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RESEARCH ARTICLE

ASSESSMENT OF PHYSICOCHEMICAL AND FUNCTIONAL PROPERTIES FROM HEART OF OIL PALM TREE (*ELAEIS GUINEENSIS* JACQ.) CONSUMED IN CÔTE D'IVOIRE.

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Abstract

The heart of the oil palm tree (*Elaeis guineensis* Jacq.) is a vegetable, very little consumed in Côte d'Ivoire and unknown to the population. The aim of this study is to evaluate its nutritional potential in order to contribute to a wide consumption and valorization. Thus the physicochemical and functional properties of different parts (proximal, median, distal) of heart of oil palm tree were assessed. Some physicochemical results obtained are as follows: moisture ($5.87 \pm 0.01 - 10.83 \pm 1.16$ %), crude proteins ($10.7 \pm 0.66 - 13.12 \pm 0.69$ %), crude fiber ($21.98 \pm 0.02 - 34.9 \pm 0.1$ %), ash ($6.91 \pm 0.07 - 8.28 \pm 0.51$ %), carbohydrates ($39.85 \pm 0.06 - 46.42 \pm 0.11$ %) and energy ($270.45 \pm 0.04 - 33.65 \pm 0.01$ kcal/100g). The major mineral is the Potassium ($1412 \pm 224.65 - 1787.43 \pm 75.57$). Some functional properties studied are as follows: Bulk density ($0.54 \pm 0.01 - 0.57 \pm 0.01$ g/cm³), Foam capacity ($26.31 \pm 0.72 - 31.61 \pm 0.54$ %), Water absorption capacity ($453.15 \pm 1.6 - 568.7 \pm 0.89$ %), Water solubility index ($25.4 \pm 0.28 - 30.25 \pm 0.21$ %), Paste clarity (0.16 - 0.21%), Wettability (135.9 - 330 sec). The physicochemical and functional properties of different parts (PP, MP, DP) from heart of oil palm tree core show significant differences ($P < 0.05$).

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Introduction:-

Wild edible plants play many roles in the life of populations. In Africa, thousands of wild plants are used daily by farming communities (Grivetti *et al.*, 1987). These plants contribute substantially to the survival of populations by providing nutrients in their diet. They provide food in the form of fruits, leaves, roots, seeds and other plant parts, either raw or cooked (Shad *et al.*, 2013). Among these plants, we can quote, rônier (*Borassus aethiopum*), coconut (*Coco nucifera*), raffia (*Raffia sp.*) and oil palm tree (*Elaeis guineensis*)

Oil palm tree (*Elaeis guineensis* Jacq.) is a monocotyledon of the Arecaceae family. It is widely grown for its fruits and seeds rich (palm oil) in oil for food and industrial use. For several years, this oil has become the main source of vegetable fats in the world market (Jacquemard, 2012). This oil is more used in food, soap making and cosmetology. Since 2006, 1% of biodiesel was produced from palm oil. In 2010, it became the most consumed vegetable oil in the world (FAO, 2013). In tropical Africa, this plant occupies a predominant position in agricultural production, trade and fat consumption (Aholoukpe *et al.*, 2013).

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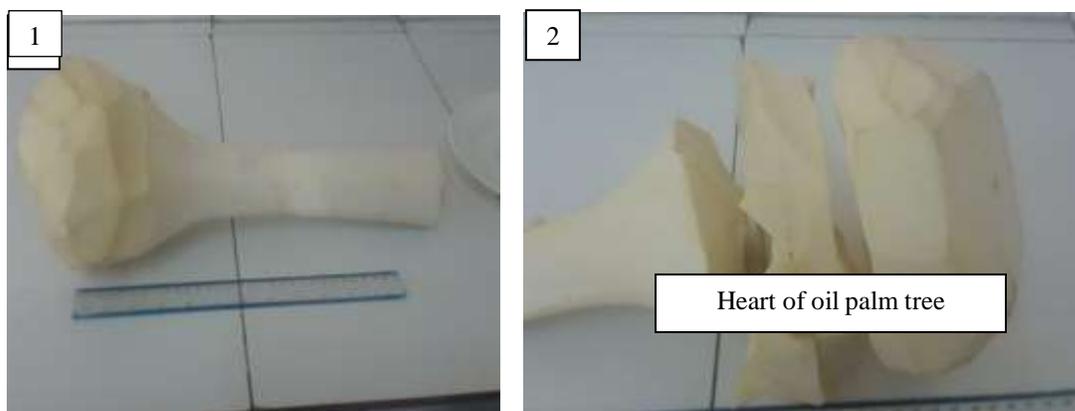
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Introduced in Côte d'Ivoire as part of the political of diversifying cash crops, the palm sector produced 400,000 t of palm oil (FAO STAT, 2013) and has 215,000 hectares of palm grove (Hubert, 2010, CIRAD, 2017). Several food products come from the oil palm: heart of palm, fruits, mushrooms, palm wine, alcohol ... The heart of oil palm tree (internal part of the stem of the tree) is much appreciated by the populations for its aperitive and digestive virtues. In the consumption zones (south, south-west) in Côte d'Ivoire, the palm heart has a socio-cultural value. It is traditionally eaten as vegetables in sauces. Some use it as a beverage, others used it replace breast milk for the infant when the mother dies after childbirth. The heart of the oil palm tree, very difficult to obtain, is a popular vegetable of the populations. Because of its nutritional composition, it could cover several daily nutritional needs (Tabora *et al.*, 1993). Unfortunately it's very little known to other peoples. Its biochemical composition remains unknown. The aim of this study is to evaluate the nutritional potential from the heart of oil palm tree in order to contribute to its valorization.

