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Functional Properties of Flours from Fresh and Boiled Wild Yam *Dioscorea praehensilis* Tubers

Soro Songuimondenin[1], Kouadio T. Martin[1], Binaté Siaka[1], Kouassi K. Appolinaire[1], Konan K. Hubert[1*] and Kouadio E. Jean Parfait[1]

[1]Laboratoire de Biocatalyse et des Bioprocédés de l'Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration between all authors. Author SS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors KTM and BS managed the analyses of the study. Authors KKA and KKH managed the literature searches. Author KEJP supervised all the works. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to evaluate the effect of boiling time on functional properties of flour from the wild yam *Dioscorea praehensilis* tuber. For this purpose, six (6) flours were produced with different boiling times of the wild yam tubers: 5 min (YT_5), 10 min (YT_{10}), 20 min (YT_{20}), 30 min (YT_{30}) and 40 minutes (YT_{40}); the raw tuber flour (YT_0) was used as reference control. Slower wettability registered for raw flour (116.33s) significantly ($p<0.05$) change with boiling as wettability of boiled tubers flours ranged from 25.32 s (YT_5) to 33.5 s (YT_{40}). The densities paste clarity and Water Absorption capacity significantly ($p<0.05$) increased with the boiling. But there were significantly ($p<0.05$) decrease in water solubility index (WSI) (from 19.45 % to 16.45 %), dispersibility (from 82.03 % to 74.2) and foam capacity (from 86.02 to 11.79 %). The foam stability increased from raw to the boiled tuber. Parameter like least gelation concentration (LGC) remained constant (at 6 g/ml) from raw to boiled tubers and increased to 8 g/ml only at the longer boiling time (30 min and 40 min). The highest emulsion capacity was registered at 20 min while the highest), water absorption capacity (WAC) was registered at 10 min. The swelling power and solubility increased significantly

**Corresponding author: E-mail: konankouassihubert@yahoo.fr;*

from 70° to 95° C with the highest values in swelling power for YT_5. The highest solubility value was registered at 70° C for YT_5. Turbidity values ranged from 1.6 to 2.8 with higher values for YT_0 and lower values for YT_{40}. Four oil types were tested for Oil Absorption Capacity (OAC). Highest OAC values were obtained in boiled flours with unrefined palm oil (all values higher than 180 %) followed by refined palm oil (values ranged 166.5 to 185 %). These results showed that the boiling and the boiling time induced significant changes in functional properties of flour from the wild yam *Dioscorea praehensilis* tuber.

Keywords: Wild yam; flour; boiling time; functional properties.

1. INTRODUCTION

Food functionality is a real concern for producers, buyers and consumers. The efficiency of functional properties of flours in food technology is that they are intrinsic physicochemical characteristics that may be affected during processing and storage of food products. Thus, product development is usually based on the functional properties that we wish to obtain; these properties provide information about future applications in food formulations [1]. Functional properties are key parameters that can give a preview on flours ability to food technology processes [2,3]. They are fundamental physicochemical properties that reflect the complex interaction between the composition, structure, molecular conformation and physicochemical properties of food components in relation with the nature of the environment in which these are associated and measured [4,5,6,7]. Functional characteristics are required to evaluate and possibly help to predict how new flours (like *D. praehensilis* one) may behave in specific systems [5,7,8].

The wild yam *D. praehensilis* emerged as the most popular one among numbers of wild species. During famine periods from June to September, while cultivated yams and other crops came out of stock, *D. praehensilis* appears as a key energy supply product for numbers of local people. In fact, at this moment of low food availability, *D. praehensilis* tubers are at physiological maturity, providing a valuable source of starch to populations. This wild yam seems now in advanced domestication scale with the cultivation of some tubers by peasants in their fields. The emerging of domestication practices for *D. praehensilis* in many African regions [9,10,11,12] is evidence that this wild yam met people appreciation standard. *D. praehensilis* is used as famine food with a preference for the white variety [10].

But the main problem with this wild yam is the impossibility of storing tubers and use it even a week later: *D. praehensilis* tubers are highly perishable as organoleptic quality depreciation and tubers physical deterioration start immediately the day after harvest if not consumed. The conversion of tubers into chips and flours could be a solution as proven for cultivated yams in some West African countries like Benin, Nigeria, Togo [13,14,15]. The advantages of *D. praehensilis* flour would be double: it would fist solve storage purpose of this wild yam and open new economic possibilities to local populations too with multiple applications possibilities in food technology. Yam fresh tubers usually undergo hydrothermal treatment before its conversion into flours [16].

