shown to be useful in the

formulation of infant foods (Nip 1997). Besides its importance as a food source, taro contains high levels of gum, which has also been shown to play a role in the reduction of high blood pressure, in hypercholesterolemia and in the management of diabetes (Njintang et al. 2011).

Recently studies have been conducted in our laboratory to promote the production and use of taro flour as ingredients for foods formulations (Njintang et al. 2006; Njintang et al. 2007; Njintang et al. 2008). Among these studies, we tested the potential of raw taro flour for the partial substitution of wheat flour for bread or biscuit manufacture (Njintang et al. 2008). Indeed the partial or total substitution of wheat has a lot of potential and offers diversification, and up-grading the use of other food materials in non-wheat producing countries (Yadav et al. 2011). The results so far obtained have shown that an increase in the level of raw taro, characterized by a high ability to absorb water compared to wheat, in the composite flour generally tended to increase the water absorption capacity and to decrease the retrogradation index. In addition an increase in the level of taro flour resulted in a significant decrease in the dough rupture pressure, extensibility, strength and elasticity index. Finally it was shown that a 10 % incorporation of taro had no significant effect on wheat dough alveography (Njintang et al. 2008).

In order to ascertain the effectiveness of taro flour incorporation on biscuit quality, the preparation and sensory characteristics from the 10 % composite was imperative. An attempt to this revealed that irritation induced by raw taro when it comes in contact with the body remained unchanged in the biscuits when tested organoleptically, suggesting that baking had no significant effect on taro acidity (unpublished data). These finding were reinforced by a recent study on Japanese taro which reported that baking significantly increased the concentration of total oxalate (Catherwooda et al. 2007). On the contrary boiling has been shown to significantly reduce the oxalate content and rapidly annihilate irritation (Catherwooda et al. 2007; Nip 1997; Aboubakar et al. 2009). The high content of calcium oxalate crystals in some varieties of *Colocasia* spp. has long been used to partly explain the acidity or irritation of this plant. From these observations the use of pre-boiled taro flour as starting material for food formulations seems a better alternative. Unfortunately the functionalities of the raw and the pre-boiled flours may be different and the use of pre-boiled taro flour demands attention. In fact the ability of flour to absorb water, which is known to play a major role in the functionality of dough by its relation to dough consistency, has been shown to increase with boiling (Tagodoe and Nip 1994; Fagbemi 1999).

The aim of this study was then to evaluate the physico-chemical, alveographic and sensory characteristics of wheat/pre-boiled taro composite flour, dough and biscuits from two varieties of taro corms.

Material and methods

Materials

Corms of two varieties of taro Red Ibo Ngaoundere (RIN) and *egg-like* giant taro were used in the study. The corms were freshly harvested from an experimental farm near the University of Ngaoundere (Adamaoua province) and taken to the laboratory, where they were washed, peeled and rinsed with copious amounts of tap water before being used for the study.

Production of raw and pre-boiled taro flour

Clean taro corms of each variety were divided into 2 batches; one was used for the production of precooked flour and the other for the production of uncooked taro flour. For the production of pre-boiled taro flour, the corms (variety RIN) or slices (variety *egg-like* taro, 2 cm thick) were boiled for 30 min in a boiling water bath. The precooked corms or slices were then cut into slices 0.5 cm thick and dried to a brittle texture in a convection oven set at 45 ± 3 °C for 24 h. The dried slices were fine-milled (500 µm) into flour using an electric grinder (Cullati, Polymix, France, Kinematica, Luzernerstrasse, Germany), packaged in polyethylene bags and stored at 4 °C until required for further analysis. For the production of uncooked taro flour, the raw corms were hand-peeled 0.5 cm thick and dried and processed into flour as described above.