Materials and Methods:-

Sample collection and preparation:-

The biological material used is the heart of oil palm tree, collected in Soubré (West, Côte d'Ivoire). Put in a cooler to preserve its fresh state, they were transported to the Laboratory of Biochemistry and Food Technology of University of Nangui Abrogoua (Abidjan, Côte d'Ivoire) where study was conducted. The heart of oil palm tree (photography 1) were cut in three equal parts: proximal part (head of heart of oil palm tree), median part (middle) and distal part (tail of heart of oil palm tree) (Photography 1). Each part were peeled, cut in small slices ($4 \times 4 \times 4 \text{ cm}^3$) and washed with distilled water. Five hundred (500) g of slices in each lot were dried at 45°C during 48 h. The dried slices were ground and pass through sieve ($250 \mu\text{m}$ size). The obtained flour was kept for analysis.



Photography 1:- Heart of oil palm tree (*Elaeis guineensis* Jacquin), 2- different parts of the heart of oil palm tree (A: proximal part (PP); B: median part (MP); C: distal part (DP))

Proximate analysis:-

Moisture content (on dry weigh basis) was determined on fresh sliced samples after oven drying at 105°C for 24 h according the procedure of AOAC (1990). Sugars were extracted from flours using 80% aqueous ethanol. Total sugars were determined using the method of phenol-sulfuric (Dubois *et al.*, 1991). Reducing sugars were determined according to the method of Bernfeld (1955) using DNS. Crude fat was determined exhaustively extracting sample of flours in a soxhlet apparatus using anhydrous hexan as solvent. Nitrogen was determined by the Kjeldahl method reported by AOAC (1990) and crude protein content was subsequently calculated by multiplying the nitrogen content by a factor of 6.25. Ash content was determined by measurement of residues left after combustion in a furnace at 550°C for 8 h (AOAC, 1990). Fiber estimate was obtained from the loss in weight of dried residue following the digestion for fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions. Energy were obtained by the summation of multiplied mean values for protein, fat and carbohydrate by their respective Atwater factors, 4, 9 and 4 (Udosen, 1995). Carbohydrate were calculated using the following formulas (FAO, 2002): Carbohydrates (dry matter basis) = $100 - (\% \text{ moisture} + \% \text{ proteins} + \% \text{ lipids} + \% \text{ ash} + \% \text{ fibers})$

Minerals analysis:-

The mineral elements were analyzed after wet-ashing using the scanning electron microscope (SEM) with variable pressure (SEM FEG Zeiss Supra 40 VP). This SEM is equipped with an X-ray detector (Oxford Instruments) connected to an energy diffusion spectrometry (EDS) microanalyzer platform (Inca Cool Dry, without liquid nitrogen). About 10 mg of the sample ash residue were applied evenly to a primed platform with double-sided adhesive carbon for analysis. To measure the content of chemical elements, the device performs a measurement of the transition energy of the electrons from electronic clouds of the K, L and M series of atoms of the sample.

Functional properties:-**Bulk density (BD):-**

The method described by Oladele and Ainaby (2007) was used for the determination of bulk density. 50 g from heart of oil palm tree flour was put into 100 ml measuring cylinder. The measuring cylinder was then tapped continuously on a laboratory table until a constant volume was obtained. BD (g/cm^3) was calculated using following the formula:

$$\text{BD (g/cm}^3\text{)} = \frac{\text{Weight of sample}}{\text{Volume of sample after taping}}$$

Foam Capacity (FC) and Foam Stability (FS):-

The foam capacity (FC) and stability (FS) of flour from heart of oil palm tree were studied by the method of Coffman and Garcia (1977). 3g of flour was transferred into clean, dry and graduated (50 ml) cylinders. The flour samples were gently level and the volumes noted. Distilled water (30 ml) was added to each sample; the cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 10 min. The FC (%) and FS (%) values were calculated as follows:

$$\text{FC (\%)} = \frac{V_t - V_0}{V} \times 100$$

$$\text{FS (\%)} = \frac{\text{FC}}{\text{FC}_0} \times 100$$

Where V_0 (ml) is the original volume of sample, V_t is the total volume after different times (ml) and FC_0 is the foam capacity at 0 min.