This process known as blanching is performed in boiling water. The effect of the boiling treatment on the *D. praehensilis* flours quality had not yet been investigated. Concretely we don’t know the effect of blanching on food technology ability regarding functional properties. The purpose of the current study is to investigate the effect of boiling time on the wild yam *D. praehensilis* flours functional properties.

2. MATERIALS AND METHODS

2.1 Raw Materials

The wild yam *D. praehensilis* was used in the present study. Fresh tubers with variables lengths (20 - 63 ± 4.46 cm) and variable weights (0.5 - 5 kg) were harvested at physiological maturity in six villages (*Hallikro, Ketasso, N'Drikro, Kouassikro, AvocaKoffikro and Diabykro*) in Divo department (5 ° 50’N; 5 ° 22’ W), about 204 km from Abidjan, Côte d'Ivoire. Harvested tubers collected from August to November were then carried the same day to Abidjan in jute bags.

2.2 Preparation of Yam Flour Samples

D. praehensilis flour was produced as described by Bell and Favier (1982) with some changes concerning the boiling time. Yam tubers were washed, peeled manually and cut into thin slices (1 cm thick). The slices were divided into six portions of 1kg each. The first portion of slices was unblanched and served as control. The second portion was blanched for 5 min in boiling water (100°C). The 3rd, 4th, 5th and 6th following portions were respectively blanched in boiling water (100°C) during 10 min, 20 min, 30 min and 40 min. Pieces of precooked yams were left cooling for 25 minutes and all the samples were cut into chips. Then these chips were dried at 45°C for 48 hours using a dryer made by I2T (Société Ivoirienne de Technologie Tropicale). The dried chips were milled and automatically pass through a 90 µm mesh size sieve to obtain the flour finally stored in plastic bags with the following inscriptions: YT_0 (control), YT_5 (flour from 2nd portion), YT_{10} (flour from 3rd portion), YT_{20} (flour from 4th portion), YT_{30} (flour from 5th portion) and YT_{40} (for flour from 6th portion).

2.3 Determination of Functional Properties of Flours

Functional properties studies were conducted in the Laboratory of Biocatalysis and Bioprocesses of University Nangui Abrogoua, Côte d'Ivoire. All flours were tested for functional properties such as bulk density [17], water solubility index (WSI), water absorption capacity (WAC) [18], oil solubility index (OSI), oil absorption capacity (OAC) [19]. The hydrophilic-lipophilic ratio (RHL) as defined by Njintang et al. [20] was calculated by the ratio of water absorption capacity to oil absorption capacity. The swelling index ([21], foam capacity and foam stability [22], turbidity [23], Emulsion capacity [24] and granulometry were tested too. Flours dispersibility was determined by the method described by Kulkarni et al. [25]. The flour sample (10 g) was weighed into a graduated cylinder. Water was added to the make up to 100 ml mark. It was shaken vigorously and allowed to stand for 3 h. The volume of settled particles was recorded.

2.4 Statistical Analysis

All analyses were carried out in triplicates. Results were expressed by means of ± SD. Statistical significance was established using one-way analysis of Variance (ANOVA) models to estimate the effect of boiling times on functional properties of flour from the wild yam *D. praehensilis* at 5 % level. Means were separated according to Duncan's multiple range analysis ($P < 0.05$), using STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France).

3. RESULTS AND DISCUSSION

Results of the effect of boiling time on functional properties as wettability, Bulk density, packed density, Foam capacity, dispersibility, least gelation concentration (LGC), Emulsion capacity and Paste Clarity of wild yam *Dioscorea praehensilis* tuber flour samples were presented in Table 1.

The wettability of raw yam tuber flour was 116.33±3.21 s and was largely higher than precooked tubers flour wettability ranged increasingly from 25.32±20 s (YT_5) to 33.51±1.25 s (YT_{40}). The higher value reported for raw tuber may suppose that flour from raw tuber of *Dioscorea praehensilis* had smaller, lightweight and more regular surfaces than boiled tuber ones [26]. In fact, wettability describes the capacity of flour particles to absorb water on their surface, thus initiating reconstitution. Wettability is the liquid penetration into the flour particles porous system due to capillary action [27]. The efficiency of this parameter is related to the fact that food flours obtained from drying processes are normally reconstituted for consumption. Thus, wettability may influence the overall reconstitution characteristics of yam flours. A higher value of wettability obtained for raw tuber flour is an indication about difficulties to use this flour for food formulations including rehydration as it will float for more time on the surface of the cold water [26]. In the over hand boiling strongly reduced wettability time and these values decreased slightly for longer boiling time. Low values of wettability are required in instantaneization of food products [28]. Low wettability recorded for boiled tuber flours may suggest usage of these flours in instantaneization of products probably in association with milk.

