Effect of softening level on physico-chemical parameters of safou (*Dacryodes edulis*) pulp and oil grown in Côte d'Ivoire

DJEDJE Bléto Patrick Gérard, KADJI Beugré Romuald Léonce, KONE Fankroma Martial Thierry*, DABONNE Soumaïla

Laboratory of Biocatalysis and Bioprocessing, Department of Food Science and Technology, University Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire.

*Corresponding author: fankrom@yahoo.fr

Original submitted in on 2nd October 2019. Published online at www.m.elewa.org/journals/ on 31st January 2020
<https://doi.org/10.35759/JABs.v145.2>

ABSTRACT

Objectives: The African pear (*Dacryodes edulis*) is an emerging economic fruit tree. Unfortunately, its fruits suffer significant postharvest losses due to their rapid softening. This study aims to determine the effect of post-harvest softening on the physico-chemical qualities of Ivorian safou pulp and oil.

Methodology and Results: Both safou varieties were collected at maturity in Grand-Morié (South-East of Côte d'Ivoire) for physico-chemical analysis. Softening index, moisture, protein and ash contents of *D. edulis* fruit increased from S₀ to S₄ levels, while fibre, lipid and carbohydrate contents decreased during softening period. However, no significant variation of nutritional parameters was observed from S₀ to S₁, and S₃ to S₄. Moreover, the iodine index of safou oil decreased between S₀ and S₄, while its saponification index increased. Acid and peroxide indexes increased but remains in compliance with food standards up to softening level S₃.

Conclusion and application of findings: The postharvest softening significantly influenced the firmness and the proximate components of safou pulp, and the chemical index of its oil. Thus, the postharvest softening effect of safou on proximate components follows a three-phases ripening process. It is the initiation (S₀ to S₁), propagation (S₁ to S₃) and decline (S₃ to S₄) that corresponds to the beginning of senescence. These results showed that up to the level S₃, safou pulp might be useful in the food industry (bakery, pastry), while its oil could be used in food, pharmaceutical and cosmetic industries.

Keywords: *Dacryodes edulis*, postharvest losses, softening, chemical parameters, pulp oil.

INTRODUCTION

In recent years, attention has focused on non-conventional crops with potential interest for local or industrial development (Akpi, African bush mango and Safou) (Kouamé et al., 2015; Kadji et al., 2016; Ano et al., 2018). *Dacryodes edulis* or safou is now cultivated in many countries of Central Africa and the Gulf of Guinea (Kadji et al.,

2018). This African pear is an emerging economic fruit tree, which can greatly contribute to reduce poverty in the countries where it is grown (Noumi et al., 2014). Safou fruits are ellipsoid drupes, 4–8 cm long by 3–6 cm wide, depending on varieties and origin (Kengué, 2002). Safou pulp would be an important source of oil (Kadji et al., 2018), and thus

find its place in food, pharmaceutical and cosmetic industries. The pulp powder may be useful in human food industry (bakery, pastry) (Ano *et al.*, 2018). Unfortunately, the potential of safou tree is not fully exploited, because of important postharvest losses as a result of fruit softening (Dossou *et al.*, 2018). Safou fruits usually ripen on the tree and no softening process occurs if they remain attached on the tree. After picking, the ambient conditions deteriorate the edible and commercial qualities of the fruits due to their rapid softening (Dossou *et al.*, 2018). High postharvest losses of safou are registered up to 50% in just 2-3 days (Mayele, 2010). Thus, the recycling of softened safou in order to transform them as powder or oil could contributed to solve the

problem of postharvest losses (Kabantu and Tshiombe, 2011). Scientific research has focused on valorisation and popularization of safou in Côte d'Ivoire. Thus, Kadji *et al.* (2016) characterized both Ivorian safou varieties, and studied them as ingredients to enrich infant flours. Subsequently, Ano *et al.* (2018) studied the biochemical and composition of pulp and seeds meal of Ivorian safou obtained after several extraction techniques. The present work is registered into this context. Indeed, there is a lack of data concerning the changes of the physico-chemical parameters of *D. edulis* fruit during the postharvest softening. Therefore, this study aims to determine the effect of the natural softening process on physico-chemical qualities of safou pulp and oil.