Water Absorption Capacity (WAC) and Water Solubility Index (WSI):-

The water absorption capacity and solubility index of flours from heart of oil palm tree were evaluated according to Phillips et al. (1988) and Anderson et al. (1969) methods respectively. 1 g of flour samples (M_0) was each weighed into a centrifuge tube and 10 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 (MEMMERT) (37°C) for 30 min and centrifuged (ALDRESA, DITACEN II) at 5000 rpm for 15 min. The resulting sediment (M_2) was weighed and then dried at 105°C to constant weight (M_1). The WAC and WSI were then calculated as follows:

$$\text{WAC (\%)} = \frac{M_2 - M_1}{M_1} \times 100$$

$$\text{WSI (\%)} = \frac{M_2 - M_1}{M_1} \times 100$$

Paste Clarity:-

The lightness of the pastes of the flour or starch was measured according to the method of Craig *et al.* (1989). A mass of 0.2 g of sample was dissolved in 20 ml of distilled water contained in a centrifuge tube. The mixture was homogenized by the use of a vortex and then heated in boiling water (100 ° C.) for 30 min. During this heating, the reaction medium was homogenized every 5 min. After this heat treatment, the reaction medium was cooled on the bench for 10 min. The clarity of the sample paste was determined by measuring the transmittance at 650 nm on the spectrophotometer against distilled water. The effect of the concentration of the sample on the clarity of the dough was also determined by repeating the procedure described above for concentrations of 2, 4, 6, 8 and 10% (w / v).

Wettability:-

The wettability of the flours was determined according to the technique of Onwuka (2005). One (1) g of flour was placed in a 25 ml graduated cylinder having a diameter of 1 cm. A finger was placed on the opening of the test piece (to avoid pouring the sample by reversing it). The finger closing the specimen 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 and the sample was poured into the beaker. Wettability was determined to be the time required for the sample to become fully wetted.

Flour dispersibility (D):-

The flour dispersibility was determined by the method described by Kulkani *et al.*, (1991). 10 g of flour were weighed into 100 ml measuring cylinder and distilled water added to make a volume of 100 ml. The set up was stirred vigorously for 1 min. The volume of the settled particles was registered after regular time step of 30 min. The volume of settled particles was subtracted from 100. The difference was reported as percentage of dispersibility.

Oil absorption capacity (OAC):-

The oil capacity of flours from heart of oil palm tree was evaluated according to Eke and Akobundu (1993) methods. 1 g of sample (M_0) was mixed with 10 ml in a weighed 20 ml centrifuge tube. The slurry was agitated on a vortex mixer for 2 min, allowed to stand at 28°C for 30 min and then centrifuged at 4500 rpm for 30 min. The clear supernatant was decanted and discarded. The adhering drops of oil were removed and the tube was weighted (M_1). The AOC was calculated as follows:

$$\text{OAC (\%)} = \frac{M_0 - M_1}{M_0} \times 100$$

Statistical analysis:-

All analyses were performed in triplicates. Results were expressed by means of \pm SD. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the physicochemical and functional properties of heart of oil palm. Means were separated according to Duncan's multiple range analysis ($p \neq 0.05$), with the help of the software Statistica (StatSoft Inc, Tulsa USA Headquarters) (Duncan, 1955)

Results and Discussion:-

The proximate composition of different parts (PP, MP, DP) from heart of oil palm (*Elaeis guineensis* Jacq.) is shown in Table 1. The physicochemical properties differ significantly ($p < 0.05$) from a part to another.

Moisture content is an index of storage of the flours. Flours moisture contents ($5.87 \pm 0.01\%$ to $10.83 \pm 1.16\%$) less than 14 % can resist microbial growth and contribute to best storage (Colas, 1998; Okonkwo and Opara. 2010).

Ash content of the different parts of heart of oil palm ($6.91 \pm 0.07\%$ to $8.28 \pm 0.51\%$) may be considered as good sources of minerals compared to cereals and tubers values (2–10 %) (FAO, 1986).

The crudes fibers content (21.98 ± 0.02 - $34.9 \pm 0.1\%$) in the three parts of heart of oil palm would be advantageous for their active role in the regulation of intestinal transit (Jenkin *et al.*, 1986 ; (Mensah *et al.*, 2008). these contents are higher compared to vegetables studied (*M. arboreus*: $12.19 \pm 0.73\%$ and *C. argentea* : $30.83 \pm 1.61\%$) in Côte d'Ivoire (Zoro *et al.*, 2013). Therefore, the consumption of heart of oil palm tree may be advantageous since high fibers content of foods help in digestion, prevention of colon cancer and in the treatment of diseases such as obesity, diabetes and gastrointestinal disorders (Saldanha, 1995; UICC/WHO, 2005).