Bulk density was reported in Table 1. The lowest value of bulk density (0.62±0.00 g/ml) was recorded for raw tuber and significantly increases during boiling from 0.75±0.00 g/ml to 0.89±0.03 g/ml respectively from 5 minutes of boiling time to 30 minutes boiling time. A slight decrease was however noted for longer boiling time as 40 minutes making it 0.85±0.07 g/ml. These boiled flours values are higher than the bulk density of yam flours sold in the Kuto-market Abeokuta, South West Nigeria, ranged from 0.54g/ml to 0.72g/ml [29]. These high values of bulk density recorded for *D. praehensilis* flours were also higher than values reported by Obadina et al. [30] for *Dioscorea rotundata* (0.76), *Dioscorea alata* (0.75) and wheat flour ranged from 0.39 g/ml to 0.47 g/ml [16]. However, values of boiled tuber bulk density agreed (closed to) those of cocoyam *Colocasia esculenta* [31] ranged from 0.66 to 0.82 g/ml and values reported by Achy [32] for *Dioscorea bulbifera* ranged (0.74 to 0.82 g/ml). A bulk density of D. *praehensilis* flours was significantly affected by boiling leading to an increase of values. Low bulk densities as in raw tuber are suitable for infant food formulation [33]. Increase in bulk density increased the sink ability of flours particles and this aids their ability to disperse [34,35]. The density of flours is important in determining the packaging requirement and material handling [36]. Plaami [37] reported that bulk density is influenced by the structure of the starch polymers and that loose structure of the starch polymers could result in low bulk density. It also seems that bulk density of flours is related to the process as influenced by particles sizes James [31]. This author found that bulk density decreases when flours particles sizes are decreasing. Generally, higher bulk density is desirable for the greater ease of dispersibility and reduction in paste thickness which is an important factor in convalescent child feeding [38].

Packed density values are higher than bulk density ones. Values reported being 0.75±0.04 g/ml for raw tuber, significantly increased during boiling and ranged 0.94±0 .01 to 1.13±0.07 g/ml as the boiling was performed from 5 minutes to 40 minutes. These values are higher than findings of Amandikwa et al. [16] reporting packed densities 0.42; 0.48; 0.53 and 0.67 g/ml respectively for *Dioscorea alata, Dioscorea rotundata, Dioscorea bulbifera* and Wheat flours. As shown in Table 1, the boiling process increased significantly the packed loose density. The increase of packed density during boiling is to be related to processing efficiency, particularly the particles size. Certainly, small particles sizes may lead to high packed densities because of better particles disposition. In the other hand, large particles size flour could lead to low packed densities with high porosity [39].

Foam capacity of raw and boiled tuber flours was reported in Table 1. The raw flour foam capacity was 36.92±1.01%. It then decreased significantly during the boiling from 18.97±0.00% (YT_5) to 11.79±0.12% (YT_{40}). These values are like blanched *D. rotundata* (19.93 %), *D. cayenensis* (13.33%) and *D. dumetorum* (13.13%) flours, but largely higher than *D. alata* (5.05 %) as reported by Wahab et al. [40]. Adeleke and Odedeji [41] reported lower foam capacity in wheat and sweet potato flours while Chandra and Samsher [2] reported very low foam capacities for rice flour. High foam capacity is related to high protein content in flours [42]. In fact, dispersion of protein causes a lowering of the surface tension at the water/air interface, thus always been due to a protein which forms a continuous cohesive film around the air bubbles in the foam [43]. This high foam capacity is correlated with a high protein content of *D. praehensilis* raw tuber flour decreasing with boiling time as reported in this study. The decrease of foam capacity for boiled *D. praehensilis* tuber flours could be associated to the reduction of nitrogen solubility of proteins [44]. The high foaming capacity of *D. praehensilis* could be desirable in food processes where excessive foaming is required since foams are used to improve texture, consistency and appearance of foods [45].

Dispersibility of raw and boiled tuber flours is reported in Table 1. Dispersibility is a useful functional parameter which measures the reconstitution of flour in water to have a fine and consistency paste, and it gives an indication on water-absorption capacity [25]. Dispersibility of raw tuber was 82.03±1.50%. But boiling process decrease significantly the dispersibility ranged from 77.85±1.1 (YT_5) to 74.24±0.85 (YT_{40}). An earlier study by Wahab et al. [40] on dispersibility of yam flours had reported a value of 51.17 %, 52.83 % and 62.83 % respectively for *D. dumetorum*, *D. cayenensis* and *D. alata* flours. However, *D. rotundata* has dispersibility value (72.17 %) like the mean value obtained in this work for the boiled tuber. These higher values of dispersibility observed for flours samples from *D. praehensilis* hence that it will easily reconstitute to give a fine consistency to the dough during mixing [46].

