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Functional properties and the antioxidant activity of *Curcuma longa* cultivated in Côte D'Ivoire

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Abstract

This study investigated some quality attributes of the functional properties of turmeric rhizome flour cultived in Côte d'Ivoire. It consisted in comparing the properties of turmeric powder with film (PWF) and powder without film (PWAF) to identify nutritionally and technologically appropriate uses. In terms of functional properties, the PWAF had the best water absorption rates (1032.156 ± 34.016%), the best stability properties (74.3%), the water solubility index (19.50%) and very good wettability (21.33 S ± 0.58). Furthermore, the dispersibility (21.3% to 41.2%), the hydrated density (1.17 ± 0.14g / ml) and the oil absorption capacity (300% to 975%) fell within the range of PWF. The study of the functional properties revealed that turmeric powders can be recommended in food formulations but the most suitable is the PWAF. Regarding the antioxidant activity, the PWF had the highest value of total vitamin E (1167.07 ± 0.62), α-tocopherol (2.72 ± 0.02) and γ-tocopherol (1134.22 ± 0.55). On the other hand, PWAF had a high value in δ-tocopherol (43.83 ± 0.06) but low in total vitamin E (443.54 ± 0.65) and in α-tocopherol (1.078 ± 0. 03). The contents of total polyphenols and total flavonoids are raised respectively 179.16 ± 0.61 mg/100g and 25.68 ± 0.32 mg/100g for the PWP flour. As for vitamin C, it gave respectively values of 137.67 ± 0.58 mg/100g for the PWP while the PWAF provided 112.17 ± 0.58 mg/100g. The DPPH and FRAP tests showed that turmeric with film is richer in anti-free radical activity than PWAF. The IC50s of the extracts PWF and PWAF on DPPH are respectively 0.032 mg / ml and 0.049 mg / ml. This research proved that functional properties value plus the oxidizing activity, make turmeric flour a functional food.

Keywords: *Curcuma longa* L; Antioxidant Activity; Functional Properties; Powder without Film; Polyphenols

1. Introduction

Curcuma longa L. is an herbaceous plant originally from India belonging to the Zingiberaceae family and, although it is grown in different tropical and subtropical regions around the world [1]. Its culture, still little known, is gradually gaining ground with the popularization of its medicinal and cosmetic virtues. Therefore, turmeric is used as a medicine, as a cosmetic product, but also as a spice. *Curcuma longa L* is a plant from which bears rhizomes similar to those of ginger, but orange in color. In effect, turmeric is a spice appreciated for its aromatic, antioxidant, antimicrobial, and anti-inflammatory properties used in pharmaceuticals and traditional medicine [2; 3]. In recent years, particular attention has been paid to the antioxidant activity of Curcuma longa L. because of its role in the prevention of chronic diseases such as heart disease, cancer, diabetes, hypertension, and Alzheimer's disease by fighting oxidative stress [4]. In addition, the rhizome is used in various forms, either raw or extracted. In fact, essential oil and turmeric powder are generally the two forms most used in commerce, kitchens and the food industry [5]. The powdered rhizome is also used as a food spice to enhance and preserve the flavor of foods, and as a food and textile coloring [5]. In line with this, the

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objective of this study was conducted to determine antioxidant capacity and analyze the functional properties of flours from turmeric cultivated in Côte d'Ivoire.

2. Material and methods

2.1. Collection of samples

Curcuma longa L rhizome roots were purchased in the market of Tiassalé (Côte d'Ivoire). These collected samples were transported in jute bags to the Nutrition and Food Safety laboratory for analysis after washed with distilled water. These cleaned and washed rhizomes were boiled for 5 minutes to remove the earthy odor. They were then cooled for 10 minutes and then divided into two lots: one lot with film and the other lot without film. These different batches were cut into thin strips; then dried at 45 °C for 24 hours in an oven. After drying, the batches were ground and sieved of diameter 500 to obtain the powder with film noted PAP and the other powder without film (PSP).