Preparation of dough and biscuit formulation

Wheat/pre-boiled taro composite flour was used for the processing of dough and biscuits. The composite flours were produced by mixing in a blender (Moulinex brand, Paris, France) precooked taro flour and wheat flour using a 2×7 factorial design consisting of two varieties of precooked taro flour (variety RIN and variety *egg-like*) and 7 levels of taro substitution (0 %, 5 %, 10 %, 15 %, 20 %, 25 % and 30 %). The baking formula employed in producing the experimental biscuits was based on the procedure described for soft dough biscuit (Mbofung et al. 2002). The fat (margarine, 150 g) and sugar (commercial sugarcane 250 g) were first poured in the mixer (a Z-blade type, Moulinex, France) and blended for 2 min. The sodium bicarbonate (7 g) and salt (3.5 g) dissolved in some volume of eggs (2 eggs) were added followed by the vanilla flavoured sugar (10 g). The flour was then introduced into the mixer, and as it started to blend with the other ingredients, the remaining eggs was added. Mixing time was between 7 and 10 min. The dough was rolled into a continuous sheet of approximately 0.5 cm thickness and cut into circular shapes with a moulding shell. Baking was at 190 °C for 8–10 min in a Michael Wenzel Ideal oven (Michael Wenzel, Arnstein, Netherlands).

Proximate analysis

Analysis of raw taro, pre-boiled and wheat flours for crude lipid, ash and moisture contents was carried out using AOAC (1990) methods, while proteins and available carbohydrates contents were evaluated as previously described (Njintang et al. 2001). Energy content (E) was calculated using the Atwater factor (Omobuwajo 2003) as:

$$\text{Energy} = (\text{Protein} \times 9) + (\text{Lipids} \times 4) + (\text{sugars} \times 4).$$

Physicochemical properties

Water absorption capacity (WAC) was determined essentially as previously described (Njintang et al. 2001), Water solubility index (WSI) was measured according to the method of Anderson et al. (1969), Oil absorption capacity (OAC) was estimated by centrifuging a known quantity of flour saturated with cottonseed oil (Sodecotton, Garoua, Cameroon) following the procedure of Beuchat (1977), Foaming capacity (FC) was determined according to the method of Coffman and Garcia (1977), Emulsifying capacity (EC) was evaluated essentially according to the method of Yatsumatsu et al. (1972), Bulk density was evaluated according to Okezie and Bello (1988). In the determination of the swelling power (expressed in mL/100 g), 10 g flour was poured in a 100 mL graduated cylinder containing 75 mL water and the increase in volume of the flour in the liquid after 1 h was reported and expressed as mL for 100 g flour.

Alveographic measurements

Dough was made from 150 g of each composite or wheat flour by first mixing it with NaCl (2.5 % w/w) while adding water to obtain a 50 % moisture level. The alveographic parameters: rupture pressure (*P*), extensibility (*L*), strength (*W*), elasticity index (*Ie*) and the configuration ratio were evaluated as described earlier (Njintang et al. 2008). For each dough, these parameters were measured five times and the mean readings taken.

Sensory evaluations of biscuits

Biscuits were subjected to sensory evaluation at different sessions by panels of 50 untrained students drawn among the student population of the University of Ngaoundere, Cameroon. During one day of assessment, 14 samples were analyzed in one session. Evaluations were made in a sensory room consisting of 14 individual separated booths under ambient temperature (28–30 °C) and white light. Polystyrene-

sealed samples coded with three digit numbers were served randomly in two batches of 7 samples each at interval of 30 min. Panelists were instructed to rinse their mouth with water between samples. The assessors were asked to appreciate how much they liked the taste, the flavour, the texture and the overall acceptability of the biscuits on a hedonic scale varying from 1 (dislike extremely) to 9 (like extremely).

Statistical analysis

The data reported for chemical analysis, functional properties, alveographic properties and sensory analysis are average values of 4, 4, 6 and 50 determinations respectively. The physicochemical characteristics of composite flour and sensory scores for the biscuit samples were each subjected to analysis of variance (ANOVA) to determine if there were statistically significant ($P \leq 0.05$) differences. Duncan multiple range test was used to determine which of the samples were significantly different. The Statgraphics 5.0 (Manugistics, Rockville, Maryland, USA) statistical Software was used for this purpose.