The least gelation concentration (LGC) is an index of gelation and it defines the lowest sample concentration at which gel remained in the inverted tube without falling. It influences the texture of food such as agidi and soup [47]. Results reported in Table 1 shows that LGC of raw tuber was (6 %). There were no variations of this parameter (6 %) in boiled flours for YT_5, YT_{10} and YT_{20} flours. Changes occur for longer boiling time (30 and 40 minutes) where LGC value is 8%. These results are closed to findings of Akubor [48] for yams (*Dioscorea spp*.), where 10 minutes blanched yam LGC was 6 % as well as results of Oluwatonyin [49] reporting a value of 6 % too. After 30 - 40 minutes of hydrothermal treatment, LGC of *D. praehensilis* flour is like that of wheat flours reported by Chandra et al. [50]. A higher value of LGC (12%) was reported in breadfruits by Arinola and Akingbala [51] in mushrooms with values ranged 12 % to 14 %. The lower the least gelation concentration is, the higher is the ability of the flour to form stable gel [52]. But very low LGC may not be suitable for infant products formulations because of the need for more dilution which would result in reduced energy and nutrient density [51].

Paste Clarity of flours is reported in Table 1. Paste clarity is another important property of flour that governs which applications different flours may have for food processing. Raw tuber flour (YT_0) has very poor light transmittance (0.34±0.17 %T) compared to boiled tuber which had higher paste clarity ranged from 2.27±0.07 %T (YT_5) to 4.42±0.10 %T (YT_{40}), the paste clarity increased with the boiling time. Yam flours had usually low paste clarity compared to other roots and tubers as taro and sweet potato reported to have higher paste clarity [53, 54]. Considering the entire flour, the raw flour appeared to be darker than boiled ones. The current study suggested that this situation could be the main reason for lower paste clarity of *D. praehensilis* flours compared to flours from boiled tubers. But the intrinsic structure of starch should not be neglected too. Cross-linking of starch has been reported to reduce paste clarity in starch [55] and probably in entire flour. This is the reason why boiling improves paste clarity as hydrothermal treatment of tubers leads to starch gelatinization with the breaking of hydrogen cross-linking. Thus, the increasing in flours or starch paste clarity during boiling could be due to reduction in light refraction by remaining starch granules [56]. Many parameters (spectrophotometer type, starch concentration, treatment temperature and storage time) had been reported by this author to influence light transmittance, testifying [57] suggestion. High paste clarity allows the application of flours and starches in confectionary and pie filling which require high clarity [58]. In this case, boiling may improve wild yam flour technological potential in the food industry.

Emulsion capacity of raw and boiled tuber of *D. praehensilis* are given in Table 1. Value of emulsion capacity of raw tuber was 18.91±1.03 %. Emulsion capacity of boiled tuber ranged 15.23±2.03 % to 22.42±2.24 %. The lowest value was reported at 40 min of boiling time while the highest emulsion capacity was recorded after 20 min. These values of emulsion activity are largely higher than those reported for some yams with 3.0 % for raw tuber and 1.5 % for 10 min blanched tuber Yam Bean [48]. The emulsion capacity in this study is closed to that of plantain (*Musa parasidiaca*) reported by Oluwatonyin [49] but largely lower than emulsion capacity of *Dioscorea bulbifera* (43.75%) *Dioscorea rotundata* (45.24%), *Dioscorea alata* (49.37%) and wheat flours (47.06%) reported by Amandikwa et al. [16]. This result suggests that YT_{20} flours may serve as a better emulsifier than all the other flour samples tested in this work.

Water Absorption Capacity (WAC) reported in Table 1 is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and give body to the food [59]. The water absorption capacity of flour is useful in determining the suitability of the material in baked flours [60]. The raw flour WAC was the lowest value (178.80±9.87 %) reported in this study. This value is higher than which recorded for areal yam *D. bulbifera* raw flour (149%) [32], the plantain raw flour (124.5%) [49] and wheat flour (161%) [61]. However, this result is largely lower than which recorded by the same author for breadfruit (402%). The boiling significantly increases the WAC of the yam tuber with values ranged 328.55±9.12 % - 392.76±7.34 %. This behaviour is consistent with findings of Koné et al. [62] showing a significant increase (150% to 350%) in flours from raw to cooked yam *"kponan" (D. cayenensis-rotundata*) tubers. The best WAC in the current study was reported for 10 min boiled sample. A decrease was recorded for longer boiling time 30 and 40 min. These higher values reported showed that boiling process may be suitable in food making ability of this wild yam tuber as it may increase consistency. *D. praehensilis* flour is certainly a high-water absorber product. But it seems that this WAC ability could be better if blanching was performed at a lower temperature such as 60°C. Adegunwa et al. [63] found the best WAC value at 60°C (blanching) with values decreasing as blanching temperature was increasing. This could suggest that non-gelatinized starches had better WAC than those which undergone the gelatinised point during tuber blanching process.