Fat content range between 7.57 ± 0.1 to 12.81 ± 0.07 % in different parts of heart of oil palm tree. These results corroborate the findings of many authors who showed that vegetables are poor sources of fat (Ejoh *et al.*, 1996).

Crude proteins content range between 12.56 ± 0.65 % to 13.12 ± 0.69 %. The proteins content was higher compared to some vegetables such as *Momordica balsamina* (11.29 %) and lower compared to *Moringa oleifera* (20.72 %) (Asaolu *et al.*, 2012). Plant which produce more than 12% of protein are a good source of proteins (Ali, 2009).

Carbohydrate content (39.85 ± 0.06 to 46.42 ± 0.11 %), are higher than vegetables as *Senna obtusifolia* (20%), *Amaranthus incurvatus* (23.7 %) and *Momordica balsamina* (39.05 %) (Hassan and Umar, 2006).

The energy value of heart of oil palm tree flours range between 270.45 ± 0.04 (MP) to 333.56 ± 0.02 (DP) Kcal/100g is agree with general observation do on the vegetables which have low energy values (Lintas, 1992) due to their low fat content and relatively high level of moisture (Sobowale *et al.*, 2011). With these energies values, flours from heart of oil palm tree could be used as energy in the flour porridge for infants and children (Butte, 1996).

Mineral composition:-

The mineral composition of flours from the heart of oil palm tree (*Elaeis guineensis* Jacq.) presented in Table 2. Minerals are considered to be essential in human nutrition (Ibanga and Okon 2009; Valvi and Rathod 2011). They help in the maintenance of acid-base balance, to physiological stimulation and blood clotting (Hanif *et al.* 2006). The results showed that the heart of oil palm tree represent a potential source in mineral, notably in potassium, calcium.

The potassium content of flours from of heart of oil palm tree ranged between 1412 ± 224.65 (PP) to 1787.43 ± 75.57 mg/100g (MP) and are higher compared to the range (300– 400 mg/100g) of various species of vegetable (Anon, 2011, Ogbede *et al.*, 2015) and carrot (178 mg/100g) , lettuce (222 mg/100g) (Mark *et al.*, 2013) .

Calcium contents in the different part of heart of oil palm is shown in Table 3. Calcium is the major component of bone, assists in teeth development, necessary for blood coagulation and for the integrity of intracellular cement substances (Okaka and Okaka 2001). The content of Calcium varied of 356.37 mg/100g (PP) to 881.18 mg/100g (DP). This result is high than the Calcium contents of Okra varieties varying between 58.22 to 58.31 mg/100 g (Adetuya *et al.*, 2011; Gemede *et al.*, 2016).

Phosphorus contents (165.31 (MP) to 276.66 (DP) are higher than phosphorus content of *Brassica oleraceae* var. capitata L.(26.92 mg/100g) , *Ossinum gratissimum* (13.8mg/100g), *Vernonia amygdalinai* (13.1 mg/100g), *Telferia occidentalis* (15.08mg/100g) , (16mg/100g) in carrot, and (22 mg/100g) in lettuce (Sobowale *et al.*, 2011; Mark *et al.*, 2013; Ogbede *et al.*, 2015). Phosphorus is an important mineral that aids the absorption of calcium which is required for growth, maintenance of bones, teeth and muscles (Turan *et al.*, 2003).

Daily calcium and magnesium requirements respectively of 800 mg and 100 mg, (FAO, 2004) could be covered by the consumption of the heart of oil palm tree. As a result, the heart of oil palm tree could be recommended for feeding to children and lactating women.

Taking into account the phospho-calcium ratio (Ca/P), the proximal part of heart of oil palm tree has the value (Ca/P) closest to that recommended by FAO/WHO (2004) for food (1.82).

Iron is an essential trace element for hemoglobin formation, normal functioning of central nervous system (Ullah *et al.*, 2012, Kermanshah *et al.*, 2014; Mlitan *et al.*, 2014). The iron contents of different parts (40.37 ± 5.26 to 51.18 ± 2.53) of the studied palm heart are higher than the daily requirements estimated at 8 mg (FAO/ WHO, 2004). This iron richness would resolve important health issue in Africa, where there are many cases of anemia caused by malaria and immune deficiency (Akindahunsi and Salawu, 2005) It also facilitates oxidation carbohydrates, protein, and fat to control body weight, which is very important factor in diabetes (Moses *et al.*, 2012).

The presence of copper and silicon in the different parts (PP, MP, DP) studied could give an added nutritional value because these trace elements are involved in the development of brain activity and in the functioning of the nervous system (Soetan *et al.*, 2010).