Results and discussion

Proximate Composition

The chemical composition of taro and wheat flours is presented in Table 1. Significant ($p < 0.05$) differences can be observed between the taro and wheat flours in concordance with our earlier report (Njintang et al. 2008). In fact compared to wheat flour, it was found that taro flours contained appreciable amounts of minerals, and were generally lower in fat. In addition it was equally observed that levels of crude proteins in taro flours (range 2.40–5.69 g/100 g) were significantly ($p < 0.05$) lower than that of wheat flour (11.0 %). It can equally been seen from Table 1 that some marginal differences existed between precooked and uncooked taro flour. In this respect the ash and fat contents of taro flour were significantly ($p < 0.05$) lower in precooked samples while no significant differences were observed on the proteins and sugars levels. The reduction in nutrients after cooking is probably due to leaching in boiling water as recently reported (Aboubakar et al. 2009). Because of the low protein and high ash content in taro flours, the substitution of wheat by taro flour will result in reduction of protein and increase in ash content of composite flours or biscuits, and also the consistency of dough made from such composites as shown earlier (Njintang et al. 2008). The data presented in Table 2 in respect of the proteins and ash levels in

Table 1 Proximate composition and functional properties of wheat, raw and boiled taro flours

Mean $\pm$ SD with different superscripts in a row differ significantly ($p < 0.05$) ($n = 4$), *RIN* taro variety *Red Ibo Ngaoundere*, *N* nitrogen, *WAC* Water absorption capacity, *WSI* Water solubility index, *SI* swelling index, *OAC* Oil absorption capacity, *BD* Bulk density, *FC* Foam capacity, *EC* Emulsion capacity

Parameters	Wheat	Egg-like variety		RIN variety	
		Raw	Boiled	Raw	Boiled
Moisture (%)	13.8 $\pm$ 0.11 ^a	8.6 $\pm$ 0.24 ^b	7.7 $\pm$ 0.32 ^c	8.7 $\pm$ 0.03 ^b	6.7 $\pm$ 0.21 ^d
Ash (%)	0.6 $\pm$ 0.08 ^d	3.7 $\pm$ 0.09 ^a	3.5 $\pm$ 0.16 ^b	3.3 $\pm$ 0.11 ^c	3.1 $\pm$ 0.06 ^c
Nx6.25 (%)	11.3 $\pm$ 0.71 ^a	2.7 $\pm$ 0.12 ^c	2.4 $\pm$ 0.08 ^c	5.7 $\pm$ 0.06 ^b	5.4 $\pm$ 0.36 ^b
Available sugars (%)	44.3 $\pm$ 0.99 ^a	44.7 $\pm$ 0.82 ^a	44.5 $\pm$ 0.13 ^a	42.7 $\pm$ 0.99 ^b	42.5 $\pm$ 0.13 ^b
Fat (%)	1.3 $\pm$ 0.01 ^a	0.6 $\pm$ 0.04 ^b	0.5 $\pm$ 0.01 ^c	0.6 $\pm$ 0.02 ^b	0.3 $\pm$ 0.04 ^c
WAC (g/100 g)	95.0 $\pm$ 1.45 ^b		520.8 $\pm$ 14.50 ^a		510.2 $\pm$ 9.41 ^a
WSI (g/100 g)	18.8 $\pm$ 0.84 ^b		20.3 $\pm$ 1.21 ^b		27.9 $\pm$ 1.42 ^a
SI (mL/100 mL)	126.1 $\pm$ 1.32 ^c		423.3 $\pm$ 1.18 ^a		391.8 $\pm$ 2.89 ^b
OAC (g/100 g)	142.4 $\pm$ 2.42 ^a		126.8 $\pm$ 7.82 ^b		121.2 $\pm$ 10.91 ^b
BD (g/100 g)	0.55 $\pm$ 0.01 ^c		0.85 $\pm$ 0.14 ^a		0.80 $\pm$ 0.14 ^b
FC (mL/100 g)	78.1 $\pm$ 3.73 ^a		0.00 ^b		0.00 ^b
EC (mL/100 g)	13.0 $\pm$ 0.65 ^a		3.7 $\pm$ 0.61 ^b		4.4 $\pm$ 0.11 ^b

biscuits did not deviate from the expected trend. Compared to data in literature, our composition of raw taro flour corroborated with those reported for Indian taro flour which were 1.2 %, 1.0 %, 2.0 % for ash, crude fat and protein respectively (Kaur et al. 2011).