2.2. Functional properties

2.2.1. Water absorption capacity and Water Solubility Index

The water absorption capacity (WAC) and solubility index of flours from curcuma were evaluated according to Phillips et al. [6] and Anderson *et al* [7] method respectively. Two gram of flour was weighed into a centrifuge tube and 50 mL distilled water added. The content of the centrifuge tube was shaken for 30 min in a KS 10 agitator. The mixture was kept in a water-bath (37ºC) for 30 min and centrifuged (Ditton LAB centrifuge, UK) at 5000 rpm for 15 min. The resulting sediment (M2) was weighed and then dried at 105 °C to constant weight (M1). The WAC and the WSI were then calculated as follows:

$$WAC(\%) = \frac{M2-M1}{M2} X100 \qquad WSI(\%) = \frac{M0-M1}{M0} X100$$

Where:

WAC= Water Absorption Capacity
M1= Dry mass of the sample after drying in grams
M2= freshness of the sample after centrifugation in grams
M0 = the original weight of sample in grams
WSI= Water Solubility Index

2.2.2. Oil absorption capacity

For the oil absorption capacity, the method of [8] was used. One gram (1 g) of flour sample was mixed with 10 mL of oil for 30 min in a mixer (Vari-whirl-mixing control set at fast speed). The sample was then allowed to stand at room temperature for 30 min. It was then centrifuged at 5000 rpm for 30 min, using a spinner (Ditton LAB centrifuge, UK) and the volume of the supernatant noted in a 10 mL graduated cylinder. The density of the oil was determined too. The volume of oil absorbed was multiplied by the density of the oil to determine the weight of oil so absorbed.

$$OAC\ (\%) = \frac{(V1 - V0)\ x\ P}{W} X100$$

Where:

OAC= oil absorption capacity
V1 = Initial volume of oil used
V2 = Volume remaining (not absorbed)
P = density of the oil used
W = Weight of sample

2.2.3. Hydrophilic-lipophilic ratio

The hydrophilic-lipophilic ratio (HLR) as defined by [9], was calculated as the ratio of water absorption capacity to oil absorption capacity. This ratio allows the comparative affinity of the powders to be evaluated for water and for oil. The hydrophilic-lipophilic ratio was defined by the following mathematical expression:

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

Where:

WAC = Water Absorption Capacity
OAC = Oil Absorption Capacity

2.2.4. Foaming capacity and foam stability

The foaming capacity (FC) and stability (FS) of flour was studied according the method of [10]. Three gram (3 g) of flour was transferred into clean, dry and graduated (50 mL) cylinders. The flour sample was gently levelled and the volumes noted. Distilled water (30 mL) was added to the sample; the cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 15 min.

$$FC(\%) = \frac{VT - V0}{V0} X100 \qquad FS(\%) = \frac{FC}{FC0} X100$$

Where;

V0 is the original volume of sample (mL)
Vt is the total volume after different times (mL)
FC is the foam capacity (FC) at 0 min;
FS is the foam stability

2.2.5. Hydrated density

The hydrated density was evaluated according to the method of [11], by pouring 0.5 g of flour (carefully to avoid sticking to the walls of the test tube) into 5 ml of distilled water contained in a 10 ml graduated cylinder. The difference between the volume of water before and after addition of 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.

2.2.6. Determination of Wettability

The method described by [12] was adopted. One gram (1 g) of flour sample was measured into a 10 cm^3 measuring cylinder. The cylinder was inverted at 10 cm above the water contained in 600 mL beaker. The finger was used to close the cylinder disallowing the flour sample from falling. By removing the finger and giving the cylinder a gentle tap, the flour sample was discharged into the water surface. The time taken by the sample to get completely wet was recorded as the time of wettability.

2.2.7. Dispersibility

The dispersibility of turmeric rhizome flour was measured according to the method of [13]. One gram of the flour was dispersed in distilled water in a 100mL stoppered measuring cylinder. Then distilled water was added to reach a volume of 30mL, the mixture was stirred vigorously and allowed to settle for three hours, the volume of settled particles was subtracted from 30 and multiplied by 100 and reported as percentage dispersibility

$$D\ (\%) = \frac{V0 - VT}{V0} X\ 100$$

Where:

D=Dispersibility
V_0 = Particle volume just after stirring (ml)
V_t = Volume of deposited particles recorded at time t

2.3. Study of anti-free radical activity

2.3.1. Vitamin E dosage

The identification and determination of the different vitamins (α-, γ-, and δ-) contents were carried out according to the standard method ISO 9936: [14] by high performance liquid chromatography

2.3.2. Total polyphenols

The total polyphenol content was determined by the method described by [15], using the Folin-Ciocalteu reagent, based on the fact that the phenolic compounds form a complex redox with the phosphotungstic (H3PW12O40) and phosphomolibdic (H3PMo12O40) acids. 1 g of sample was dried and ground then homogenized in 10 mL of 70% methanol and then centrifuged at 1000 rpm for 10 min. Then the pellet was recovered in 10 mL of 70% methanol and centrifuged again. The supernatants were pooled in a 50 mL flask and adjusted with distilled water. One (01) mL of this methanolic extract was taken from a tube and was added to 1 mL of Folin-Ciocalteu's reagent. The tube was allowed to stand for 3 min and 1 mL of 20% sodium carbonate solution was added to it. Then the volume was adjusted to 10 mL with distilled water and the tube was placed in the dark for 30 min, then the reading of the optical density was read on a spectrophotometer at 725 nm against the blank. A calibration range was carried out using a standard solution of gallic acid at 1 mg/mL.