Functional properties:-

The result presented in Table 3 showed the functional properties of the flours from heart of oil palm tree. Functional properties of food are defined as physicochemical properties reflecting complex interactions between the composition, structure, conformation and physicochemical properties components (Kohnhorst *et al.*, 1990; Hussain *et al.*, 2008). There could have significant differences ($P < 0.05$) between the three parts flours functional properties. The bulk density (BD) is presented in table 1. BD is a measure of the weight of flour (Adejuyitan *et al.*, 2009) which determines the suitability of a flour to be easily packaged, would facilitate the transport of a large amount of food (Shittu *et al.*, 2005). The BD result is used to evaluate the flour heaviness, handling requirement and the type of packaging materials suitable for storage and transportation of food materials (Oppong *et al.*, 2015). Nutritionally, low bulk density promotes the digestibility of food products, especially in children because of their immature digestive system (Nelson-Quartey *et al.*, 2007). It has been reported that bulk density is influenced by the structure of the starch polymers and loose structure of the starch polymers could result in low bulk density (Malomo *et al.*, 2012). The Bulk Density value of heart of oil palm tree flour range between $0.54 \pm 0.01 \text{ g/cm}^3$ to $0.57 \pm 0.01 \text{ g/cm}^3$ is similar to $0.55\text{-}0.62 \text{ g/cm}^3$ reported for tigernut (*Cyperus esculentus*) seed flour (Oladele and Aina, 2007) and lower than wheat flour (0.80 g/cm^3 to 0.90 g/cm^3) and chickpea (0.94 g/cm^3) (Ijarotimi, 2012; Jagannadham *et al.*, 2015). Low BD is advantageous for the infants as both calorie and nutrients density in enhanced per feed of the child (Onimawo and Egbekun, 1998). The low bulk density of heart of oil palm tree flours, suggests that they may be use in formulating infant food.

Foams are used to improve texture, consistency and appearance of foods (Akubor, 2007). Results showed that foam capacity (FC) of heart of oil palm tree flours varied from $26.31 \pm 1.73\%$ (CPPO) to $31.61 \pm 0.54\%$ (CPMO). The FC values obtained were higher than those reported by Amon *et al.* (2011) in taro flour (*Colocasia esculenta*) Cv Yatan. Foam capacity and stability are a function of the type of protein, pH, processing methods, viscosity and surface tension (Fekria *et al.*, 2012). The values of FC range between $26.31 \pm 0.72\%$ (CPPO) to $31.61 \pm 0.54\%$ (CPMO) (Table 2). The foam capacity values of flours did not differ significantly ($P < 0.05$). The foam Capacity values were higher than those *Artocarpus altilis* ($14.51 \pm 1.61\%$) (Oulai *et al.*, 2014), Cassava pulp flour (13.70 %) and the breadfruit kernel flour (20 %) (Akubor and Badifu, 2004, Ubbor and Akobundu, 2009). The presence of fat (7.57 to 12.81) in flours might be responsible for the low foaming capacity observed.

Water absorption capacity (WAC) values ($453.15 \pm 1.6\%$ to $568.7 \pm 0.89\%$) were higher than the WAC values of uncooked rice (225%), potato (277%) and cassava (197%) (Abulude, 2004; Nwosu *et al.* 2014). The presence of fat, though in small quantity, may be responsible for the moderate quantity of WAC of each of these legume samples. The relationship between the content of hydrophilic group of proteins and WAC had been established which gave the indication that legume plants rich in protein have more hydrophilic groups exposed to water (Oyebode *et al.*, 2007; Hermanson, 2008). In addition, this result could also be explained by the destruction of the cell membranes during osmosis phenomena causing a massive entry of water into the cells. Therefore, the flours of heart of oil palm would be useful in enhancing the water binding capacity of food products like dough, sausages mayonnaise and cakes.

The water solubility index (WSI) reflects the extent of starch degradation (Diosady *et al.*, 1985), determines the amount of free polysaccharides or released from the granule after addition of excess water (Sriburi and Hill, 2000). The flours WSI values vary significantly at the 5% threshold. The variation in the solubility of the various flours would be related to the high water absorption caused by the disorganization of the cell walls (Tucker and Grierson, 1987). The WSI values (25.4 - 30.25 %) of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.) are higher than those of different raw flours of wheat flour (12.3 %) rice flour (14.7%) and raw taro flours (18% to 27%) (Mbofung *et al.*, 2006, Kaur, 2015).

Oil absorption capacity (OAC) measures the ability of food material to absorb oil The OAC (table 2) is an important property in food formulation because fats improve the flavor and mouth feel of foods (Kinsella, 1976). They are also important because of storage stability in the rancidity development (Siddiq *et al.*, 2010).

