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

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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,
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, Luzernestrasse, 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:

\[
WAC(\%) = \frac{M2 - M1}{M1} \times 100
\]

\[
WSI(\%) = \frac{M0 - M1}{M0} \times 100
\]

The method of [20] was used to determine the oil absorption capacities (OAC) of flours. One (1) g (M0) of flour 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:

\[
OAC(\%) = \frac{M1 - M0}{M0} \times 100
\]

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:

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

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

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.

\[
D(\%) = \frac{V0 - Vt}{Vt} \times 100
\]
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 ($V_t$) was obtained.

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

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

$$P \ (%) = \frac{V_0 - V_t}{V_0} \times \ 100$$

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 breakdown 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 amylopectin. Indeed, [48] attributed the increased solubility to the solubilization of amyllose 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) and 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 | 0.50±0.01 | 0.53±0.05 | 0.53±0.05 | 0.56±0.11 | 0.60±0.01 |
| **Bulk density (g/mL)**      | 0.85±0.01 | 0.84±0.03 | 0.84±0.11 | 0.84±0.10 | 0.82±0.04 | 0.82±0.02 |
| **Clarity (%)**              | 0.84±0.02 | 0.82±0.02 | 0.74±0.04 | 0.70±0.01 | 0.69±0.01 | 0.69±0.01 |
| **Wettability (Sec)**        | 193.66±3.21 | 193.66±3.50 | 179.00±1.00 | 171.00±3.00 | 165.33±2.57 | 159.66±2.88 |
| **WAC (%)**                  | 120.58±0.38 | 121.08±0.77 | 122.43±0.76 | 123.79±1.31 | 124.89±1.85 | 126.92±0.63 |
| **WSI (%)**                  | 20.66±1.15 | 21.00±1.00 | 21.33±0.57 | 21.46±0.57 | 21.00±1.00 | 20.33±0.57 |
| **Porosity (%)**             | 49.01±0.84 | 48.74±1.62 | 48.58±1.40 | 48.05±0.86 | 47.53±0.89 | 46.19±0.82 |
| **FC (%)**                   | 10.33±1.15 | 9.73±1.14 | 8.67±1.10 | 8.67±1.15 | 6.67±1.15 | 6.67±1.15 |

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 (3%); **FCF6**: composite flour from wheat flour (97%) 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 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         |
|--------------------|--------------------|---------------|---------------|---------------|---------------|---------------|
| Refined 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\(^d\) |
| Unrefined palm     | 380.00±1.00\(^d\)  | 374.00±1.00\(^e\) | 369.66±0.57\(^d\) | 364.00±1.00\(^c\) | 363.00±1.00\(^b\) | 361.00±1.00\(^d\) |
| Tournesol          | 98.66±0.57\(^d\)   | 95.33±0.57\(^c\) | 94.33±0.57\(^b\) | 94.00±1.00\(^a\) | 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         |
|-----------------------|-------------|--------------|---------------|---------------|---------------|---------------|
| Refined palm (Dinor)  | 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\(^a\) |
| Unrefined palm (Red oil) | 0.31±0.06   | 0.32±0.02\(^a\) | 0.32±0.04\(^a\) | 0.33±0.02\(^b\) | 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\(^d\) | 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 oil. 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.

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

**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

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Disclosure of conflict of interest
The authors declare no conflict of interest.

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