2.3.3. Total flavonoids

The flavonoid content is determined according to [16]. This method is based on the formation of a yellow chromophore between the hydroxyl groups of flavonoids with aluminum. Rutin is used for the calibration curve. Absorbance was measured at 430 nm with a UV-VIS spectrophotometer [17]. To perform the assay, one (01) ml of sample or standard (prepared in methanol) was added to 1 ml of the aluminum trichloride solution AlCl3 (2% in methanol). After 10 minutes of reaction, the absorbance is measured at 430 nm. A calibration ranged with rutin made it possible to determine the total flavonoid content of the extracts, the results are expressed in mg of rutin equivalent/g of dry extract.

2.3.4. Vitamin C

The dosage of vitamin C was done according to the method of [18]. Ten (10) g of sample were ground then dissolved in 40 mL of 20% metaphosphoric acid-acetic acid then centrifuged at 3000 rpm for 20 min. The supernatant was introduced into a 50 mL flask and adjusted with boiled distilled water then cooled in the absence of air. Then 10 mL of the contents of the flask were withdrawn and titrated with a solution of 2.6 DCPIP at 0.5 g/L until the color changed to persistent pink.

2.3.5. DPPH free radical scavenging test (2.2'-diphenyl-1-picrylhydrazyl)

The DPPH radical scavenging activity was measured according to the protocol described by [19]. Fifty (50) µl of each methanolic solution of the extracts at different concentrations were added to 1.95 ml of the methanoic solution of DPPH (0.025g / l). At the same time, a negative control was prepared by mixing 50 µl of methanol with 1.95 ml of the methanolic solution of DPPH. The absorbance reading was taken against a blank prepared for each concentration at 515 nm after 30 min incubation in the dark and at room temperature. The positive control was represented by a solution of a standard antioxidant; ascorbic acid, the absorbance of which was measured under the same conditions as the samples and for each concentration [20].

Results were expressed as anti-free radical activity or free radical inhibition in percent (I %) using the following formula:

$$I\ (\%) = \left[1 - (\text{Sample absorbance} - \text{Absorbance of negative control}) \right] \times 100$$

2.3.6. Ferric reducing-antioxidant power (FRAP): iron reduction test

The reducing power of iron (Fe3 +) in the extracts was determined according to the method described by [21]. The iron reduction method is based on the reduction of ferric iron to iron salt by the antioxidants which give the color blue. One milliliter of the extract at different concentrations (from 0.007 to 2.5 mg / ml) was mixed with 2.5 ml of a 0.2 M phosphate buffer solution (pH 6.6) and 2.5 ml of a solution of potassium ferricyanide K3Fe (CN) 6 to 1%. The whole was incubated in a water bath at 50 ° C for 20 min then; 2.5ml of 10% trichloroacetic acid was added to stop the reaction. The tubes were centrifuged at 3000 rpm for 10 min. An aliquot (2.5ml) of the supernatant was combined with 2.5ml of distilled water and 0.5ml of 0.1% aqueous FeCl3 (Ferric Chloride) solution. The absorbance of the reaction medium was read at 700 nm against a similarly prepared blank, replacing the extract with distilled water which enabled the device to be calibrated (UV-VIS spectrophotometer). The positive control was represented by an antioxidant standard; ascorbic acid, the absorbance of which was measured under the same conditions as the samples. The absorbance is directly proportional to the reducing power. The EC50 value is calculated from the absorbance versus concentration curve of the sample. The percentage of iron reducing power is calculated by the following reaction:

$$Iron\ reducing\ power\ (mg/ml) = \frac{(A0 - A1)}{A0} X100$$

Where A0 is the absorbance of FeCl3
A1 is the absorbance of FeCl3 solution in the presence of the extract [22].

2.3.7. Statistical analysis of the data

All measurements were performed in triplicate. Statistical analyses of the data were performed using Statistical version 7.1 software. Comparisons of means were determined according to the Student Test and statistical significance was set at $p \leq 0.05$.

3. Results and discussion

3.1. Functional properties

Functional properties of foods and flours are influenced by the components of the food material, especially the carbohydrates, proteins, fats and oils, moisture, fibre, ash, and other ingredients or food additives added to the food (flour), such as sugar alcohols [23]. The knowledge functional properties of an ingredient improve manufacturing processes food, because it gives access to its field of use and allows to predict its main effects in a formulation. Such functional properties could be used to determine the suitability or otherwise of the studied turmeric as food additive.