The low PC of the raw flour would be explained by the fact that the not swollen starch granules remained dense reflecting the maximum of light entering the medium (Tetchi *et al.*, 2007). Consequently, pastes were turbid or opaque as described in the literature (Craig *et al.*, 1989).

The paste clarity is an important property which control different applications of flour and starch for the processing of food products. The clarity study showed that there was a significant difference ($p \leq 0.05$) between heart of oil palm flours. These values of clarity (0.21 CPP0; 0.16 CPM0 and 0.17 CPD0) are much lower than those obtained by Oulai *et al.*, (2014) for breadfruit flours "*Artocarpus altilis*" (30.56%) and by Amani (2002) for "kangba" yam flour (42%). This small percentage of clarity can be explained by the presence of the uninflated granules of the flour in the suspension which reflected the maximum light (Tetchi *et al.*, 2007) and on the other hand by the crude fat contents, crude protein (Craig *et al.*, 1989), the botanical source and the ability of granules to form aggregates (Amani *et al.*, 2005). The flours of heart the oil palm (*Elaeis guineensis* Jacq.) could be ideal for the salad dressing.

The wettability study showed that there is variability between hearts of oil palm flours. This difference is due to the composition of flours and to the affinity between its components and water and to the accessibility of water to flour constituents (Schuck *et al.*, 2007). Our values are higher than those of soybean flour (31 s) and wheat (52 s) noted by Nwosu *et al.* (2014). Indeed, flour is said to be very wettable if the wettability time is less than 30 seconds; it is wettable if the time is less than 60 seconds. On the other hand, it is considered as non-wettable if the wettability time is greater than 120 seconds (Pohl, 2004). Thus, the CPP0, CPM0 and CPD0 flours would not be wettable and cannot be used for swelling because according to Schuck *et al.* (2007) flour capable of getting wet would be able to swell when handling the pasta. Indeed, the wettability of a food takes into account the balance between the cohesive forces within the liquid and the adhesion forces (Haugaard *et al.*, 1978). Therefore, the presence of primary particles, density and porosity improve wettability (Haugaard *et al.*, 1978). On the other hand, the presence of fat at the surface of the particles reduces or limits the wetting.

The values of flours foam stability (FS) decreases slowly during the time (120 min) (Figure 1). Reducing of foaming properties was related to protein denaturation. FS values were higher than those reported for defatted ground nut flour (4% - 4.2%) (Fekria *et al.*, 2012). Flours of heart of oil palm tree has potential for application in food systems that require high percentage of porosity such as ice cream and cakes also in nonfood products as a foaming agent.

Dispersibility (D) is the ability of flour to be wet without the formation of lumps, with simultaneous disintegration of agglomerates. It gives an indication of particles suspensibility in water, which is useful functional parameter in various food products formulations (Mora-Escobedo *et al* 1991). The importance of dispersibility is that it indicates the reconstitution ability of the sample. In order to know how heart of oil palm flours reconstructed in water, the dispersibility test was done. After 50 min, the dispersibility of the various parts increases and stabilized. Samples were significantly different in terms of their dispersibility. The flours dispersibility of heart of oil palm tree (55.61 % PP; 20.97 % MP; 32.1 % DP) are lower than the dispersibility of soy-enriched tapioca (63.0 to 87.0 %) (Otegbayo *et al.*, 2013) and that of local rice in Nigeria (56-66%) (Eke-Ejiofor *et al.*, 2011) and breadfruit flour *Artocarpus altilis* (54 %) (Oulai *et al.*, 2014). Furthermore, dispersibility is influenced by solubility, wettability, crude protein content, particle size profile, air temperature and reconstitution conditions (Wester-gaard, 1994). According to the standard, the milk powder is dispersible when its dispersibility index is greater than 90% (Haugaard *et al.*, 1978). Therefore, the dispersibility values of heart of oil palm flours recorded after 60 min are less than 90, which is why they are not dispersible. The water solubility index (WSI) reflects the extent of starch degradation (Diosady *et al.*, 1985).

Oil absorption capacity (OAC) presented in figure 3 measures the ability of food material to absorb oil. The flours from heart of oil palm tree showed moderate oil absorption capacity (OAC). The OAC values of flours ranged from 72.95 to 87.35 % (PP), 75.35 to 93.25 % (MP) and 84.7 to 100.05 % (DP). These values were lower than *Artocarpus altilis* flour (139 %), breadfruit (150 %) and ground nut flour (287 % and 293 %) (Appiah *et al.*, 2001, Fekria *et al.*, 2012, Oulai *et al.*, 2014). The low OAC means the flour could be used as a coating in deep fat frying to reduce oil absorption by the fried food. Interactions of water and oil with proteins are very important in food systems because of their effects on the flavor and texture of foods (Amadou *et al.*, 2010). Fekria *et al.*, (2012) reported that the ability of the flour to absorb and retain water and oil may help to improve the binding capacity and enhance flavor retention, improve mouthfeel and reduce moisture.