Functional properties of precooked taro flour

Although boiling induced little changes on the composition of the flours, it did induce important changes in the structure of molecules. The most important molecular modification that has been shown to arise during boiling of taro is starch gelatinization (Aboubakar et al. 2009). Basically, structural changes generally have

marginal effect on the composition, while they result in significant ($p < 0.05$) modifications in functional properties. The functional properties of wheat and precooked taro flours are given in Table 1. Compared to data reported earlier on functional properties (WAC = 2.2–3.75 %; OAC = 1.07–186 %) of raw taro (Njintang et al. 2008; Kaur et al. 2011), the water and oil absorption capacities of the precooked flours are systematically higher compared to uncooked flour, while the foaming capacity is lost. Compared to wheat flour, the precooked taro flours exhibited higher water absorption capacity (WAC) as well as higher water solubility index (WSI), swelling capacity (SC) and bulk density (BD). In addition the foam and emulsion capacities (FC and EC) and

Table 2 Composition and energy of wheat taro composite biscuits

Taro level (%)	Moisture (%)	Ash (%)	Crude protein (%)	Crude lipids (%)	Available sugars (%)	Energy (Kcal/100 g)
<i>RIN</i> Variety						
0	2.2 $\pm$ 0.05 ^c	0.85 $\pm$ 0.022 ^g	10.6 $\pm$ 0.09 ^a	25.4 $\pm$ 0.29 ^a	52.8 $\pm$ 0.67 ^{abc}	481 $\pm$ 3 ^a
5	2.9 $\pm$ 0.05 ^a	0.95 $\pm$ 0.008 ^f	10.2 $\pm$ 0.18 ^b	25.1 $\pm$ 0.21 ^a	52.9 $\pm$ 0.67 ^{ab}	478 $\pm$ 4 ^{ab}
10	2.5 $\pm$ 0.27 ^{abc}	1.02 $\pm$ 0.028 ^e	10.0 $\pm$ 0.09 ^c	24.9 $\pm$ 0.39 ^a	53.1 $\pm$ 0.15 ^a	478 $\pm$ 4 ^{ab}
15	2.6 $\pm$ 0.29 ^{abc}	1.08 $\pm$ 0.017 ^d	9.8 $\pm$ 0.09 ^{bc}	24.8 $\pm$ 0.53 ^a	52.5 $\pm$ 0.32 ^{abc}	474 $\pm$ 3 ^{ab}
20	2.5 $\pm$ 0.21 ^{bc}	1.13 $\pm$ 0.015 ^c	9.6 $\pm$ 0.13 ^c	24.8 $\pm$ 0.39 ^a	52.1 $\pm$ 0.12 ^c	471 $\pm$ 3 ^b
25	2.8 $\pm$ 0.35 ^{ab}	1.23 $\pm$ 0.027 ^b	9.3 $\pm$ 0.09 ^d	24.8 $\pm$ 0.25 ^a	52.2 $\pm$ 0.14 ^{bc}	471 $\pm$ 3 ^b
30	2.5 $\pm$ 0.04 ^{abc}	1.27 $\pm$ 0.029 ^a	9.2 $\pm$ 0.02 ^d	25.4 $\pm$ 0.29 ^a	52.0 $\pm$ 0.22 ^c	469 $\pm$ 4 ^b
<i>Egg-like</i> variety						
0	2.2 $\pm$ 0.05 ^a	0.85 $\pm$ 0.022 ^f	10.6 $\pm$ 0.09 ^a	25.4 $\pm$ 0.29 ^a	52.8 $\pm$ 0.67 ^c	481 $\pm$ 3 ^a
5	2.7 $\pm$ 0.19 ^a	0.92 $\pm$ 0.014 ^e	10.0 $\pm$ 0.09 ^b	25.0 $\pm$ 0.59 ^a	53.4 $\pm$ 0.08 ^d	480 $\pm$ 3 ^a
10	2.7 $\pm$ 0.87 ^a	1.01 $\pm$ 0.017 ^d	9.9 $\pm$ 0.15 ^b	25.0 $\pm$ 0.39 ^a	54.1 $\pm$ 0.09 ^c	482 $\pm$ 3 ^a
15	2.8 $\pm$ 0.19 ^a	1.07 $\pm$ 0.028 ^c	9.7 $\pm$ 0.10 ^c	25.0 $\pm$ 0.29 ^a	54.3 $\pm$ 0.18 ^c	482 $\pm$ 3 ^a
20	2.8 $\pm$ 0.42 ^a	1.19 $\pm$ 0.064 ^b	9.5 $\pm$ 0.18 ^d	25.0 $\pm$ 0.21 ^a	54.5 $\pm$ 0.04 ^c	482 $\pm$ 4 ^a
25	2.8 $\pm$ 0.15 ^a	1.28 $\pm$ 0.024 ^a	9.2 $\pm$ 0.09 ^e	24.8 $\pm$ 0.39 ^a	55.7 $\pm$ 0.11 ^b	484 $\pm$ 4 ^a
30	2.6 $\pm$ 0.09 ^a	1.32 $\pm$ 0.021 ^a	9.0 $\pm$ 0.09 ^e	24.7 $\pm$ 0.53 ^a	56.4 $\pm$ 0.26 ^a	485 $\pm$ 3 ^a

