GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

Check for updates

# Functional properties of composite flours produced with Ivorian taro (*Colocasia esculenta* L. *Cv Fouê*) corms flour and wheat (*Triticum aestivum* L.) flour

Anon Attoh Hyacinthe [1, 2, *], Fagbohoun Jean Bedel [3], Koffi Amoin Gisèle [2], Anno Hermann Fourier Atta [2] and Kouamé Lucien Patrice [2]

[1] *Laboratory of Biochemistry, Microbiology and Valorization of Agro-Resources (LBMVA), Institute of Agropastoral Management, Peleforo Gon Coulibaly University (UPGC), Korhogo, BP 1328 Korhogo, Côte d'Ivoire.*
[2] *Laboratory of Biocatalysis and Bioprocesses, Nangui Abrogoua University (UNA), Abidjan, 02 BP 801 Abidjan 02, Côte d'Ivoire.*
[3] *Laboratory of Biochemistry-Genetics, Peleforo Gon Coulibaly University (UPGC), Korhogo, BP 1328 Korhogo, Côte d'Ivoire.*

GSC Biological and Pharmaceutical Sciences, 2021, 15(03), 164–176

Publication history: Received on 14 April 2021; revised on 31 May 2021; accepted on 04 June 2021

Article DOI: https://doi.org/10.30574/gscbps.2021.15.3.0131

## Abstract

The general objective of this work was to assess the functional properties of composite flours obtained from the flour of Ivorian taro corms (*Colocasia esculenta, Cv Fouê*) with wheat flour (*Triticum aestivum* L.). The results concerning the functional properties revealed significant differences ($p < 0.05$). Indeed, the water absorption capacity, the water solubility index and the hydrated density increase considerably in the various composite flours. On the other hand, the bulk density, clarity, wettability and porosity have decreased in these flours. In addition, the stability of the foam and the dispersibility have increased over time. On the other hand, the hydrophilic / lipophilic ratio is greater than 1 with the exception of red oil.

**Keywords:** Functional properties; Composite flour; Wheat; *Colocasia esculenta*; Taro corms

## 1. Introduction

Research focused on the production of composite flour with wheat flour partially substituted by locally sourced food products such as cereals, tubers, roots and legumes is increasing [1, 2, 3]. Wheat-free composite flours made from the appropriate combinations of cereals, tubers and legumes have also been developed [2, 4]. The development of composite flours was mainly aimed at reducing dependence on wheat imports and also at developing gluten-free food products suitable for people with gluten intolerance. Research results showed that partial or total substitution of wheat by other locally available crops produced a composite flour with acceptable physicochemical and rheological properties [3].

Taro (*Colocasia esculenta* L.), a monocotyledonous plant and member of the Araceae family, is an ancient crop cultivated in the humid tropics for its edible corms and leaves, as well as for its traditional uses [5]. The most important taro producers are West African countries, i.e. Nigeria, Ghana and Côte d'Ivoire, followed by China, which provide 6.7 and 3 respectively, 9 million tonnes of taro, or 83.6% of global taro production [6, 7, 8]. In addition, taro is the second most important root crop in West Africa. Although it is less important than other tropical roots such as yam, cassava and sweet potato, it remains a major staple food in parts of the tropics and subtropics [9]. Taro is rich in digestive starch, good quality protein, vitamin C, thiamine, riboflavin, niacin, and essential protein and amino acids [10, 11, 12]. Today,

* Corresponding author: Anon Attoh Hyacinthe
Laboratory of Biochemistry, Microbiology and Valorization of Agro-Resources (LBMVA), Institute of Agropastoral Management, Peleforo Gon Coulibaly University, Korhogo, BP 1328 Korhogo, Côte d'Ivoire.

taro is widely produced across Africa because of its richness in carbohydrates, mainly in the form of starch, which not only gives it desirable functional properties to foods but also provides metabolizable energy and promotes consumer satiety [13, 6, 14].

In Côte d'Ivoire, the majority of taro production was carried out by smallholder farmers [15]. The use of powder from the corms of taro, *Fouê* cultivar in the technological field in Ivory Coast could be a major challenge for this country. A partial substitution of wheat flour by powder from taro corms, cultivar *Fouê* could be considered as an alternative to other starches (sweet potato, yam or plantain), potentially transforming it into a raw material of choice for the elaboration of a wide range of products in the food industry [14]. This is because composite flours can also be considered as mixtures of wheat and other flours, or mixtures of wholly other than wheat flours for the production of various food products, including bakery products, pasta, porridge and snack foods [16, 17]. According to these latter authors, the purpose of composite flour for the manufacture of staple foods such as bakery products is generally for economic and nutritional benefits. Thus, the wheat-taro combination can help developing taro producing countries to reduce the importation of wheat, which would affect the cost of the commodities obtained from these food products. In order to assess the potential application of the flour of taro corms, cultivar *Fouê* in the food industry, it was of fundamental importance to evaluate the functional properties of the composite flours obtained with Ivorian taro (*Colocasia esculenta, Cv Fouê*) corms flour and wheat (*Triticum aestivum* L.) flour which determine the quality of the final product.

## 2. Material and methods

### 2.1. Materials

Taro (Colocasia esculenta, Cv Fouê) corms were used in this work. They were randomly harvested at maturity (9 months after planting) from a farm in Affery, South-East portion of Côte d'Ivoire (West Africa). They were immediately transported to the Laboratory of Biocatalysis and Bioprocesses (Nangui Abrogoua University, Abidjan, Côte d'Ivoire) and stored under prevailing tropical ambient conditions (19-28°C, 60-85% RH) for 24 h before the preparation of flours from raw taro corms. The commercially available soft wheat flour was purchased from local suppliers at Bonoua market in Côte d'Ivoire.

### 2.2. Methods

#### *2.2.1. Production of Taro Corms and Composite Flours*

The ivorian taro (*Colocasia esculenta*, cv *Fouê*) corms were cleaned and rinsed with copious amounts of tap water. The corms were thereafter peeled using a stainless-steel knife. The peeled samples were rewashed with clean water in order to remove much mucilaginous material. After washing, they were 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. Taro corms and wheat flours were blended in various proportions to come up with different formulations of wheat/taro as 99:1, 97:3, 94:6, 91:9 and 88:12 (table 1).