3.2. Water and oil absorption capacity

Interactions of water and oil with flours are very important in food transformation because of their effects on the flavor and texture of foods. Water absorption capacity (WAC) is desirable in most food processing systems to improve yield and provide the appropriate organoleptic properties that make foods unique and acceptable to consumers [24]. Oil holding capacity is also an important physical property for food products since lipids often improve flavor and texture of foods [25]. According [26], the use of flour in a food formulation is strongly linked to its interaction with water. The results of water and oil absorption capacity of the two samples are shown in Table 1. The PWAF flour (1032.156 ± 34.016%) had higher water absorption capacity (WAC) than PWF (838.808 ± 53. 639%).These values are higher than that of cake dried aril and cake roasted aril of *Blighia sapida* collected in Côte d'Ivoire [27]. According to [28], flours with high water absorption are more hydrophilic. This hydrophilicity would be due to polysaccharides but also to proteins. Therefore, the high values of water absorption in these flours could be attributed to the presence of a large amount of hydrophilic constituents. This better explains the high water absorption capacity of turmeric powder. These results are in agreement with those of [29; 30] and [31] who worked respectively on raw and pre-cooked taro corm flours, raw and cooked Xanthosoma corm flours and soaked and cooked rice flours.

Table 1 Hydrated density, wettability, foaming stability, foaming capacity, water solubility, Oil absorption capacity and Water absorption capacity o of flours from curcuma

Parameters	**Content**	
Properties	**PWF**	**PWAF**
Water absorption capacity (%)	838.808 ± 53.639	1032.156 ± 34.016
Oil absorption capacity (%)	975.994 ± 14.323	898.536 ± 32.438
Water Solubility Index (%)	18.783 ± 0.882	19.501 ± 1.118
Foaming capacity (%)	2.289 ± 1.457	4.789 ± 0.087
Foaming stability (%)	22 ± 2.32	25.73 ±1.83
Wettability (S)	78.33 ± 3.05	21.33 ± 0.58
Hydrated density (g/ml)	1.17 ± 0.14	0.56 ± 0.06

As regards the oil absorption capacities, the results of turmeric powders studied in crude palm oil are very high (898% to 975%) superior to those of breadfruit flour from Ghana (150% to 250) [32] and those of sweet potato *Ipomoea*

batatas flour (122 to 149.65 %) [33]. since the turmeric powders studied have a high oil absorption capacity, they could be good lipophilic constituents and therefore suitable for the preparation of sausages, soups and cakes [34]. The oil binding capacity of proteins is a clue to express the capacity to absorb and retain oil, which influences its behavior in food products. It is an important parameter for flours intended for the development of cooked and watery foods. The ability of flours to bind with oil makes them useful in food applications where optimal oil absorption is desired, making flours to have potential functional applications in foods such as production of pastries, sausage. The oil absorption capacity also makes the flour suitable in facilitating enhancement in flavor and mouth feel when used in food preparation [35].

Water Solubility Index (WSI) analysis showed that there was a significant difference ($p \leq 0.05$) between the values of the two turmeric flours. This observation is believed to be due to the fact that the water solubility index (WSI) reflects the extent of starch degradation (Mbofung et al., [36] 2006; Ma et al., [37] 2017). This value observed in table 1 (18.78% to 19.50%) were lower than those of the composite wheat / taro flour (20% to 22.33%) (Mbofung et al., [36]) but higher than those of flours of sweet potato native (3.4 to 9.7%) of Ghana. found by Tortoe et *al*. [38]. Water solubility index cannot be attributed solely to starch degradation. Protein, 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 or powders to be used as thickeners in the food industry [33].

Wettability is a functional property related to the hydration mechanism [39]. In this study, the wettability of the various turmeric powders obtained is from 21.33 S ± 0.58 to 78.33 S ± 3.05. Pohl et al [40] suggested that, a flour is considered to be very wettable if the wettability time is less than 30 s, if it is less than 60 s, the flour is considered to be wettable and if this time is greater than 120 s, the flour is non-wettable. The times of wettability of turmeric flours are lower than those suggested by Moutaleb et *al.* [41] which observed a time of wettability of 234 seconds in composite flours (50-50%) of the vegetable (*Vigna unguiculata*) and of sweet potato (*Ipomoea batatas*) native of Niger. So, we therefore deduce that, turmeric PWAF would be very wettable and turmeric PWF would be wettable. This Tumeric flour wettability would be due on the one hand to the composition of the powders and to the affinity between its components and water, and on the other hand to the accessibility of water in terms of structure (porosity and capillarity) to constituents of flour [42]. According to this author, a flour capable of getting wet would be capable of swelling during handling of the pasta.