$n = 4$; means $\pm$ standard deviation followed by different letters in the same line within each variety are different at $p < 0.05$; *RIN* taro variety *Red Ibo Ngaoundere*

the oil absorption capacity (OAC) of the wheat flour were systematically significantly ($p<0.01$) higher than those of taro flours. Similar differences, but more acute in the present case, were observed earlier between wheat and raw taro flours (Njintang et al. 2008). As a consequence the functional properties of the composite wheat/pre-cooked taro flour will vary much with the level of taro flour in the blend. The changes on some functional properties of composite flour as a function of level of substitution are shown in Fig. 1a, b, c. It can be seen that irrespective of the variety, increase in the level of taro in the composite led to a significant ($p<0.05$) increase in WAC, SC, WSI, bulk density and a significant decrease in OAC and EC. Generally significant ($p<0.02$) linear correlations were observed between the level of taro in the composite and WAC ($r=0.97$), WSI ($r=0.89$), OAC ($r=-0.89$), EC ($r=-0.80$), SC ($r=0.97$) and BD ($r=0.77$). These trends were expected based on the properties of individual flour as shown above. Compared to our previous study with raw taro flour, similar effects of flour incorporation were observed on the WAC, WSI and OAC of the composite.

However different trends were observed for EC which, in the present study, significantly ($p<0.05$) decreased with taro level in the composite. This suggested a positive interaction between the soluble protein (mostly mucilage in the case of taro, Njintang et al. 2011) in raw taro flour favourable to emulsion formation which is degraded in pre-boiled taro flour, but this needs to be investigated. Indeed, the emulsion and foaming of flours are often attributed to proteins which has always been associated with formation of cohesive interfacial film around the air/or oil and water in the mixture system (Njintang et al. 2001; Kaur et al. 2011). These properties also depend on the structure and nature of proteins involved. In this respect the values of FC reported in the present study for wheat flour were higher compared to 58 % reported for soya beans flour (Kaur et al. 2011).

Water absorption capacity is a functional property that characterizes the ability of flour to rehydration, the first step of its conversion into dough. Previous finding revealed that the ability to absorb water was directly related to the dough maximum pressure,

Fig. 1 Variation in (a) water absorption capacity (WAC), swelling capacity (SC), oil absorption capacity, (b) Emulsion capacity (EC), and Water solubility index (WSI), and (c) Bulk density of wheat-taro

composite dough with level of taro incorporation. RI Red Ibo Ngaoundere variety, egg-like taro variety. Each observation is a mean of 4 replicate experiments; Error bars: Standard deviations