**Table 1** Blends of wheat flour and Ivorian Taro (*Colocasia esculenta, Cv Fouê*) Corms flours used in composite flour formulation

| Sample code | Wheat flour (%) | Taro corms flour (%) |
|---|---|---|
| FB/FC: wheat flour (100%) | 100 | 0 |
| FCF1/FC1: wheat flour (99%) + taro corms flour (1%) | 99 | 1 |
| FCF3/FC3: wheat flour (97%) + taro corms flour (3%) | 97 | 3 |
| FCF6/FC6: wheat flour (94%) + taro corms flour (6%) | 94 | 6 |
| FCF9/FC9: wheat flour (91%) + taro corms flour (9%) | 91 | 9 |
| FCF12/FC12: wheat flour (88%) + taro corms flour (12%) | 88 | 12 |

*2.2.2. Functional properties analysis*

The water absorption capacities (WAC) and the water solubility indexes (WSI) of the flours were determined respectively according to the methods of [18] and [19]. One (1) g of flour (M0) are dissolved in 10 ml of distilled water contained in a centrifuge tube. This mixture is stirred for 30 minutes with a stirrer and then kept in a water bath at 37 °C. for 30 minutes. It is then centrifuged at 5000 rpm for 15 minutes. The pellet obtained (M2) is weighed and then dried at 105 ° C to a constant mass (M1). WAC and WSI are calculated from the following relationships:

$$\text{WAC (\%)} = \frac{\text{M2} - \text{M1}}{\text{M1}} \times 100$$

$$\text{WSI (\%)} = \frac{\text{M0} - \text{M1}}{\text{M0}} \times 100$$

The method of [20] was used to determine the oil absorption capacities (OAC) of flours. One (1) g (M0) of flours is dissolved in 10 ml of oil. The mixture is stirred for 30 minutes at room temperature using a mechanical stirrer and then centrifuged at 4500 rpm for 10 minutes. The pellet recovered is weighed (M1). The oil absorption capacity (OAC) is calculated from the following formula;

$$\text{OAC (\%)} = \frac{\text{M1} - \text{M0}}{\text{M0}} \times 100$$

The hydrophilic-lipophilic ratios (HLR) of the flours were calculated according to the method of [21] using the ratio of water absorption capacity to oil absorption capacity:

$$HLR = \frac{WAC}{OAC}$$

The foaming capacities (FC) and stabilities of flour foams (SF) were determined according to the method of [22]. Three (3) grams of flours are transferred into a graduated 50 ml test tube previously dried in an oven at 50 °C. The flour is leveled and the volume noted (V0). Then, thirty (30) ml of distilled water is added to the sample to facilitate the dispersion of the flour in the test tube and the volume is also noted (volume before homogenization); then the test tube is vigorously stirred by hand and the new volume is read on the test piece (volume after homogenization). The volume of foam obtained is calculated by making the difference between the volume after homogenization and the volume before homogenization. The specimen is allowed to stand on the bench at room temperature (28 ° C) until the foam collapses. At 10 min intervals and for 1-hour time, the volume of the foam was determined. The foaming capacity and the stability of the foam were calculated from the following formulas:

$$\text{FC (\%)} = \frac{\text{Vol after homogenization} - \text{Vol before homogenization}}{\text{Vol before homogenization}} \times 100$$

$$\text{SF (\%)} = \frac{\text{Volume of the foam at time t}}{\text{Volume initial of the foam}} \times 100$$

The clarities of the doughs of the flour were measured according to the method of [23]. A mass of 0.2 g of flour was dissolved in 20 mL of distilled water contained in a centrifuge tube. The mixture, homogenized by vortexing for 2 min, was then heated in a boiling water bath for 30 min. During this heat treatment, the reaction medium was homogenized every 5 min by manual stirring at room temperature (28 °C.) for 2 min. After this heating, the reaction medium was cooled on the bench for 10 min at room temperature (28 °C). The clarity of the paste of the sample was determined by measuring the transmittance at 650 nm with a spectrophotometer.

The method described by [24] was used to determine the dispersibility of flour. One (1) g of flour was dissolved in 10 mL of distilled water contained in a 50 mL graduated cylinder. The resulting mixture was stirred carefully by hand for 2 min. The volume of the particles was noted. The dispersibility (D) of the flour was defined as the difference between the total volume (V0) of the particles just after manual stirring and the volume (Vt) of the deposited particles recorded every 10 min.

$$\text{D (\%)} = \frac{\text{V0} - \text{Vt}}{\text{Vt}} \times 100$$

The hydrated densities (HD) of the flours were determined according to the method of [25]. A mass of 0.5 g of flour was dissolved (carefully to avoid sticking to the walls of the test tube) in 5 mL of distilled water contained in a 10 mL graduated cylinder. The difference between the volume of water before and after adding the sample was marked as the volume of water displaced in mL. The hydrated density of the flour was expressed in grams of flour per mL of displaced water.

The method of [25] made it possible to determine the bulk density (BD) of flour. Fifty (50) g of flour (ME) were placed in a 100 mL graduated cylinder. The volume ($V_0$) of this sample was noted after good leveling with a spatula (without tapping the test tube on the bench). Then the test tube was gently tapped on the bench until a constant volume (Vt) was obtained.

$$\text{BD (g/ml)} = \frac{\text{ME}}{\text{Vt}}$$

The porosity (P) was calculated according to the following relationship:

$$\text{P (\%)} = \frac{\text{Vo} - \text{Vt}}{\text{V0}} \times 100$$

The wettability of the flour was determined according to the method described by [26]. A finger closing a graduated cylinder having a diameter of 1 cm and a capacity of 25 cm containing 1 g of flour was placed at a height of 10 cm from the surface of a 600 mL beaker containing 500 mL of distilled water. The finger was removed from the flour and the flour was poured into the beaker. Wettability was determined as the time required (in seconds) for the flour to become completely wet.

The method of [27] slightly modified by [28] was used to measure the turbidities of flour. Two (2) g of flour was dissolved in 100 mL of distilled water. The resulting mixture, homogenized by magnetic stirring for 20 min at room temperature (28°C), was heated in a boiling water bath for 1 h with constant stirring. The homogenized solution was cooled to room temperature (28°C) for 10 min, then placed in a refrigerator for 14 days at 4°C. Turbidity was determined every 24 h by measuring the absorbance at 640 nm with a spectrophotometer.

### 2.3. Statistical Analysis

All data analyzes were done in triplicates and subjected to analysis of variance (ANOVA). The means were then separated with the use of Duncan's multiple range test, compared by Least Significant Difference (LSD) with mean square error at 5% probability using the statistical package for the social sciences, SPSS 19.0 software.

## 3. Results and discussion

Some functional properties (water absorption capacity, water solubility index, porosity, clarity, wettability index, Hydrated density and bulk density) of the composite flours studied were recorded in Table 2 while the stability of foam (SF) was shown on figure 1.

Water absorption capacity (WAC) plays an important role in the food preparation process by influencing certain functional and sensory properties [29]. The significant differences in the water absorption capacity observed in wheat flour and composite flours of wheat and corms of the taro (*Colocasia esculenta, Cv Fouê*) could be explained by the variability of the biochemical composition of these flours. This situation allowed these composite flours to have high water absorption capacities as reported by [30] whose work focused on composite wheat / taro / lotus seed flours. Indeed, the work of [31] have shown that the high carbohydrate content of flour is responsible for the high capacity of a food to absorb water. In addition, according to [32] and [33], flours with high water absorption are more hydrophilic. This hydrophilicity would be due to the polysaccharides. It should also be noted that the water absorption capacity of foods is sometimes attributed to their protein content [34, 35]. In fact, it is well known that the polar amino acids in proteins have an affinity with water molecules [36]. These contradictory observations show that carbohydrate and protein content are not the only determinants of the water absorption capacity of food flours. Therefore, the strong water absorption capacities of the present composite flours could be explained by their low lipid content. Indeed, according to [37], the presence of lipids in large quantities in a flour would reduce the binding capacity of water to particular substances, thus limiting the water absorption capacity. The water absorption capacity plays a major role in dough formation. With the strong water absorption capacities of the present flours, they could be used in the formulation of certain foods such as sausage, dough, processed cheese and bakery products [38, 39, 40]. On the other hand, a high-water absorption capacity would indicate the addition of an optimal amount of water to the dough, thus improving its workability. In addition, the good water absorption capacity of composite flours can prove useful in the manufacture of products where good viscosity is required. This is the case with soups and sauces [41, 42]. The water absorption capacities obtained in this study are greater than those mentioned by [43] on wheat-taro composite flours whose values were between 49.0 ± 1.4 and 111.5 ± 2.1%. In contrast, the water absorption capacities obtained by [44] in the wheat / plantain composite flour (50:50) and by [45] in composite wheat flours are (168%; 132.00 ± 22.80 to 176.00 ± 16.73%) greater than our water absorption capacities.