Table 1. Some functional properties of raw and boiled flours from wild yam *Dioscorea praehensilis* tubers

Parameters	Raw and boiled flours					
	YT_0	YT_5	YT_{10}	YT_{20}	YT_{30}	YT_{40}
Wettability (s)	116.33±3.21[d]	25.32±20[a]	26.45±0.57 [a]	26.12±3.60 [a]	28.17±1.53[b]	33.51±1.25[c]
Bulk density (g/ml)	0.62±0.00 [a]	0.75±0.00[b]	0.86±0.03[c]	0.89±0.02[e]	0.89±0.03[d]	0.85±0.07[c]
Packed density (g/ml)	0.75±0.04[a]	0.94±0.01[b]	1.12±0.05[d]	1.13±0.02[d]	1.08±0.03[c]	1.13±0.07[d]
Foam capacity (%)	36.92±1.01[c]	18.97±0.00[b]	15.38±0.12[ab]	12.87±0.18[a]	13.42±0.07[a]	11.79±0.12[a]
Dispersibility (%)	82.03±1.50[d]	77.85±1.10[c]	77.58±1.02[c]	75.86±1.00[b]	74.55± 0.75[a]	74.24±0.85[a]
LGC (% m/v)	6	6	6	6	8	8
Paste Clarity (% T)	0.34±0.17[a]	2.27±0.07[b]	2.55±0.11[b]	2.58±0.04[b]	2.75±0.28[b]	4.42±0.10[c]
Emulsion capacity (%)	18.91±1.03[c]	15.67±2.65[a]	19.08±0.79[c]	22.42±2.24[d]	16.95±0.40[b]	15.23±2.03[a]
WAC (%)	178.80±9.87[a]	385.44±12.30[e]	392.76±7.34[e]	375.36±8.17[d]	354.83±7.26[c]	328.55±9.12[b]
WSI (%)	19.45±4.95[d]	17.8±1.85[c]	17.3±0.99[b]	17.95±2.05[c]	17.9±0.56[c]	16.45±1.15[a]

YT_0 =fresh wild Yam Flour; YT_5=wild yam with 5 min of Boiling time; YT_{10}= wild yam with 10 min of Boiling time; YT_{20}= wild yam with 20 min of Boiling time; YT_{30}= wild yam with 30 min of Boiling time; YT_{40}= wild yam with 40 min of Boiling time; least gelation concentration (LGC); Water Absorption Capacity (WAC); Water Solubility Index (WSI)
Each value is an average of three replicate. Values are mean ± standard deviation. Means not sharing a similar letter in a line are significantly different ($p \le 0.05$) as assessed by the test of Duncan

Table 2. Oil Absorption Capacity (OAC) of raw and boiled flours from wild yam *Dioscorea praehensilis* tubers

Oil used	Raw and boiled flours					
	YT_0	YT_5	YT_{10}	YT_{20}	YT_{30}	YT_{40}
Refined palm oil	167.5±2.12[a]	166.5±9.19[a]	171.5±2.12[a]	179.5±3.53[b]	185.5±10.67[c]	176.5±2.12[b]
Olive oil	181±8.48[d]	178±9.89[c]	175±5.65[b]	170.5±2.12[a]	177.5±4.95[c]	172.5±2.12[a]
Sunflower oil	178.5±6.36[d]	178.5±0.707[d]	172.5±3.53[b]	178±5.65[d]	176±4.24[c]	162.5±2.12[a]
Unrefined palm oil	181±1.41[a]	192±9.90[c]	181±1.20[a]	184±2.82[b]	183±0.00[b]	180.5±0.70[a]

YT_0 =fresh wild Yam Flour; YT_5=wild yam with 5 min of Boiling time; YT_{10}= wild yam with 10 min of Boiling time; YT_{20}= wild yam with 20 min of Boiling time; YT_{30}= wild yam with 30 min of Boiling time; YT_{40}= wild yam with 40 min of Boiling time;
Each value is an average of three replicate. Values are mean ± standard deviation. Means not sharing a similar letter in a line are significantly different ($p \le 0.05$) as assessed by the test of Duncan

Water Solubility Index (WSI) was determined simultaneously with Water absorption capacity and reported in Table 1. This parameter reflects the extent of starch degradation [64]. WSI of raw tuber (19.45±4.95 %) is higher than that of boiled tubers ranged from 16.45±1.15 % to 17.95±2.05 %. This is in opposition with the finding of Koné et al. [62] and Amon et al. [65] showing an increase in WSI from raw to cooked tubers. This suggests that the WSI cannot be attributed only to the extent of starch degradation. The biochemical properties play an important role in this functional property change as suggested by Koné et al. [62].