MATERIAL AND METHODS

Sample collection: Based on the morphological characteristics of safou fruits, two varieties were selected: variety *edulis* and variety *parvicarpa* (Figure 1, Table 1). The fruits were collected from Grand-Morié (Agneby-Tiassa region), located at southeast of Côte d'Ivoire. After harvesting, mature safou fruits were immediately transported in perforated bags to the laboratory and stored at ambient temperature ($27 \pm 1.2^\circ\text{C}$) for 12 days. A total of 200 fruits of each variety were subjected to this study. Samples of stored safou fruits were picked at fixed time intervals, i.e. every three (3) days until the 12th day of storage according to the

modified method of Ozdemir and Topuz (2004). Analyses were carried out on 5 softening periods (S_0 , S_1 , S_2 , S_3 , and S_4) as follows:

- S_0 corresponds to the sampling carried out when the fruit has been freshly harvested;
- S_1 corresponds to the sampling carried out after 3 days storage and which corresponds to the first day of softening when 80% of the fruits are softened;
- S_2 corresponds to $S_1 + 3$ days;
- S_3 corresponds to $S_2 + 3$ days;
- S_4 corresponds to $S_3 + 3$ days.

Figure 1: Safou fruits: *D. edulis* variety *edulis* (a) and *D. edulis* variety *parvicarpa* (b).

Table 1: Morphological characteristics for the two varieties of safou fruit

Variety	Mass (g)	Length (mm)	Width (mm)	Pulp thickness (mm)
<i>edulis</i>	49.63 ± 1.51 ^b	71.23 ± 2.54 ^b	37.65 ± 1.49 ^b	3.86 ± 0.42 ^b
<i>parvicarpa</i>	27.34 ± 1.42 ^a	38.37 ± 1.72 ^a	33.73 ± 2.15 ^a	2.92 ± 0.63 ^a

Values are mean of 50 fruits ± standard deviation. Significant differences at $p < 0.05$ are indicated in the same column by different letters.

Texture measurement: According to the modified method of Dossou *et al.* (2012), a K19500 penetrometer (Koehler Instrument Company, INC, USA) equipped with a piston (47.5 g) was used to measure the texture of the fruits expressed in softening index. For each softening level, one sample of 10 fruits was constituted. This sample was stored at ambient temperature and fruit texture was measured every 3 days up to the 12th day. For each fruit, 12 measurements were taken, uniformly spread along its surface area. Thus, the average of 60 measurements on 5 fruit samples allowed the determination of the softening index.

Chemical analysis methods: Moisture content was determined by drying in an oven at $103 \pm 2^\circ\text{C}$ during 4 h to constant weight (AOAC, 2000). Ash content was determined by incinerating dried samples in a muffle furnace at 550°C for 4 h (AOAC, 2000). Lipid content was determined by the Soxhlet extraction method using hexane as solvent (AOAC, 2000). Protein content was

calculated from nitrogen contents ($\text{N} \times 6.25$) obtained using the Kjeldahl method (AOAC, 2000). Carbohydrate content was calculated by difference that is by deducing the mean values of other parameters (moisture, ash, lipid, protein and crude fibre) that were determined from 100. Crude fibre content was measured from the loss in weight of the crucible and its content on ignition (AOAC, 2000). Standards ISO were used to determine the iodine value (ISO 3961, 2009), saponification value (ISO 3657, 2003), acid value (ISO 660, 2009) and peroxide value (ISO 3960, 2007) of safou pulp oil.

Statistical analysis: For all analyses, three samples of each variety were used to calculate the mean value and the standard deviation. Data were assessed by Analysis of Variance (ANOVA) and Duncan Multiple Range analysis ($p = 0.05$). The correlation between all parameters was examined by Pearson independence test. Statistical analysis was performed using the Statistica software 7.1 (Stat Soft Inc, Tulsa USA Headquarters).