The high-water solubility indices (WSI) of wheat flour and composite flours of wheat and corms of taro (*Colocasia esculenta, Cv Fouê*) may be due to the breakage of starch granules and exposure of hydrophilic groups under the effect of the increase in temperature [46]. In other words, the water solubility index is related to the amount of water soluble molecules [47]. Likewise, the increase in the water solubility index is linked to the high level of amyloidosis. Indeed, [48] attributed the increased solubility to the solubilization of amylose in heating water. However, the water solubility index cannot be attributed solely to starch degradation. In fact, proteins, total sugars and crude fat could play an important role in this change in functional properties. This physico-functional characteristic plays an important role in the choice of flours to be used as thickeners in the food industry [41]. In addition, the high solubility of composite flours would suggest that they are easier to digest; they could therefore be used as ingredients in infant formula [49]. The water solubility index values of wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms corroborate those observed by [46] and [50] which are between 11.83 ± 0.15 and 27.64 ± 2.97%. On the other hand, these values are lower than those indicated by [42] which are between 34.23 ± 1.40 and 32.30 ± 2.43%.

The stability of the foam (SF) improves the texture, uniformity and appearance of foods [51, 39]. It corresponds to a colloid of many bubbles of the gas trapped in a liquid [39, 30]. In the present study, the volume of the foam of each flour studied decreases over time at room temperature until it collapses, contrary to the finding made by [52] in their work on composite flours produced with date fruit pulp, roasted watermelon seeds and wheat. This variation in foam could be explained by the bursting of the air bubbles formed [34]. According to [35], [53] and [54], foam formation and stability depend on the type and degree of protein denaturation, pH, viscosity and processing methods. The foaming capacities of the flours studied are low. However, the collapse of the foams is quite slow. As a result, these flours can be used as an ingredient in brewing and baking [55]. The foaming capacities of composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms are similar to those reported by [30] in their work on composite wheat / taro / lotus seed flours (5.99 ± 0.25-10.12 ± 0.02%). On the other hand, the present foaming capacities are lower than those mentioned by [44] during their work on composite wheat-banana flours. These foaming capacities vary from 18.2 to 26%.

The high porosities (P) of the composite flours would suggest that they could be useful in the formulation of infant foods. The porosities obtained are higher than those indicated by [56] who worked on some functional properties of certain starches. The latter found porosities between 34.83 ± 0.29 and 35.83 ± 0.29%. These porosities show that our flours can easily be packaged, which will facilitate their transport [57]. According to [51], flours with bulk densities greater than 0.7 g / mL are used as thickeners in food products. From the above, our composite flours having high bulk densities could be used as thickening agents in infant feeding. Our results corroborate with those of [49] whose work focused on the chemical composition and functional properties of wheat. However, [58] reported higher bulk densities (1.03 ± 0.03-1.85 ± 0.05 g / mL) than our flours. The bulk densities of composite wheat and taro (*Colocasia esculenta, Cv Fouê*) corms flours are higher than those reported by [43] in their work on wheat-taro composite flours (0.55 ± 0.03 – 0.74 ± 0.04 g / ml). Bulk density is important in determining packaging requirements, material handling and application in processing in the food industry [59, 60]. Low bulk density is a desirable factor in feed formulation, especially feeds with less demotion [61, 52]. On the other hand, a high bulk density is a good physical attribute for determining the mixing quality of a particular material [59]. Hydrated density is important in the feed separation process such as sedimentation and centrifugation [62]. This is a desirable quality factor for the evaluation of flours.

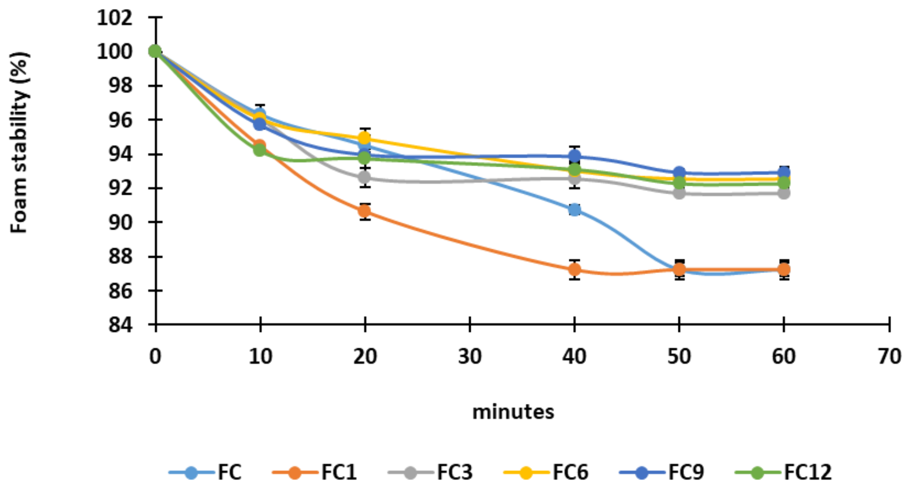
The incorporation of *Colocasia esculenta, Cv Fouê* taro corms flour into wheat flour results in a significant decrease ($p <0.05$) in the clarity of the composite flour. This reduction would be due to the storage time of the composite flours and the clarity of the gel of the flour of taro (*Colocasia esculenta*) corms. According to [63] and [64], the low transmittance is due to the storage time. Likewise, according to [65], the transmittance (% T) of gel depends mainly on the type of spectrophotometer, the concentration of starch, the temperature of the treatment and the storage time. In addition, the low transmittance is justified by the protein and tannin contents [66]. The clarity of gels is a very desirable property of starches used as thickeners in the food industries, as it directly influences the brightness and opacity in foods [67]. The poor dough clarity observed among cereal starches makes them suitable for use in sauces and thickened foods where low transparency is desired [66]. Therefore, our composite flours with transmittances of less than 1% could be used in the above-mentioned foods. Our values are close to those indicated in the work carried out by [64] on the morphological and physicochemical properties of some starchy foods for seventy-two (72) hours of storage. Other authors have also mentioned very high clarity values. This is the case with [68] and [69] who worked respectively on taro (*Colocasia esculenta var Bentul*) then on yam (*Dioscorea alata var Krimbang*) and on amaranth flour (*Amaranthus Hypocondriacus*).