Foam stability of raw and boiled tuber flours is presented in Fig. 1. Foam stability is defined by the time elapsed before the foam collapses. For all the samples, foam stability decreases with the passage time at room temperature. This result may be due to collapsing and bursting of the formed air bubbles [4]. Results on Fig. 1 show that raw material had better foam stability with foam collapse taking more time (more than 3h) than boiled ones which collapse exactly at 160 min, 160min, 150min, 140min and 140min respectively for YT_0, YT_5, YT_{10}, YT_{20}, YT_{30} and YT_{40} flours. This may be in relation with the decreasing of protein content during the boiling or thermal denaturation of these molecules. Thus, Lin et al. [21] found that the native protein gives higher foam stability than denatured one. The decreasing of *D. praehensilis* flours foam stability is correlated to protein content evolution as boiled flours had less proteins amounts, which lead to its lower foam stability compared to raw tubers.

Swelling power of flours is presented in Fig. 2. Results showed that boiled samples (YT_{10}, YT_{20}, YT_{30}, YT_{40}) had better swelling power at lower temperature 50°C and 60°C, while raw sample (YT_0) and 5 minutes boiled sample (YT_5) had better swelling power at higher temperature 70°C, 80°C and 95°C. Considering each flour, there was no significant difference in swelling power at lower temperatures 50°C and 60°C. Values ranged from 45 g/g to 55 g/g. This is consistent with findings of Aprianita [53] with no changes in swelling power for several flours. The lowest swelling power was recorded for raw flour (YT_0), and 5 minutes boiled tuber (YT_5) with values 45 and 46 respectively. But the swelling power increased significantly for temperatures at 70°C, 80°C and 95°C. Sibanda *and al.* [66] explained that there was a rapid swelling of starch granule at gelatinization temperature (72-81°C) which is probably responsible for high swelling power observed between 60°C and 90°C compared to that observed at/under 60°C. In the current study, the most important swelling power recorded from 60°C to 95°C was noted for raw tuber flour YT_0 and boiled flour YT_5 with 111.11% of net increase. The lowest increase was recorded for the longest boiling time flour (YT_{40}) with a net increase of 63,63 % from 60°C to 95°C. These samples may contain starch granules seriously damaged by the long boiling pretreatment which may reduce its swelling capacity. Anyway, the swelling power of all samples ranged from 45 to 96 g/g. Considering, the classification reported by Shimelis et al. [67] for flours and starches as (high swelling, moderate swelling, restricted swelling or highly restricted swelling), both raw and boiled *D. praehensilis* flour could be considered as high swelling flours since their swelling power at 95°C is higher than 30%. These high values of swelling power recorded for the current study agrees with those reported for sweet potato by Aprianita [53] with values ranged from 10 to 80g/g.

The flour solubility (Fig. 3) is water ability indicative to enter starch granule. Solubility is a measure of the ease with which the flour particles can dissolve in cooking water. It permits rapid and extensive dispersion of flour particles in solution [33]. It gives an indication on water ability to enter starch granule. The raw flour (YT_0) solubility was reported to be the lowest with values ranged 6.25% to 8.75%. These values are higher than those reported by Oluwatonyin [49] for flour from unbleached plantain with values of 5.89%. The boiling process significantly increases the solubility with the highest solubility values ranged 7.15% to 13.75% recorded for flour sample YT_{40}. These results are consistent with results of Onuegbu *and al.* [68] for three-leaved yam (*Dioscorea dumetorum* which values ranged from 9 to 11.58% from raw to 120 min boiled tuber. Anyway, for each sample, there was no significant change in flours solubility at temperatures 50°C and 60°C but the solubility of each flour starts to increase significantly from 60°C to 95°C. The increase of solubility from 60°C to 90°C was previously reported by Oluwamukomi and Akinsola [69], although these authors found a significant increase in solubility from 45°C to 60°C which is in contradiction to current results. It seems that solubility as swelling power increase with the increase of temperature and this increase is more important at gelatinised temperature 72°C-80°C [66]. The results in the current study suggest that boiled flours may dissolve easily in cooking water during food technology.