RESULTS

Softening index and proximate composition of safou pulp: The softening index and the proximate composition of safou pulp during four softening stages are showed in Table 2. The softening index of *D. edulis* fruit ranged between 0.86 to 3.53 mm for var. *edulis* and 0.85 to 2.86 mm for var. *parvicarpa*. ANOVA and Duncan test at $p = 0.05$ revealed that the safou softening index significantly increased from S_0 to S_4 , with a slight decrease in intensity from S_3 to S_4 . Moreover, it is observed in this study that softening index is been significantly different ($p < 0.05$) from one variety to another. Concerning the proximate composition, there is a significant variation ($p < 0.05$) in all parameters studied according to the softening level for the two safou *D. edulis* varieties. However, no significant difference ($p = 0.05$) was observed between S_0 and S_1 , and between S_3 and S_4 softening levels. The moisture content of safou pulp ranged from 41.52 to 47.76%

(var. *edulis*) and from 41.32 to 47.81% (var. *parvicarpa*). Ash contents of safou ranged between 2.95 and 3.33% (var. *edulis* and *parvicarpa*). Protein content varied from 3.34 to 6.83% (var. *edulis*) and 3.31 to 6.88% (var. *parvicarpa*). Results also shows that these three parameters (moisture, ash and protein) significantly increased ($p < 0.05$) during the postharvest softening from S_1 (3 days) to S_3 (9 days). Table 2 shows that lipid content ranged from 31.19 to 37.27% (var. *edulis*) and from 28.23 to 34.68% (var. *parvicarpa*). Carbohydrate content of safou pulp varied from 10.35 to 12.18% (var. *edulis*) and from 13.21 to 15.01% (var. *parvicarpa*). Fibre content ranged from 0.54 to 2.72% (var. *edulis*) and from 0.54 to 2.71% (var. *parvicarpa*). ANOVA and Duncan test at $p = 0.05$ revealed that these parameters (lipid, carbohydrate and fibre) significantly decreased during the natural softening process from S_1 (3 days) to S_3 (9 days).

Table 2: Proximate composition of safou pulp during the natural softening process

Var.	SL	Softening index (mm)	Moisture (%)	Ash (%)	Lipid (%)	Protein (%)	Carbohydrate (%)	Crude fibre (%)
E	S ₀	0.86±0.06 ^a	41.52±0.1 ^a	2.95±0.02 ^a	37.27±0.42 ^f	3.34±0.34 ^a	12.18±0.18 ^c	2.72±0.04 ^a
	S ₁	1.78±0.03 ^c	41.74±0.17 ^a	2.97±0.01 ^a	37.24±0.51 ^f	3.39±0.16 ^a	11.98±0.21 ^c	2.70±0.06 ^a
	S ₂	2.85±0.06 ^f	45.15±0.23 ^b	3.15±0.03 ^b	33.49±0.63 ^d	5.16±0.13 ^b	11.53±0.17 ^b	1.52±0.03 ^b
	S ₃	3.42±0.05 ^g	47.51±0.12 ^c	3.32±0.02 ^c	31.22±0.58 ^c	6.81±0.11 ^c	10.58±0.13 ^a	0.56±0.03 ^c
	S ₄	3.53±0.03 ^h	47.76±0.21 ^c	3.33±0.01 ^c	31.19±0.31 ^c	6.83±0.19 ^c	10.35±0.21 ^a	0.54±0.03 ^c
P	S ₀	0.85±0.05 ^a	41.32±0.22 ^a	2.95±0.02 ^a	34.68±0.52 ^e	3.31±0.22 ^a	15.01±0.26 ^f	2.71±0.02 ^a
	S ₁	1.48±0.06 ^b	41.53±0.31 ^a	2.97±0.01 ^a	33.75±0.31 ^d	3.32±0.31 ^a	14.74±0.23 ^f	2.71±0.01 ^a
	S ₂	2.53±0.03 ^d	45.17±0.16 ^b	3.15±0.03 ^b	30.59±0.43 ^b	5.19±0.16 ^b	14.37±0.12 ^e	1.53±0.04 ^b
	S ₃	2.71±0.05 ^e	47.69±0.12 ^c	3.32±0.02 ^c	28.27±0.45 ^a	6.83±0.12 ^c	13.33±0.15 ^d	0.56±0.02 ^c
	S ₄	2.86±0.04 ^f	47.81±0.17 ^c	3.33±0.01 ^c	28.23±0.51 ^a	6.88±0.17 ^c	13.21±0.32 ^d	0.54±0.01 ^c