The wettability index is defined as the time (in seconds) required to wet all the particles of a solid material (flour) [70]. The decrease in the wettability index obtained in taro wheat composite flours could be explained by the variability of their chemical composition. Indeed, according to [71], the decrease in wettability is due to the increase in foaming capacity. In addition, some authors such as [72], explain the variation in wettability by certain parameters such as the polarity of the molecules, the heterogeneity of the flour, the contact surface and the porosity. According to [71], the wettability of black bean flours with a time of 113.75 to 186.333 seconds indicate that these may well improve the quality of the texture of meat and baked goods. The wettability indices of our composite flours are close to those of [71], which allows us to say that our composite flours could also be used for improving the texture of certain dishes and bakery products.

**Table 2** Some technological characteristics of wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms

| | FB | FCF1 | FCF3 | FCF6 | FCF9 | FCF12 |
|---|---|---|---|---|---|---|
| Hydrated density (g/mL) | 0.46±0.11$^a$ | 0.50±0.01$^b$ | 0.53±0.05$^c$ | 0.53±0.05$^c$ | 0.56±0.11$^d$ | 0.60±0.01$^e$ |
| Bulk density (g/mL) | 0.85±0.01$^b$ | 0.84±0.03$^b$ | 0.84±0.11$^b$ | 0.84±0.10$^b$ | 0.82±0.04$^a$ | 0.82±0.02$^a$ |
| Clarity (%) | 0.84±0.02$^d$ | 0.82±0.02$^c$ | 0.74±0.04$^b$ | 0.70±0.01$^a$ | 0.69±0.01$^a$ | 0.69±0.01$^a$ |
| Wettability (Sec) | 193.66±3.21$^f$ | 193.66±3.50$^e$ | 179.00±1.00$^d$ | 171.00±3.00$^c$ | 165.33±2.57$^b$ | 159.66±2.88$^a$ |
| WAC (%) | 120.58±0.38$^a$ | 121.08±0.77$^b$ | 122.43±0.76$^b$ | 123.79±1.31$^c$ | 124.89±1.85$^d$ | 126.92±0.63$^e$ |
| WSI (%) | 20.66±1.15$^a$ | 21.00±1.00$^a$ | 21.33±0.57$^a$ | 21.46±0.57$^a$ | 21.00±1.00$^a$ | 20.33±0.57$^a$ |
| Porosity (%) | 49.01±0.84$^c$ | 48.74±1.62$^b$ | 48.58±1.40$^b$ | 48.05±0.86$^b$ | 47.53±0.89$^a$ | 46.19±0.82$^a$ |
| FC (%) | 10.33±1.15$^d$ | 9.73±1.14$^c$ | 8.67±1.10$^b$ | 8.67±1.15$^b$ | 6.67±1.15$^a$ | 6.67±1.15$^a$ |

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter (a or b) are significantly different between them on the threshold of 5% according to the test of Duncan. ***FB****: wheat flour*
***FCF1****: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%);* ***FCF3****: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;* ***FCF6****: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%) ;* ***FCF9****: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%) ;* ***FCF12****: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*




***FC****: wheat flour;* ***FC1****: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%);* ***FC3****: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;* ***FC6****: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%) ;* ***FC9****: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%)* ***FC12****: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*

**Figure 1** Foam stability of wheat flours and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms.

Oil absorption capacity (OAC) is an important property in food formulation because the oil improves flavor and gives the food a smooth texture [73, 74]. It is also important in the preservation of foods by preventing the development of oxidative rancidity [75]. The oil retention observed in wheat flour and composite flours of wheat and corms of the taro *Colocasia esculenta, Cv Fouê* (Table 3) would be due to an availability of lipophilic groups and to the ability of the proteins of these flours to retain oil [54, 30]. This inherent property of these proteins is an interesting characteristic insofar as it allows good retention of flavor during food processing processes, thus improving palatability [14, 40].

**Table 3** Oil absorption capacities of wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms

| Oils | FB | FCF1 | FCF3 | FCF6 | FCF9 | FCF12 |
|---|---|---|---|---|---|---|
| Rafined palm | 88.33±0.57$^{c}$ | 88.00±1.00$^{c}$ | 88.00±1.00$^{c}$ | 88.00±1.00$^{c}$ | 87.00±1.00$^{b}$ | 86.00±1.00$^{a}$ |
| Colza | 86.33±0.57$^{a}$ | 88.66±0.57$^{a}$ | 88.00±1.00$^{a}$ | 94.00±1.00$^{b}$ | 96.33±0.57$^{c}$ | 97.66±0.57$^{d}$ |
| Unrafined palm | 380.00±1.00$^{f}$ | 374.00±1.00$^{e}$ | 369.66±0.57$^{d}$ | 364.00±1.00$^{c}$ | 363.00±1.00$^{b}$ | 361.00±1.00$^{a}$ |
| Tournesol | 98.66±0.57$^{d}$ | 95.33±0.57$^{c}$ | 94.33±0.57$^{b}$ | 94.00±1.00$^{b}$ | 91.00±1.00$^{a}$ | 91.00±1.00$^{a}$ |
| Huilor | 98.66±0.57$^{d}$ | 98.66±0.57$^{d}$ | 98.33±0.57$^{d}$ | 95.33±0.57$^{c}$ | 94.66±0.57$^{b}$ | 91.66±0.57$^{a}$ |

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter (a or b) are significantly different between them on the threshold of 5% according to the test of Duncan; ***FB**: wheat flour;*
***FCF1**: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%)*; ***FCF3**: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;**FCF6**: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%); **FCF9**: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%)*; ***FCF12**: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*

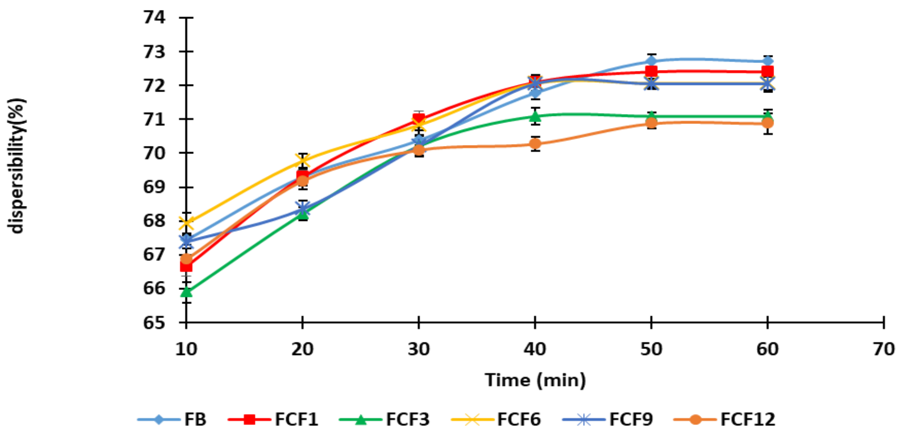
The decrease in the absorption capacity of unrefined sunflower, oil and palm oils in composite flours results in an absorption capacity of these oils in wheat flour that is higher than that of taro corms flour. This difference in oil absorption could be explained by a greater availability of lipophilic groups in wheat flour. However, the increased absorption capacity of rapeseed oil in composite flours suggests that this factor is not the only factor involved in the uptake of an oil by a flour. Indeed, this same observation of increased oil retention was revealed by [30] in their work on composite wheat / taro / lotus seed flours. The nature of the molecules that compose it and the initial quantity of oil in the flours can also play very important roles in the evolution of the oil absorption capacity in these flours. Since the wheat- taro composite flours studied have on the whole great oil absorption capacities, they could be good lipophilic constituents and therefore be suitable for the preparation of sausages, soups, baked goods, donuts and cakes in which the absorption of oils is desired [76, 77, 40]. It should be noted that the absorption capacities of unrefined palm oil or red oil of the composite flours studied are high (256.33 ± 0.57-374.00 ± 1.00%) and greater than those of the composite flour's wheat-taro (2.12 ± 0.00 to 2.18 ± 0.00 g / ml) mentioned by [17]. However, in this study, the absorption capacities of sunflower, vegetable (huilor), Dinor (refined palm oil) and Colza oil were lower than those reported by [42] on composite flours with values between 93.53 ± 15.67 and 123.30 ± 9.76%.