Table 1:- Proximate composition of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.).

Parameters (%)	Flours		
	PP	MP	DP
Moisture	5.87 ± 0.01 ^b	10.83 ± 1.16 ^a	8.82 ± 0.27 ^a
Ash	8.28 ± 0.51 ^a	6.91 ± 0.07 ^b	8 ± 0.06 ^a

Acidity(meq/100g)	5.64 ± 0.6 ^a	4.93 ± 0.61 ^a	4.58 ± 0.61 ^a
pH	5.79 ± 0.01 ^a	6.09 ± 0.01 ^c	5.90 ± 0.01 ^b
Total sugars (g/100g)	30.45 ± 3.25 ^b	96.68 ± 0.31 ^a	96.64 ± 0.14 ^a
Reducing sugars (g/100g)	0.02 ± 0.00 ^b	0.05 ± 0.00 ^a	0.02 ± 0.00 ^b
Carbohydrate	39.85 ± 0.06 ^a	39.88 ± 0.02 ^a	46.42 ± 0.11 ^b
Crude fiber	26.49 ± 0.13 ^a	34.9 ± 0.1 ^b	21.98 ± 0.02 ^a
Crude fat	12.81 ± 0.07 ^c	7.57 ± 0.1 ^a	10.61 ± 0.05 ^b
Crude protein	12.56 ± 0.65 ^{ab}	10.7 ± 0.66 ^a	13.12 ± 0.69 ^b
Energy (Kcal/100 g)	324.93 ± 0.02 ^c	270.45 ± 0.04 ^a	333.65 ± 0.01 ^b

Mean values with different superscripts within a column are significantly different ($p < 0.05$). PP: Proximal Part; MP: Median Part, DP: Distal Part.

Table 2:- Mineral composition of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.).

Minerals (mg /100g DM)	Flours		
	PP	MP	DP
Calcium	356.37 ± 3.16 ^a	522.29 ± 12.03 ^b	881.18 ± 63.08 ^c
Magnesium	208.45 ± 8.73 ^a	316.73 ± 29.20 ^b	433.61 ± 16.72 ^c
Phosphorus	193.98 ± 7.18 ^a	165.31 ± 7.03 ^a	276.66 ± 21.53 ^b
Potassium	1494.57 ± 74.73 ^{ab}	1787.43 ± 75.57 ^b	1412 ± 224.65 ^a
Ca/P	1.83	3.16	3.18
Iron	40.37 ± 5.26 ^b	47.27 ± 4.1 ^a	51.18 ± 2.53 ^a
Copper	10.23 ± 2.53 ^a	12.14 ± 3.13 ^a	12.58 ± 3.54 ^a
Silicon	14.72 ± 4.10 ^a	16.08 ± 8.29 ^a	18.72 ± 2.68 ^a

Mean values with different superscripts with in a column are significantly different ($p < 0.05$). PP: proximal part; MP : median part, DP : distal part. DM: Dry Matter.

Table 3:- Functional properties of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.)

Functional Properties (%)	Flours		
	PP	MP	DP
Bulk Density (g/cm ³)	0.54 ± 0.01 ^a	0.56 ± 0.01 ^a	0.57 ± 0.01 ^a
Foam Capacity	26.31 ± 0.72 ^b	31.61 ± 0.54 ^a	31 ± 1.41 ^a
WAC	453.15 ± 1.6 ^a	534.58 ± 0.2 ^b	568.70 ± 0.89 ^c
WSI	27.8 ± 0.42 ^b	30.25 ± 0.21 ^c	25.4 ± 0.28 ^a
Paste Clarity	0.21 ± 0.00 ^b	0.16 ± 0.00 ^a	0.17 ± 0.01 ^a
Wettability (sec)	135.9	230	330

Mean values with different superscripts within a column are significantly different ($p < 0.05$). PP: Proximal Part ; MP : Median Part, DP : Distal Part.

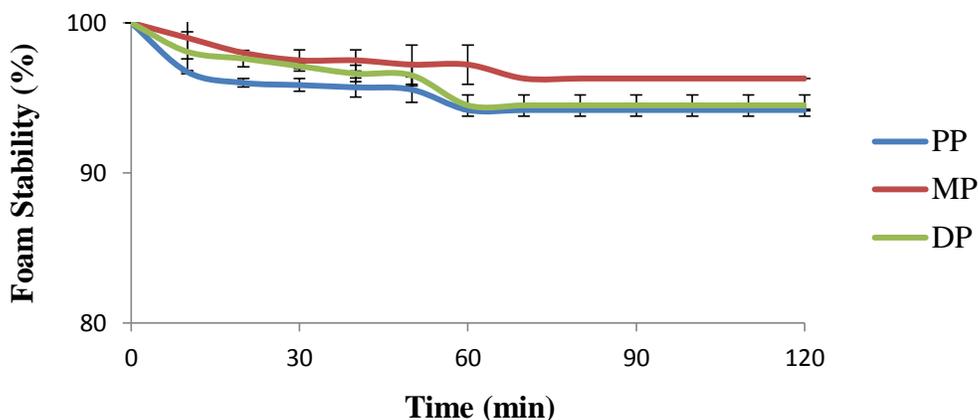


Figure 1:- Foam stability of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.).