Hydrated density analysis shows that there is a significant difference between the two turmeric powders studied. The obtained value for the powder PWAF (0.56 ± 0.06 g/ml) is similar to that recorded by Hsu et al. [43] on yam (0.49 to 0.63 g / ml) but lower than that of wheat flour (0.80 g/ ml) [44] and PWF flour (1,17 ± 0,14 g / ml.) Nutritionally, high hydrated density of flours suggests their suitability for application in food preparations. On the other hand, low hydrated density would be useful in the formulation of complementary foods [35]. Thus, the low hydrated density of turmeric powder suggests that it could be useful in the formulation of food products.

Foaming capacity is by definition the ability of a substance to produce a foam after it has been vigorously homogenized [45]. This property depends on the protein and carbohydrate content [46]. According Akubor, [47], foams are used to improve the texture, consistency and appearance of foods. Protein in the dispersion may cause a lowering of the surface tension at the water-air interface, as protein forms a continuous cohesive film around the air bubbles in the foam [48]. The foaming capacity of turmeric powders ranged between 2.29% and 4.79% are lower than those reported by Kacou et al [49] on cassava flour (5.71-21.42 %) and fruit flour African bread (*Treculia africana*) (20%) [50]. However, this low foaming capacity in this study would probably be attributed to the high content of lipid in the powders as these were not defatted before use [51].

The foam stability refers to the ability of protein to stabilize against the gravitational and mechanical stresses [52]. Flours with high foaming ability could form large air bubbles surrounded by thinner a less flexible protein film. This air bubbles might be easier to collapse and consequently lowered the foam stability [53]. The observed foam stability value for flour PWF was 22% while the value for PWAF was 25%. Therefore, foam stability also depends on molecular size which is directly correlated to interface properties [54]. The values observed in this study were comparatively higher than the value of 1.94%, 4.0%, and 9.2% reported for different flour samples by Suresh et al [55].

3.3. Dispersibility

The dispersibility percentage is an indicator of good water absorption capacity of flours and an indicator of good quality of the gel [56]. The dispersibility percentages of the flours from turmeric powder shown in figure 1varies from 21.3% to 41.2%/ The higher the percentage of dispersibility, the greater the ability of the flour to reconstitute in water to give a fine and cohesive dough. According to Mora-Escobedo et al.[13], the dispersibility of flour gives an indication of the

suspension of the particles in water and constitute a useful functional parameter in the formulations of various food products The values observed in this study were similar to those reported by Himeda ([57] on taro flour (29 - 30.56%); but comparatively lower than those of Eke-Ejiofor et al., [56,45], which worked respectively on local rice (55-66%) and Caprice rice (50-70%) in Nigeria; and some pulp of,the fruit of *Artocarpus altilis* (62-72%). Thus, turmeric powders could not be used as an improver of products resulting from emulsions and foams.

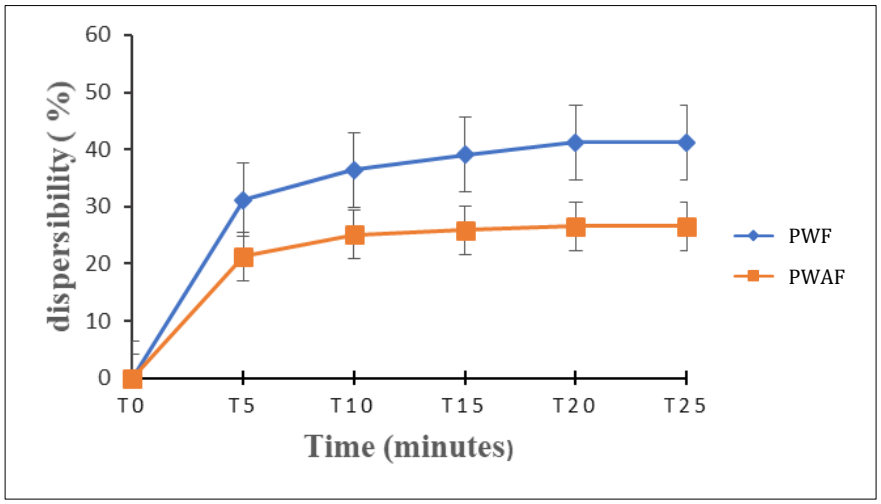

Figure 1 Evolution of dispersibility curve of turmeric rhizome as a function of time