**Table 4** Hydrophilic-lipophilic ratios of wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms

| Oils | FB | FCF1 | FCF3 | FCF6 | FCF9 | FCF12 |
|---|---|---|---|---|---|---|
| Rafined palm (Dinor oil) | 1.36±0.02 | 1.37±0.02$^{a}$ | 1.37±0.01$^{a}$ | 1.37±0.04$^{a}$ | 1.38±0.02$^{a}$ | 1.4±0.04$^{a}$ |
| Unrafined palm (Red oil) | 0.31±0.06 | 0.32±0.02$^{a}$ | 0.32±0.04$^{a}$ | 0.33±0.02$^{a}$ | 0.33±0.01$^{a}$ | 0.33±0.02$^{a}$ |
| Colza | 1.39±0.04 | 1.36±0.02$^{b}$ | 1.37±0.02$^{b}$ | 1.28±0.04$^{a}$ | 1.25±0.02$^{b}$ | 1.23±0.04$^{a}$ |
| Tournesol | 1.22±0.02 | 1.26±0.01$^{a}$ | 1.27±0.06$^{a}$ | 1.28±0.04$^{a}$ | 1.32±0.02$^{b}$ | 1.32±0.04$^{b}$ |
| Huilor | 1.22±0.02 | 1.22±0.04$^{a}$ | 1.22±0.02$^{a}$ | 1.26±0.04$^{a}$ | 1.27±0.02$^{a}$ | 1.31±0.04$^{a}$ |

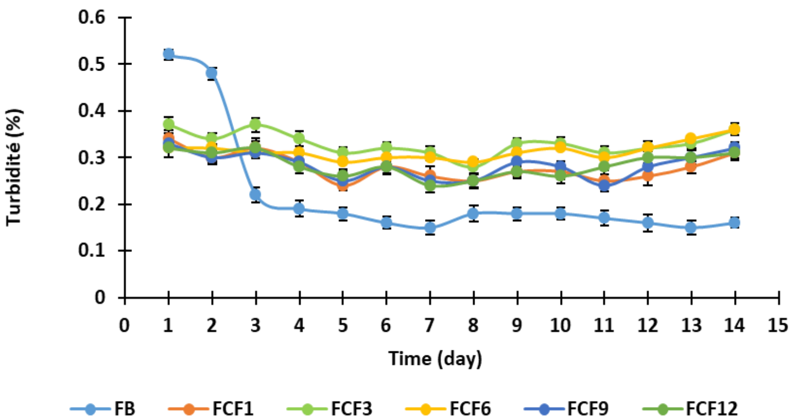
The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter (a or b) are significantly different between them on the threshold of 5% according to the test of Duncan; ***FB**: wheat flour;*
***FCF1**: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%)*; ***FCF3**: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;**FCF6**: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%); **FCF9**: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%)*; ***FCF12**: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*

The hydrophilic-lipophilic ratios obtained for the red oil concerning wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms are less than 1 (Table 4), which clearly means that the flours absorb this flour. Oil more than water [78]. On the other hand, the hydrophilic / lipophilic ratios of rapeseed, sunflower, Dinor (refined palm oil) and vegetable (huilor) oils are greater than 1. In these cases, the water absorption capacity is greater than oil absorption capacity. This situation has already been demonstrated by [21] and [79] who worked respectively on cowpea flour (1,12) and on the flours of three new Irish potatoes whose hydrophilic / lipophilic ratio values oscillate between 1.41 ± 0.12 and 1.70 ± 0.16. The present composite flours should preferably be intended for the formulation of products requiring a high-water absorption capacity.




*FB: wheat flour; FCF1: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%); FCF3: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;FCF6: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%); FCF9: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%); FCF12: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*

**Figure 2** Evaluation of the dispersibility of wheat flour and composite flours of wheat and of taro (*Colocasia esculenta, Cv Fouê*) corms over time




*FB: wheat flour; FCF1: composite flour from wheat flour (99%) and taro (Colocasia esculenta, Cv Fouê) corms flour (1%); FCF3: composite flour from wheat flour (97%) and taro (Colocasia esculenta, Cv Fouê) corms flour (3%) ;FCF6: composite flour from wheat flour (94%) and taro (Colocasia esculenta, Cv Fouê) corms flour (6%); FCF9: composite flour from wheat flour (91%) and taro (Colocasia esculenta, Cv Fouê) corms flour (9%); FCF12: composite flour from wheat flour (88%) and taro (Colocasia esculenta, Cv Fouê) corms flour (12%).*

**Figure 3** Evaluation of the turbidity of wheat flour and composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms as a function of the days

The increased dispersibility of composite flours of wheat and taro (*Colocasia esculenta, Cv Fouê*) corms is due to the chemical composition and particle size profile of the compounds in the composite flours (Figure 2). Indeed, according to [80] and [39], these differences could be justified by the presence of hydrophilic molecules such as polysaccharides and proteins. The dispersibility of a flour corresponds to its ability to reconstitute in water. This functional parameter is useful in formulations of various food products [24]. The higher the percentage of dispersibility, the greater the ability of the flour to reconstitute in water to give a fine and coherent paste [81]. On the other hand, a high percentage dispersibility is an indicator of a water absorption capacity [82]. The dispersibilities of our flours are similar to those indicated by [83] in rice flour from Nigeria (56-66%). In addition, they are higher than those reported by [84] whose values were between 32.70 and 34.93% in the flours of certain cereals.

According to [85], the variation in turbidity would be justified by the decrease in protein, fat and amylose content, which decreases the absorption of light. The turbidities of the wheat-taro composite flours (Figure 3) are lower than those mentioned by [86] during their work on the functional properties of modified corn starches. These authors found turbidity values between 1.5 and 2.4%.

## 4. Conclusion

Overall, wheat-taro (*Colocasia esculenta, Cv Fouê*) composite flours have valuable nutritional functional properties. The high-water absorption capacity of these composite flours implies that they could be used as thickening or gelling agents in various food products (soups, sauces). In addition, the hydrophilic-lipophilic ratio greater than 1 for most oils attests that the composite flours of wheat and taro corms *Colocasia esculenta, Cv Fouê* have a greater affinity for water than for oil. In view of these interesting functional characteristics, the composite flours studied could be used for the production of bread sticks and donuts.