Fig. 2 Alveographic behaviours of the wheat-taro composite dough. P pressure necessary to deform the dough patty, L the square root of the volume of air, *RIN* Red Ibo *Ngaoundere* variety, *egg-like* taro variety. Each observation is a mean of 6 replicate experiments. For each observation the coefficient of variation was less than 0.5 %

elasticity and force (Njintang et al. 2008). Presently and irrespective of the variety, we found a significant ($r > 0.96$, $p < 0.01$) linear increase of the maximum pressure (P) and the extensibility (L) with increase in WAC. The dough alveograph characteristics of the composites are shown in Fig. 2. The parameters related to the dough properties as shown in Table 3 all varied significantly ($p < 0.05$) not only with the level of taro in the composite, but also with the variety of taro. In fact, the maximum pressure P which was shown to increase, as expected with the level of taro in the composite, was systematically higher for *RIN* variety (99–166 mm H₂O) than for *egg-like* variety (99–146 mm H₂O). In addition the strength (W) of the dough decreased with incorporation of

flour varying from 281 to 150×10^{-4} joules for *RIN* variety, and from 281 to 139×10^{-4} joules for *egg-like* variety. Increase in level of substitution equally resulted to a gradual decrease in the elasticity index (I_e) from 59.8 % (100 % wheat dough) to 55.7 % (10 % substitution with *RIN*) or to 49.2 % (15 % substitution with *egg-like* variety). Above these substitutions, a drastic drop to zero of the elasticity index was observed. Based on the minimal limit of I_e (40 %) necessary for a good baking dough (especially for bread), substitution above 10 % with *RIN* variety and 15 % with *egg-like* variety is not advisable (Njintang et al. 2008). Similar observations were made earlier on 3 varieties of raw taro flour with a drop to zero observed beyond 10 %. The decrease in elasticity is more probably due to the dilution effect of taro flour on gluten, the

Table 3 Alveograph parameters of wheat composite precooked taro flour

Variety	Level of substitution (%)	Alveograph parameters					
		<i>P</i> (mmH ₂ O)	<i>L</i> (mm)	<i>G</i>	<i>W</i> (10 ⁻⁴ joules)	<i>P/L</i>	<i>Ie</i>
<i>RIN</i>	0	99.1±2.31 ^f	78.0±1.81 ^a	19.7±0.45 ^a	281.0±6.55 ^a	1.3±0.03 ^g	59.8±1.40 ^a
	5	108.3±5.20 ^e	59.1±2.80 ^b	17.1±0.82 ^a	254.1±9.21 ^b	1.8±0.09 ^f	59.3±2.71 ^{ab}
	10	117.2±2.06 ^d	49.0±0.86 ^c	15.6±0.20 ^b	235.3±4.10 ^c	2.4±0.04 ^e	55.7±0.97 ^b
	15	135.2±3.22 ^c	33.1±0.50 ^d	12.8±0.20 ^c	198.2±3.20 ^d	4.1±0.07 ^d	0.00
	20	137.8±3.10 ^c	26.8±0.61 ^e	11.5±0.20 ^d	167.5±3.72 ^e	5.2±0.12 ^c	0.00
	25	153.1±2.05 ^b	22.2±0.29 ^f	10.5±0.14 ^e	150.0±2.01 ^f	6.8±0.09 ^b	0.00
	30	165.7±6.03 ^a	22.3±0.80 ^f	10.4±0.38 ^e	161±5.86 ^g	7.5±0.27 ^a	0.00
<i>Egg-like variety</i>	0	99.0±2.03 ^d	78.0±1.60 ^a	19.7±0.40 ^a	280.8±5.76 ^a	1.3±0.03 ^e	59.9±1.23 ^a
	5	102.2±4.12 ^d	61.1±2.43 ^b	17.4±0.70 ^{ab}	243.1±9.80 ^b	1.7±0.07 ^d	58.4±2.35 ^{ab}
	10	105.0±6.01 ^{cd}	52.1±2.87 ^c	16.0±0.91 ^b	219.1±9.98 ^c	2.0±0.12 ^d	55.1±3.15 ^b
	15	115.2±3.13 ^c	41.2±1.11 ^d	14.2±0.38 ^c	198.2±5.38 ^d	2.8±0.07 ^c	49.2±1.32 ^c
	20	125.1±4.19 ^b	37.1±1.20 ^e	13.6±0.45 ^c	198.0±6.61 ^d	3.3±0.11 ^b	0.00
	25	140.3±4.20 ^a	22.2±0.65 ^f	10.5±0.31 ^d	139.0±4.16 ^e	6.3±0.19 ^a	0.00
	30	146.2±5.02 ^a	22.0±0.75 ^f	10.4±0.36 ^d	145.1±4.98 ^e	6.6±0.22 ^a	0.00