3.4. Hydrophilic-lipophilic ratio

He hydrophilic-lipophilic ratio is a ratio which makes it possible to evaluate the comparative affinity of flours for water and for oil [58]. The values obtained in this study for flours of curcuma were in agreement with those reported by the latter author who worked on flours from the yam *Dioscorea dumetorum* (2.5 to 4.1). The results obtained with refined palm oil and crude vegetable oil are similar to those reported for cowpea (1.12) by Njintang et al. [59]. On the other hand, the hydrophilic / lipophilic ratios of crude palm oil, refined palm oil and vegetable oils concerning curcuma flours are greater than 1. In these cases, the water absorption capacity is greater than oil absorption capacity. These results suggest that flours of curcuma should be intended preferentially for the formulation of products requiring a strong absorption capacity of water.

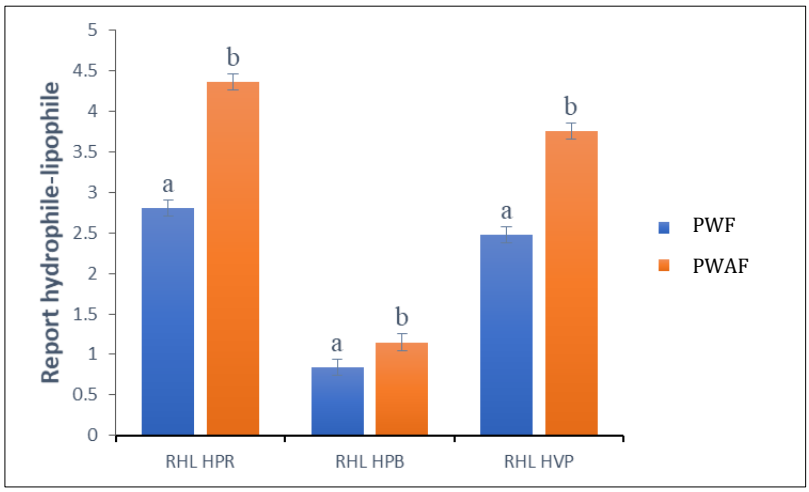

Figure 2 Report hydrophile-lipophile of flours of turmeric rhizome

Turmeric powder contains phytochemicals, such as polyphenols and flavonoid summarized in Table 2. According Nimse and Pal [60], polyphenolic compounds are natural compounds ubiquitous in plants and are the product of secondary plant metabol. In the present study, the total polyphenolic contents of tumeric powder (*Curcuma longa* l.) were ranged from 70.82 ± 0.50 to 179.16 ± 0.61 mg/100g. This value was higher than those reported by Ghazal and Shahhat [61] in

Lupinus termis L. (202.4 µg gallic acid eq)/ g); but lower than *Stenochlaena tenuifolia* leaf (457.01±0.15 mg) [62]. As regards the total flavonoid content of tumeric powder ranging from 13.15 ± 0.23 to 25.68 ± 0.32 mg/100g; it was quite comparable to those of armatum fruit (22.8 ± 1.33 mg/g) by Nyrmala et al.[63]. Whereas, according to Lougasi and Hovari [64] reported that spinach contained 33,86 mg/100g total flavonoids, besides, total flavonoids content of celery root was 2, 59 mg/ 100 g. Flavonoids were a class of natural polyphenolic compounds which cannot be synthesized by humans. These substances possess a series of biological properties, acting on biological systems as antioxidants. Intake of flavonoids may be associated with decreased risk of cancer, cardiovascular and inflammatory diseases in humans [65]. The vitamin C and E content of turmeric powder were respectively between 112.17 – 137.67 mg/100 g and 443.54 – 1167.07 mg/Kg. However, powder with film (PWF) had the highest value in total vitamin E (1167.07 ±0.62 mg/Kg), α-tocopherol (2.72± 0.02 mg/Kg) and γ-tocopherol (1134.22± 0.55 mg/Kg) (figure 3). Plants synthesize a wide range of vitamins that are essential not only for human metabolism but also for plants, because of their redox chemistry and role as cofactors, and some of them also have strong antioxidant potential [66].