## Compliance with ethical standards

### *Acknowledgments*

We sincerely thank the entire team of the Laboratory of Biocatalysis and Bioprocesses at Nangui Abrogoua University, Abidjan, Côte d'Ivoire for the help provided.

### *Disclosure of conflict of interest*

The authors declare no conflict of interest.

## References

[1] Olaoye OA, Onilude AA, Idowu OA. Quality characteristics of bread produced from composite flours of wheat, plantain and soya beans. *African Journal of Biotechnology*. 2006; 5(11): 1102–1106.

[2] Awolu OO, Oluwaferanmi PM, Fafowora OI, Oseyemi GF. Optimization of the extrusion process for the production of ready-to-eat snack from rice, cassava and kersting's Groundnut Composite Flour LWT. *Food Science and Technology*. 2015; 64: 18–24.

[3] Awolu OO, Oyebanji OV, Sodipo MA. Optimization of proximate composition and functional properties of composite flours consisting wheat, cocoyam *(Colocasia esculenta)* and bambara groundnut *(Vigna subterranea)*. *International Food Research Journal*. 2017; 24(1): 268-274.

[4] Omoba OS, Awolu OO, Olagunju AI, Akomolafe AO. Optimisation of plantain-brewer's spent grain biscuit using response surface methodology. *Journal of Scientific Research and Reports*. 2013; 2(2): 665- 681.

[5] Ganongo-Po FB, Matos L, Kimbonguila A, Ndangui CB, Nzikou JM, Scher J. Sieving Effect on the Physicochemical and Functional Properties of Taro (*Colocasia esculenta.*) Flour. *Advance Journal of Food Science and Technology*. 2018; 14 (2): 42-49.

[6] Rashmi DR, Raghu N, Gopenath TS, Pradeep P, Pugazhandhi B, Murugesan K, Ashok G, Ranjith MS, Chandrashekrappa GK, Kanthesh MB. Taro (*Colocasia esculenta*): An overview. *Journal of Medicinal Plants Studies*. 2018; 6(4): 156-161.

[7] FAO. Food and Agriculture Organization of the United Nations. Statistics Division: Production of Taro. 2020.

[8] Ribeiro PP, Bertozzi AME, Nitzsche TFCAC, Afonso VM, Margaret FPV. Anticancer and Immunomodulatory Benefits of Taro (*Colocasia esculenta*) Corms, an Underexploited Tuber Crop. *International Journal of Molecular Sciences*. 2021; 22(265): 1-32.

[9] Ojinaka MC, Akobundu ENT, Iwe MO. Cocoyam starch modification effects on functional, sensory and cookies qualities. *Pakistan Journal of Nutrition. 2009;* 8: 558-567.

[10] Lewu MN, Adebola PO, Afolayan AJ. Effect of cooking on the proximate composition of the leaves of some accessions of *Colocasia esculenta* (L.) Schott in KwaZulu-Natal province of South Africa. *African Journal of Biotechnology*. 2009; 8(8): 1619–1622.

[11] Jayanthi A, Pritha C, Papiya D, Sudeshna C, Bohnisikha C. Cytotoxicity and antimicrobial activity of *Colocasia esculenta. Journal of Chemical and Pharmaceutical Research. 2015;* 7(12): 627-635*.*

[12] Saklani A, Kaushik R, Chawla P, Kumar N, Kumar M. Effect of taro (*Colocasia esculenta*) enrichment on physicochemical and textural properties of cake. *International Journal of Food Studies*. 2021; 10: 14-25.

[13] Owusu-Darko PG, Paterson A, Omenyo EL. Cocoyam (corms and cormsels) an underexploited food and feed resource. *Journal of Agricultural Chemistry and Environment*. 2014; 03(01): 22-29.

[14] Coronell-Tovar DC, Chávez-Jáuregui RN, Bosques-Vega A, López-Moreno ML. Characterization of cocoyam (*Xanthosoma* spp.) corms flour from the Nazareno cultivar. Food Science and Technology. 2019; 39(2): 349-357.

[15] Bell A, Mueck O, Schuler B. Les richesses du sol: les plantes à raciness et tubercules en Afrique : une contribution au développement des technologies de récolte et d'après-récolte. Ed. Deutsche Stiftung fuer Internationale Entwicklung, Feldafing (Germany). 2000; 237.

[16] Chandra S, Singh S, Kumari D. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal Food Science Technology*. 2015; 52: 3681-3688.

[17] Olaoye OA, Obidegwe F. Chemical Composition, Anti-Nutrients and Functional Properties of Composite Flours Formulated from Wheat and Three Cultivars of Cocoyam Corms (Xanthosoma Sagittifolium) Commonly Found in Nigeria. *Journal of Food Science and Nutrition*. 2018; 4(1): 1-6.

[18] Phillips RD, Chinnan MS, Branch AL, Miller J, Mcwatters KH. Effects of pre-treatment on functional and nutritional properties of cowpea meal*. Journal of Food Sciences. 1988;* 53: 805-809.

[19] Anderson RA, Conway HF, Pfeifer VF, Griffin EL. Roll and extrusion-cooking of grain sorghum grits. *Cereal Sciences Today. 1969;* 14: 372–380.

[20] Eke OS, Akobundu ENT. Functional properties of African yam bean (*Sphenostylis stenocarpa*) seed flour as affected by processing. *Food Chemical. 1993;* 48: 337-340.

[21] Njintang NY, Mbofung CMF, Waldron KW. *In vitro* protein digestibility and physicochemical properties of dry red bean flour (*Phaseolus vulgaris*) flour: effect of processing and incorporation of soybean and cowpea flour. *Journal of Agriculture Food Chemical. 2001;* 49: 2465–2471.

[22] Coffman CWL, Garcia VC. Functional properties and amino acid of a protein isolate from mungbean flour. *Journal of Food Technology. 1977;* 12: 473-484.

[23] Craig SAS, Maningat CC, Seib PA, Hoseney RC. Starch paste clarity. *Cereal Chemistry. 1989;* 45: 378-382.

[24] Mora-Escobedo R, Lopez OP, Lopez GFG. Effect of germination on the rheological and fonctional properties of amaranth sedes. *Lebensmittel Wissenschaft und Technology*. 1991; 24: 241-244.

[25] Narayana K, Narasinga R. Functional properties of raw and heat processed winged bean flour. *Journal of Food Science. 1982;* 47: 1534-1538.

[26] Onwuka GI. Food analysis and instrumentation: theory and practice. Naphtali Prints, Lagos (Nigeria). 2005; 133-137.

[27] Sodhi NS, Singh N. Morphological, thermal and rheological properties of starches separated from rice cultivars grown in India. *Food Chemistry. 2003;* 80: 99–108.

[28] Yu S, Ma Y, Menager L, Sun Da-Wen. Physicochemical properties of starch and flour from different rice cultivars. *Food Bioprocess Technology*. 2010; 5: 626–637.