The turbidity of raw and boiled tubers is reported on Fig. 4. The turbidity of pastes is inversely related to paste clarity (capacity to transmit light when exposed to a ray of light passing through these pastes defines its clarity) the transparency of pastes, the dispersion of the solutes and the tendency to the retrogradation of the starches [70]. In this work the highest turbidity behaviour was recorded for raw flour with values ranged from 2.6 to 2.71. The lowest values were recorded for the YT_{40} flour with values ranged from 1.60 to 2.00. For all the samples, there were increase scales of turbidity during 5 or 6 days followed by a slight decrease step tile the 14[th] day. Turbidity is affected by granules swelling too [71]. Turbidity values are higher than those reported [71] who found values ranged from 1 to 1.5. The lowest turbidity values of YT_0 and YT_5 suspension may be due to their low amylose content. The turbidity values of flours suspensions progressively increased with increase in storage period. The increase in turbidity during the storage period may be due to the leached amylose and amylopectin chains and the aggregation and crystallisation of amylose that leads to the development of the functional zone which scatters a significant amount of light [72].

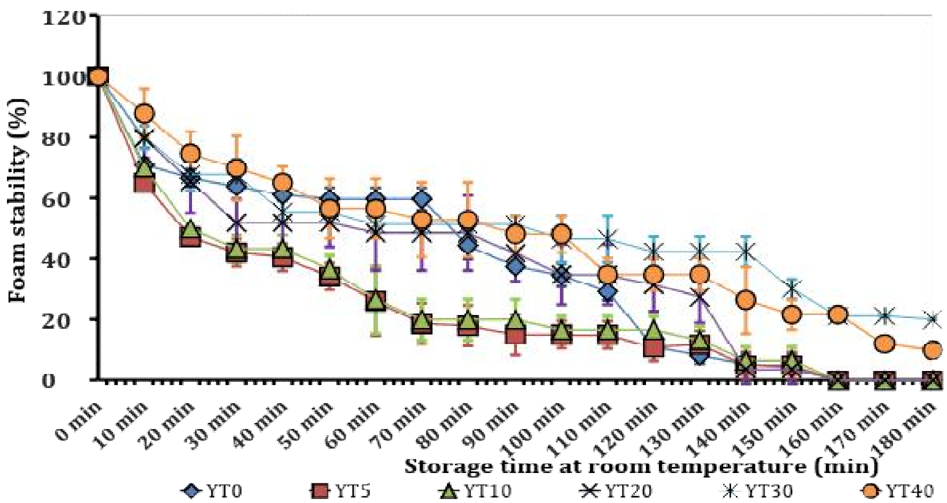

Fig. 1. Foam stability of raw and boiled wild yam *D. praehensilis* tubers flours

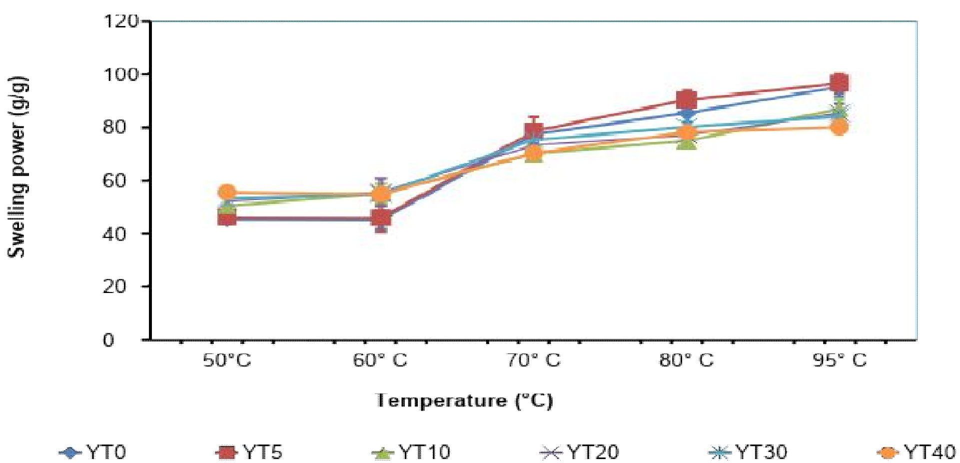

Fig. 2. Swelling power of raw and boiled wild yam *D. praehensilis* tubers flours