Table 2 Levels of total polyphenols, total flavonoids, vitamin C, E of turmeric rhizome powder

components	PWF	PWAF
Total flavonoid (mg/100g)	25.68 ± 0.32	13.15 ± 0.23
Total polyphenolic (mg/100g)	179.16 ± 0.61	70.82 ± 0.50
Vitamin C mg/100g	137.67 ± 0.58	112.17 ± 0.58
Vitamin E(mg/Kg)	1167.07 ± 0.62	443.54 ± 0.65

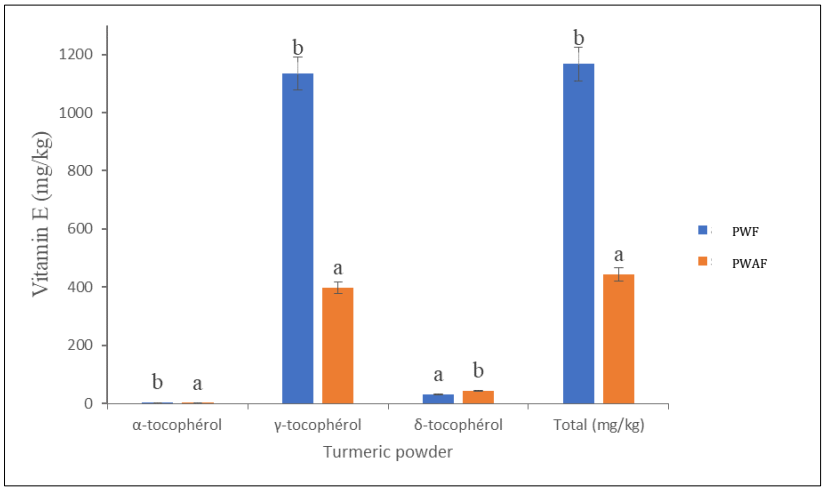

Figure 3 Alpha, beta and gamma tocopherol content in turmeric rhizome powder

3.5. Antioxidant activity

The chemical reaction in the DPPH technique involves the transfer of electrons from a donor (antioxidant) to the free radical DPPH and the reduction of the latter to yellow α-α, diphenyl-b-picryl-hydrazine. Antioxidant activity of turmeric powder was determined by DPPH free radical scavenging assay, and their reducing power was determined on the basis of their concentration providing 50% inhibition (IC50) values. The results obtained in figure 4, showed that The IC50 values for the aqueous extracts of the film and film-free powders were 0.032 mg/mL and 0.049 mg/mL, respectively. Therefore, turmeric flower almost reaches its maximum activity at 0.1 mg / ml with a highest percentage inhibition ranged to 75.50 - 82.13 %. While, ascorbic acid used as a reference inhibited the DPPH radical by 67.71 ± 0.07% at 0.01 mg / ml (Figure 4). The radical scavenging activity of tumeric flower may be due to the presence of polyphenols, flavonoids, and phenolic compounds, and most of the antioxidant activity of plants was because of the phenols [67]. Natural antioxidants present in plants are responsible for inhibiting or preventing the harmful consequences of oxidative stress. DPPH assay among many other assays is one of the convenient methods for determining the antioxidant potential of plants. The presence of antioxidant substances containing hydrogen-donating groups such as flavonoids and phenols causes the methanolic DPPH solution to get reduced due to the formation of non-radical [68]. These results

suggest that *C. longa* rhizomes could serve as an alternative source of antioxidant for the protection of humans against infectious disease and oxidative damage induced by free radicals.

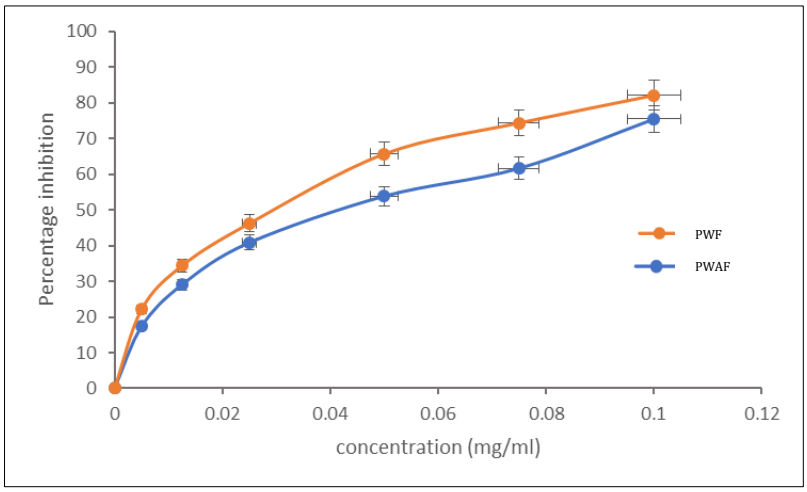

Figure 4 DPPH inhibition percentage curves of different turmeric powders

Concerning the Ferric reducing-antioxidant power test (FRAP), figure 5 showed that ascorbic acid used in this study as a reference had a higher reducing power than those of turmeric powders because at low concentration (0.01 mg / ml), it absorbs 0.17 nm. These results were in agreement with the work of Rebaya et al. [69] who demonstrated a correlation between the content of the extracts in polyphenols and flavonoids of *Cistus salvifolius* and its antioxidant and reducing activity. The work of Ksouri et al. [70] would have also shown that there is a strong correlation between the content of polyphenols and flavonoids in methanolic extracts from the flowers and leaves of *Tamarix gallica* and their antioxidant activity.