[29] Singh S, Riar CS, Saxena DC. Effect of incorporating sweet potato flour to wheat flour on the quality characteristics of cookies*. African Journal of Food Science*. 2008; 2: 65-72.

[30] Surbhi A, Shraddha G, Smita T, Shubham M, Rizwan MA. Evaluation of nutritional and functional properties of partially substituted whole wheat flour with taro root and lotus seed flour (Composite flour). *The Pharma Innovation Journal*. 2019; 8(10): 125-128.

[31] Njintang YN, Scher J, Mbofung CMF. Physicochemical thermal properties and microstructure of six varieties of taro (*Colocasia esculenta L. Schott*) flours and starches. *Journal Food Engineering. 2008;* 86: 294–305.

[32] Prinyawiwatkul W, McWatters KH, Beuchat LR, Phillips RD. Functional characteristics of cowpea (*Vigna unguiculata*) flour and starch as affected by soaking, boiling and fungal fermentation before milling. *Food Chemistry*. 1997; 58: 361–372.

[33] Sila B, Malleshi NG. Physical, chemical and nutritional characteristics of premature-processed and matured green legumes. *Journal Food Sciences and Technology*. 2012; 49(4): 459-466.

[34] Kinsella JE. Functional properties of proteins in foods: a survey. *CRC Critical Reviews in Food Science and Nutrition. 1976;* 7: 219–280.

[35] Lawal OS, Adebowale KO. Effect of acetylation and succinylation on solubility profile, water absorption capacity, oil absorption capacity and emulsifying properties of muncuna bean (*Mucuna pruiens*) protein concentrate. *Nahrung/Food*. 2004; 48(2): 129-136.

[36] Yusuf AA, Ayedun H, Sanni LO. Chemical composition and functional properties of raw and roasted Nigerian benniseed (*Sesamum indicum*) and Bambara groundnut (*Vigna subterranean*). *Food Chemistry*. 2008; 111: 277-282.

[37] Nelson-Quartey FC, Amagloh FK, Oduro I, Ellis WO. Formulation of an infant food based on breadfruit (*Artocarpus altilis*) and breadnut (*Artocarpus camansi*). *Acta Horticulturae (ISHS). 2008;* 757: 212-224.

[38] Lazaridou A, Duta D, Papageorgiou M, Belc N, Biliaderis CG. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations.*Journal of Food Engineering*. 2007; 79: 1033–1047.

[39] Aguemon TM, Mankambou JG, Tetchi AF, Dué EA, Kouamé LP. Evaluation of functional properties of *blighia sapida* seeds flour from Côte d'Ivoire. *European Journal of Pharmaceutical and Medical Research*. 2019; 6(6): 88-95.

[40] Hasmadi M, Noorfarahzilah M, Noraidah H, Zainol MK, Jahurul MHA. Functional properties of composite flour: a review. *Food Research*. 2020; 4(6): 1820 – 1831.

[41] Kaur M, Kaushal P, Sandhu KS. Studies on physicochemical and pasting properties of taro (*Colocasia esculenta L.*) flour in comparison with a cereal, tuber and legume flour. *Journal of Food Sciences Technology. 2011;* 48: 1-7.

[42] Diallo KS, Soro D, Koné KY, Assidjo NE, Yao KB, Gnakri D. Fortification et substitution de la farine de blé par la farine de Voandzou (*Vigna subterranea* L. verdc) dans la production des produits de boulangerie. *International Journal of Innovation and Scientific Research*. 2015; 18 (2): 434-443.

[43] Olakunle MM, Olalekan JA. Vitamins, Functional and Sensory Attributes of Biscuit Produced from Wheat-Cocoyam Composite Flour. *Journal of Scientific and Innovative Research*. 2020; 9(2): 77-82.

[44] Mepba HD, Eboh L, Nwaojigwa SU. Chemical composition, functional and baking properties of wheat-plantain composite flours*. African Journal of Food Agriculture, Nutrition and Development*. 2007; 7(1): 1-22.

[45] Suresh C, Samsher S, Durvesh K. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology*. 2015; 52: 3681-3688.

[46] Mbofung CMF, Aboubakar NYN, Njintang YN, Abdou BA, Balaam F. Physicochemical and functional properties of six varieties of taro (*Colocasia esculenta* L. Schott) flour. *Journal Food Technology. 2006;* 4: 135–146.

[47] Hernandez-Nava RG, Bello-Perez LA, San Martın-Martınez E, Hernandez-Sanchez H, Mora-Escobedo R. Effect of extrusion cooking on the functional properties and starch components of lentil/banana blends: response surface analysis. *Revista Mexicana de Ingeniería Química*. 2011; 10(3): 409-419.

[48] Chiang PY, Li PH, Huang CC, Wang CCR. Changes in functional characteristics of starch during water caltrop (trapa quadrispinosa 207 roxb.) *growth. Food Chemistry. 2007;* 104: 376-382.

[49] Oppong D, Eric A, Kwadwo SO, Badu E, Sakyi P. Proximate composition and some functional properties of soft wheat flour. *International Journal of Innovative Research in Science, Engineering and Technology*. 2015; 4(2): 2319 – 8753.

[50] Amon AS, Soro YR, Koffi KBP, Ahipo DE, Kouamé LP. Biochemical characteristics of flours from ivorian taro (*Colocasia esculenta,* Cv *Yatan*) corms as affected by boiling time. *Advance Journal of Food Science and Technology. 2011;* 3(6): 424-435.

[51] Akubor PI, Badifu GIO. Chemical composition, functional properties and baking potential of African breadfruit kernel and wheat flour blends*. International Journal of Food Science & Technology*. 2004; 39(2): 223 – 229.

[52] Peter-Ikechukwu AI, Ogazi CG, Uzoukwu AE, Kabuo NO, Chukwu MN. Proximate and functional properties of composite flour produced with date fruit pulp, toasted watermelon seed and wheat. *Journal of Food Chemistry & Nanotechnology. 2020;* 6(3): 159-166.

[53] Salma HA, Mohamed ME, Elfadil EB, Isam AMA, Suha OA. Functional properties of selected legumes flour as influenced by pH. *Journal of Agricultural Technology*. 2011; 7(5): 2091-2102.

[54] Suresh C, Samsher. Assessment of functional properties of different flours. *African Journal of Agricultural Research*. 2013; 8(38): 4849-4852.

[55] Moure A, Sineiro J, Dominguez H, Parato JC. Functionality of oilseed protein products: A revie. *Food Research International*. 2006; 38(9): 945-963.

[56] Oluwamukomi MO, Akinsola OO. Thermal and Physicochemical Properties of Some Starchy Foods: Yam (Dioscorea rotundata), Cocoyam (Xanthosoma sagittifolium) and Plantain (Musa paradisiaca). *Food Science and Technology*. 2015; 3(1): 9-17.

[57] Shittu TA, Raji AO, Sanni LO. Bread from composite cassava wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. *Food Research International. 2007;* 40: 280–290.

[58] Maha AMA, Abdullahi HET, Abd Elmoneim OE, Limya OM, Elfadil EB. Effect of Different Supplementation Levels of Soybean Flour on Pearl Millet Functional Properties. *Food and Nutrition Sciences*. 2012; 3: 1-6.