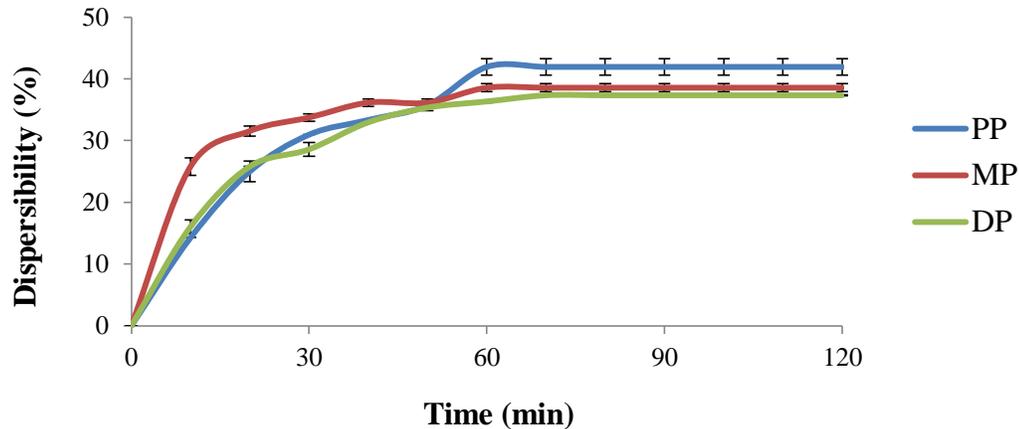


Figure 2:- Dispersibility of flours from heart of oil palm tree (*Elaeis guineensis* Jacq.)

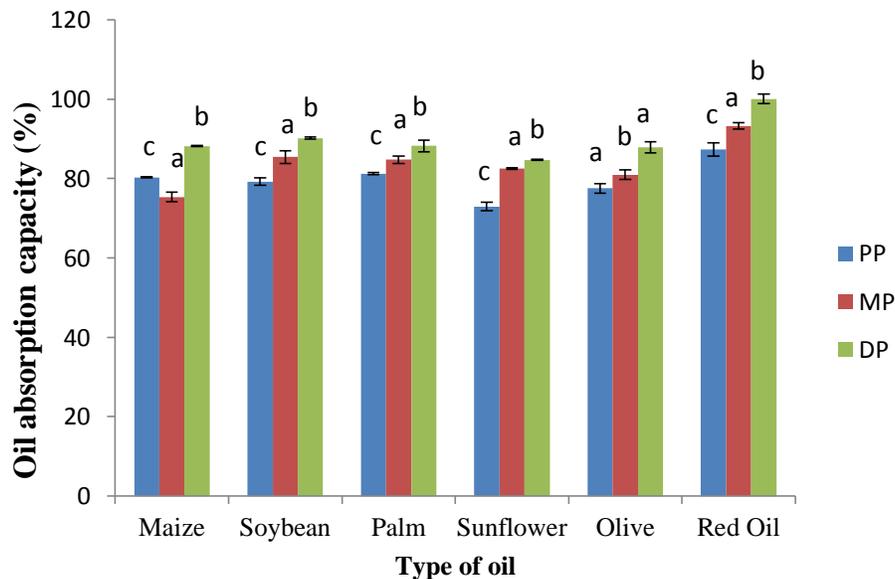


Figure 3:- Oil Absorption Capacity (OAC) of various oils of flours from the heart of oil palm tree (*Elaeis guineensis* Jacq.)

Conclusion:-

The conducted study revealed that the flours from heart of oil palm tree are a good source of ash, total sugars, carbohydrate, crude fiber, energy value and potassium hence their interest in the use of human diet. The low moisture content which makes them store for a long time. Therefore, it would be wise to cook heart of oil palm tree before eating. The low moisture content which makes them store for a long time. Therefore, it would be wise to cook heart of oil palm tree before eating. Then high Water absorption capacity (WAC) of flours from heart of oil palm tree was good providing agent and can thus used as a thickener or gelling agent in various food. The low bulk density (BD) were as well as the high solubility, so heart of oil palm flours would be useful in infant meals formulation. The functional properties of flours from heart of oil palm tree are also a promotion to be used in food formulation

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