n=5; means were generated automatically by the alveograph; means ± standard deviation followed by different letters in the same line within each variety are different at *p*<0.05. *RIN* taro variety *Red Ibo Ngaoundere*; *P* rupture pressure; *W* strength; *Ie* elasticity index; *L* extensibility of the dough; *G* extensibility index, *P/L* (dimensionless) is the graphic configuration ratio

protein complex found in wheat which provides desirable organoleptic properties (texture and taste) to many bakery and other food products (Rai et al. 2011). However gluten seems to play a limited role in defining the processability and end product quality of cookies. In this respect it has been suggested that soft wheat flour or composite flour is preferred

for production of good quality biscuits (Eneche 1999). Practically the sensory acceptability of the biscuits is the most used parameter to assess the limit of substitution and many studies reported with success acceptable biscuits at very high levels of substitution with non-wheat flours (Rai et al. 2011; Eneche 1999) (Table 4).

Table 4 Sensory quality of wheat taro composite biscuits

Taro level (%)	Colour	Texture	Taste	Flavour	Aroma	Itchiness	General acceptability
<i>RIN</i> variety							
0	6.7±2.11 ^b	6.5±1.51 ^b	6.7±1.52 ^c	6.5±1.48 ^c	6.5±1.51 ^b	7.9±0.81 ^a	6.7±1.63 ^b
5	7.8±0.89 ^a	7.0±1.28 ^{ab}	7.8±0.81 ^a	7.6±1.03 ^a	7.6±0.94 ^a	7.4±1.13 ^a	7.8±0.78 ^a
10	7.7±1.02 ^a	7.8±0.91 ^a	7.7±0.82 ^{ab}	7.4±1.21 ^{ab}	7.3±0.74 ^a	7.5±1.07 ^a	7.7±0.72 ^a
15	6.6±1.18 ^b	6.4±1.82 ^b	6.5±2.02 ^c	6.1±1.84 ^c	6.1±1.62 ^b	7.5±1.16 ^a	6.5±1.41 ^b
20	6.7±1.56 ^b	6.6±1.78 ^b	7.1±1.27 ^{ac}	6.9±1.34 ^{bc}	6.5±1.64 ^b	7.4±1.01 ^a	6.9±1.04 ^b
25	6.5±1.56 ^b	6.4±1.54 ^b	6.6±1.11 ^c	6.6±1.11 ^c	6.3±1.42 ^b	7.4±1.11 ^a	6.3±1.02 ^b
30	6.3±2.01 ^b	6.3±2.01 ^b	6.5±1.72 ^c	6.8±1.31 ^{bc}	6.5±1.84 ^b	7.6±1.06 ^a	6.3±2.04 ^b
<i>Egg like variety</i>							
0	6.7±2.01 ^a	6.5±1.52 ^a	6.7±1.49 ^{ab}	6.5±1.49 ^a	6.5±1.49 ^a	7.9±0.81 ^a	6.7±1.57 ^a
5	6.1±1.32 ^a	6.2±1.44 ^a	6.8±1.28 ^{ab}	6.6±1.61 ^a	6.9±1.39 ^a	7.8±1.04 ^a	6.7±1.18 ^a
10	6.4±1.64 ^a	6.5±1.64 ^a	6.9±1.26 ^{ab}	6.9±1.47 ^a	6.5±1.21 ^a	7.8±1.04 ^a	6.6±1.21 ^a
15	6.8±1.58 ^a	6.3±1.62 ^a	6.2±1.93 ^b	6.2±1.31 ^a	6.4±1.46 ^a	7.9±1.02 ^a	6.2±1.51 ^a
20	6.3±1.51 ^a	6.1±0.83 ^a	6.5±1.67 ^{ab}	6.5±1.38 ^a	6.6±1.37 ^a	7.7±1.09 ^a	6.3±1.09 ^a
25	6.2±2.04 ^a	6.2±1.01 ^a	6.2±1.47 ^b	6.8±0.92 ^a	6.2±1.32 ^a	7.8±1.03 ^a	6.1±1.18 ^a
30	6.2±1.13 ^a	6.4±1.82 ^a	7.1±1.14 ^a	6.8±1.32 ^a	6.3±1.38 ^a	7.8±1.09 ^a	6.2±1.43 ^a