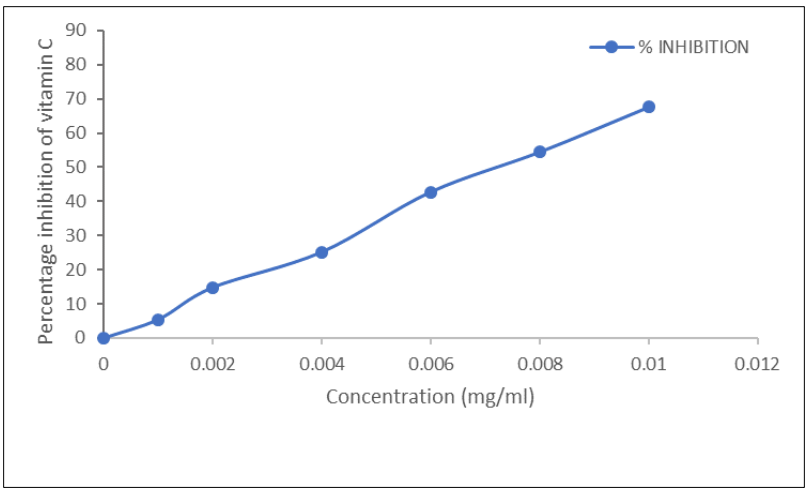

Figure 5 Evolution of vitamin C inhibition curve

The results of the Ferric reducing-antioxidant power test of the formulated extracts of turmeric rhizome were presented in Figure 6. Statistical analysis of these results also showed that the reducing activities of PWF and PWAF were significantly different at the 5% threshold almost at all concentrations except the concentration 0.1 and 0.15 mg/ml. It can be seen from this result that powder with film had a reducing power greater than powder without film. These results suggest that turmeric had great radical activity and remarkable power to give electrons to reactive free radicals (or reactive species), converting them into more stable non-reactive species.

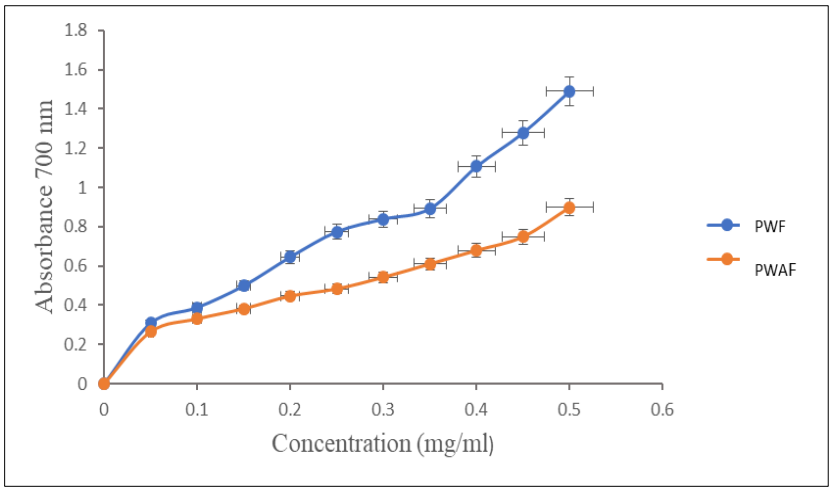

Figure 6 Absorbance curves of different turmeric powders as a function of concentration

4. Conclusion

The result of this study showed that turmeric powder had a high water absorption capacity, a low hydrated density, a low foaming capacity and a low affinity for refined oils. Therefore, these powders can be recommended in the food industry in the preparation of food dough and can also be used in food formulations as a texturing agent, thickening agent. Turmeric rhizome could also be a good source of natural antioxidants. Finally, the natural antioxidants of local plant species and especially those of both types of turmeric powders can be very useful to strengthen the body in case of oxidative stress and prevent various pathologies that may arise after a radical attack. Therefore, this will ensure the proper functioning of the human body thanks to the presence of phytochemicals, such as polyphenols flavonoids and vitamin E which are all powerful natural antioxidants.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have not reported any conflicts of interest.

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