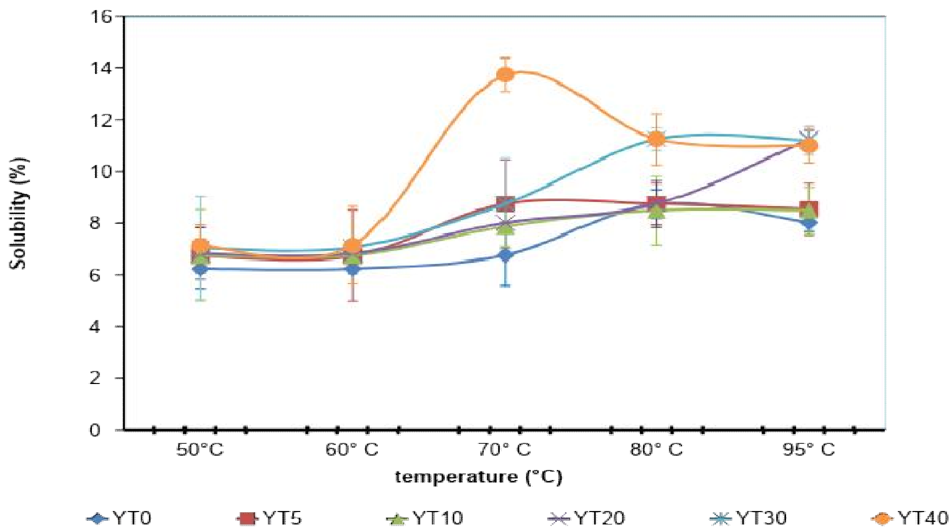

Fig. 3. Solubility of raw and boiled wild yam *D. praehensilis* tubers flours

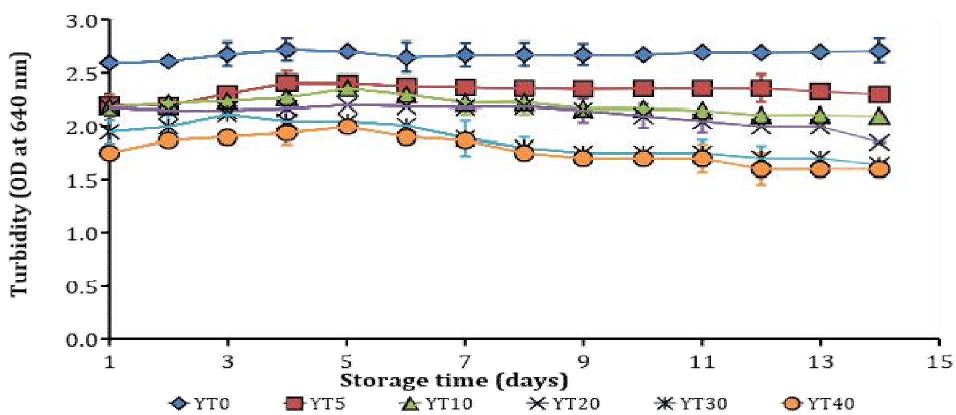

Fig. 4. Turbidity of raw and boiled wild yam *D. praehensilis* tubers flours

Oil Absorption Capacity (OAC) of wild yam tuber flours was tested using 4 different oils (Refined palm oil, Olive oil, Sunflower oil and unrefined palm oil). Results reported in Table 2 showed the best OAC values for unrefined oil with values ranged 180.5% to 192%. The lowest values were recorded for Sunflower oil with values 162.5% to 178.5%. Unless, unrefined palm oil, raw flour showed better OAC than boiled ones. In general, OAC decrease with the boiling time but all the OAC values recorded in the current work made *D. praehensilis* tubers flours, a better oil absorption capacity flour product than plantain (*Musa parasidiaca*) flour (108 – 112%) [49], wheat flour (106 %) and breadfruit flours (160 %) as reported by Ajani *and al.* [61]. Thus, flours from *D. praehensilis* tubers could be considered as very high OAC product like. This characteristic is desired in food technology for the making of preparations that involve oil mixing like in bakery products where oil is an important ingredient.

4. CONCLUSION

Boiling *D. praehensilis* led to improvement in this wild yam flours ability to foods making processes. Functional properties such as densities, paste clarity, water absorption capacity and solubility significantly increase during boiling. This is reported to enable ease dispersibility in reconstituting paste, application in confectionery and easy dissolution in cooking water. *D. praehensilis* flour is a high water absorption product with the best WAC flour reported at 10 min boiling. The LGC suggest that boiling should not be performed over 30 min if flour is to make stable gels. *D. praehensilis* is also a good oil absorption product, showing possibilities in food technology applications using oil. Best oil absorption was recorded for unrefined oil for a shorter boiling time. The reduction of swelling power and foam capacity and stability showed that the boiling led to starch and protein denaturation and should be as shorter as possible. Wettability and emulsion capacity values suggest that *D. praehensilis* boiled flours could be used as emulsifiers and in instantaneization of products probably in association with milk. Finally, flours from boiled *D. praehensilis* tubers could have multiple applications in food technology if the boiling is moderate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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