n=50; means ± SD followed by different letters in the same column within each taro variety are different at *p*<0.05, *RIN* taro variety *Red Ibo Ngaoundere*

Composition and sensory characteristics of biscuits composite

Mean nutrient compositions and energy contents of biscuits made from taro-wheat composite flours at various levels of substitution are shown in Table 2. Generally a non significant variation was observed on the crude lipids of biscuits while a significant ($p<0.05$) decrease in protein and increase in ash was observed following the increase in taro level. It was also observed that the level of moisture and energy value did not vary significantly among *egg-like* composite biscuit while significant ($p<0.05$) decrease in energy value and inconsistent changes in moisture content were observed for *RIN* composite biscuit samples. In addition it was generally observed that available sugars significantly decreased with increasing level of substitution with taro flour, but this change was inconsistent for variety *RIN*. Since the level of ash were higher and the level of protein lower in taro flours, biscuits made from composite flours were expected to have an increase in the level of ash and decrease in the level of proteins with increasing level of substitution with taro flour. The data presented in Table 2 did not deviate from this expected trend. Furthermore, the inconsistent changes observed for moisture content of the biscuits could be due to the procedure used in the preparation of dough. In fact based on the WAC shown in Table 1, wheat flour required less water for mixing when compared with the taro flour. In the event of dough preparation, the ability of flour to absorb water is often used to determine the total water required for mixing the dough (Omobuwajo 2003), which in this case have been expected to increase with increasing level of substitution. In this work, dough was developed using a fixed volume of water which has affected not only the dough development, but also the expansion of biscuits. The fat content of the biscuits did not vary significantly probably because of the low level of fat in taro and the high and similar quantities of fat added. The mean energy value of the biscuits was 4.78 kCal/g not far from the range 4.06–4.42 kCal/g reported for breadfruit wheat composite biscuit (Omobuwajo 2003).

The analyses of the mean sensory scores for the biscuits are shown in Table 3. A look at the table revealed that biscuits made with egg like taro flour were as acceptable as 100 % wheat biscuits. Similar results were observed for *RIN* variety except that the substitution at 5 and 10 % possessed higher hedonic score for all the attributes compared to 100 % wheat biscuits. This suggests that *RIN* taro flour has induced attractive sensory attribute to biscuits, in particular flavour and taste.

Conclusion

Based on the composition, precooked taro flour is not considerably different from raw taro flour, but it exhibits very high ability to bind water. Incorporation of precooked taro flour in wheat also increases this ability. The alveograph characteristics of doughs made from composite wheat–taro flours are significantly ($p<0.05$) affected by the level of taro incorporation. In this respect up to 10 % level of incorporation of precooked taro flour variety *RIN* and 15 % *egg-like* variety, the composite taro-wheat dough exhibits alveograph characteristics acceptable for baking. Up to these critical values of substitution, the composite dough exhibits very low extensibility, no elasticity and weak strength. However at all levels of substitution (up to 30 %), the biscuits are either acceptable as or better than 100 % wheat biscuit. More over taro flour variety *RIN* induced attractive flavour and taste to biscuit contributing to a more accepted composite biscuit at 5–10 % substitution. This demonstrates the potential of taro for the production of fast-snack foods. The implementation of this result will enhance food security and stimulate demand for taro flour as industrial raw material.

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