[59] Chukwu MN, Kabuo NO, Nwokocha NJ. Effects of fermentation time on the functional properties of ogiri-ahuekere (Arachis hypogaea Linn) seed condiment. *International Journal of Biotechnology and Food Science. 2018;* 6(5): 77-85.

[60] Oluwaseun PB, Fasogbon BM. Nutritional and functional properties of maizeoyster mushroom (*Zea mays-Pleurotus ostreatus*) based composite flour and its storage stability. *Open Agriculture*. 2020; 5: 40-49.

[61] Oladele AK, Aina JO. Chemical composition and properties of flour produced from two varieties of tigernut (*Cyperns esculentus*). *African Journal of Biotechnology*. 2009; 6(1): 2473-2476.

[62] Lewis MJ. Density and specific gravity of Foods. In: Physical properties of foods and food processing systems. Ellis Howard Ltd, Chichester, England. 1987; 53-57.

[63] Bello-Perez LA, Romero-Manilla R, Paredes-Lopez O. Preparation and Properties of Physically Modified Banana Starch Prepared by Alcoholic-Alkaline Treatment. *International Information System for the Agricultural Science and Technology*. 2000; 52 (5): 154-159.

[64] Gani A, Haq SS, Masoodi FA. Broadway AA. Physico-chemical, morphological and pasting properties of starches extracted from water chestnuts (Trapa nata). From three lakes of Kashmir, India. *Brazilian* Archives of *Biology* and *Technology: An International Journal*. 2010; 53: 731-740.

[65] Tetchi FA, Amani NG, Kamenan A. Contribution to light transmittance modelling in starch media. *African Journal of Biotechnology. 2007;* 6: 569-575.

[66] Nuwamanya E, Chiwona-Kaltun L, Kawuki RS, Baguma Y. Bio - ethanol production from non-food part of cassava (Manihot esculenta Crantz). *AMBIO Journal of Human Environment*. 2011; 10: 1-16.

[67] Mweta DE, Labuschagne MT, Koen E, Benesi IRM, Saka JDK. Some properties of starches from cocoyam (*Colocasia esculenta*) and cassava (Manihot esculenta Crantz.) grown in Malawi. *African Journal Food Sciences. 2008;* 2: 102-111.

[68] Aprianita A, Todor V, Anna B, Stefan K. Physicochemical properties of flours and starches derived from traditional Indonesian tubers and roots. *Journal of Food Science* and *Technology. 2013;* 51(12): 3669–3679.

[69] Sindhu R, Khatkar BS. Physico-chemical and functional properties of starch and flour of Amaranth (Amaranthus hypochondriacus) seeds, *Annals of Agricultural and Biological Research*. 2016; 21 (2): 168-173.

[70] Nguyen SHT, Webba HK, Hasan J, Tobin MJ, Crawford RJ, Ivanova EP. Dual role of outer epicuticular lipids in determining the wettability of dragonfly wings. *International Journal of Engineering Science*. 2013; 106: 126-134.

[71] Okafor DC, Ibeabuchi JC, Serah A, Enwereuzoh RO, Uzoukwu AE. Udenkwo C. Production of flour types from black bean (phaseolus vulgaris) and effect of ph and temperature on functional physico-chemical properties of the flours. *European Journal of Food Science and Technology*. 2015; 3(2): 64-84.

[72] Mohebby B, Fallah-Moghadam P, Ghotbifar AR Kazemi-Najafi S. Influence of Maleic-Anhydride-Polypropylene (MAPP) on Wettability of Polypropylene/Wood Flour/Glass Fiber Hybrid Composites. *Journal of Agricultural Science and Technology*. 2011; 13: 877-884.

[73] Aremu MO, Olaofe O, Akintayo ET. Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. *Journal of Food Technology*. 2007; 5: 109–115.

[74] Ubbor SC. Akobundu ENT Quality characteristics of cookies from composite flours of watermelon seed, cassava and wheat. *Pakistan Journal of Nutrition*. 2009; 8: 1097-1102.

[75] Siddiq M, Ravi R, Harte JB, Dolan KD. Physical and functional characteristics of selected dry bean (*Phaseolus vulgaricus* (L.) flours. *LWT-Journal Food Sciences and Technology*. 2010; 43: 232-237.

[76] Seena S, Sridhar KR. Physicochemical, functional and cooking properties of under explored legumes, Canavalia of the southwest coast of India. *Food Research International*. 2005; 38: 803–814.

[77] Okpala L, Okoli E, Udensi E. Physico-chemical and sensory properties of cookies made from blends of germinated pigeon pea, fermented sorghum, and cocoyam flours. *Journal of Food Science and Nutrition*. 2013; 1(1): 8-14.

[78] Kacou MA, Ekissi GSE, Ebbah-Djedji BC, N'zué B, Kouamé PL. Assessment of Functional Properties Flours from Seven Local Varieties of Cassava (*Manihot esculenta* Crantz) Consumed in Côte d'Ivoire. *International Journal of Current Microbiology and Applied Sciences. 2018;* 7(10): 815-826.

[79] Klang J M, Tene S T, Kalamo LGN, Boungo GT, Houketchang SCN, Foffe HAK, Womeni HM. Effect of bleaching and variety on the physico-chemical, functional and rheological properties of three new Irish potatoes (Cipira, Pamela and Dosa) flours grown in the locality of Dschang (West region of Cameroon). *Heliyon*. 2019; 5: 1-14.

[80] Schuck P. Modifications des propriétés fonctionnelles des poudres de protéines laitières: Impact de la concentration et du séchage. *Innovations Agronomiques. 2011;* 13: 71-99.

[81] Oulaï SF, Ahi AP, Kouassi-Koffi JD, Gonnety JT, Faulet BM, Djè MK, Kouamé LP. Treatments Effects on Functional Properties of Breadfruit (Artocarpus altilis) Pulp Flour harvested in Côte d'Ivoire. *International Journal of Recent Biotechnology*. 2014; 2(4): 1-12.

[82] Kulkarni KD, Kulkarni DN, Ingle UM. Sorghum malt-based weaning formulations. Preparation, functional properties, and nutrictive value. *Food and Nutrition Bulletin. 1991;* 13: 322-327.

[83] Eke-Ejiofor J, Barber LI, Kiin-Kabari DB. Effect of Pre-Boiling on the Chemical, functional and Pasting Properties of Rice. *Journal of Agriculture and Biological Sciences. 2011;* 2: 214 -219.

[84] Edema MO, Sanni LO, Sanni AI. Evaluation of maize-soybean flour blends for sour maize bread production in Nigeria. *African Journal of. Biotechnology*. 2005; 4 (9): 911–918.

[85] Eiamwat J, Wanlapa S, Kampruengdet S. Physicochemical Properties of Defatted Rambutan (*Nephelium lappaceum*) Seed Flour after Alkaline Treatment. J*ournal Molecules*. 2016; 21: 1-7.

[86] Rayan AM, El-Shamei ZS, Shatta AA, Gab-Alla AA, Moussa EA. Physicochemical properties of starch isolated from genetically modified corn (Ajeeb YG). *Journal of Agroalimentary Processes and Technologies*. 2015; 21(1): 53-66.