Values given are mean ± standard deviation of triplicate determination. Significant differences at p<0.05 are indicated in the same column by different letters.

Var.: Variety; SL: Softening level; E: variety *edulis*; P: variety *parvicarpa*.

Chemical parameters of safou pulp oil: The variation of the chemical parameters of safou pulp oil during the postharvest softening is presented in Figure 2. During the softening process (S₀ to S₄), the iodine values of safou pulp oil decreased significantly (p<0.05) from 57.01 to 26.12 mg/100g in var. *edulis* and from 58.36 to 28.32 mg/100g in var. *parvicarpa* (Figure 2A). Between S₀ and S₁, a small reduction in iodine value (about 1.5 mg/100g) was observed. Afterwards, a significant decrease in the iodine index (about 17.5 mg/100g) was observed from the 3rd (S₁) to the 12th day (S₄). Figure 2B shows that saponification index of safou pulp oil increased significantly (p<0.05) during the postharvest softening from S₀ (day 0) to S₄ (day 12). These values

ranged from 212.26 to 287.85 mg KOH/g for var. *edulis* and from 198.24 to 259.43 mg KOH/g for var. *parvicarpa*. A significant increase (p<0.05) was also observed for acid and peroxide indexes of safou pulp oil during the postharvest softening from S₀ to S₄ (Figures 2C and 2D). Indeed, the acid index values increased from 1.49 to 4.62 mg KOH/g (var. *edulis*) and from 1.48 to 4.18 mg KOH/g (var. *parvicarpa*), while the peroxide index values increased from 3.57 to 8.82 meq O₂/kg (var. *edulis*) and from 3.53 to 8.39 meq O₂/kg (var. *parvicarpa*) during postharvest softening. Moreover, the results of current study showed that all indexes of safou oil were significantly different (p<0.05) from one variety to another.

Figure 2: Chemical index of safou pulp oil during postharvest softening: iodine index (A), saponification index (B), acid index (C) and peroxide index (D).

DISCUSSION

Changes in firmness and proximate parameters of safou pulp during natural softening process:

Firmness is an important parameter for measuring the quality of fresh fruits and vegetables. In this study, the softening index (0.85-0.86 mm) taken on the day of harvest (S₀) was close to those reported by Dossou *et al.* (2018) (0.85 mm) for safou fruits. Between S₀ (day 0) and S₃ (day 9), a sudden drop in firmness is observed. Afterwards, the firmness loss is gradual until S₄ softening level (day 12). Similar observation has been found by several authors who reported that safou softening appeared on the third day of postharvest storage (Kengué, 2002; Silou *et al.*, 2007; Mayele, 2010). According to Dossou *et al.* (2018), the softening stage is characterized by significant cell wall carbohydrate degradation, and changes during postharvest storage have an impact on safou texture.

This could be attributed to a reduction in insoluble pectin during ripening (Mamiro *et al.*, 2007). Thus, fruit softening is associated with cell wall disassembly (Abu-Bakr *et al.*, 2003). In *D. edulis* var. *edulis*, the softening index was found to be higher than that from *D. edulis* var. *parvicarpa*. This result indicates that the higher the size, the greater the softening of safou fruits (Dossou *et al.*, 2012). This study also showed that there was no significant difference in all chemical composition of safou pulp between S₀ (day 0) and S₁ (day 3) softening levels. This would correspond to the beginning of softening process. However, moisture, ash and protein contents increased rapidly within S₁ (day 3) to S₃ (day 9) softening level, when lipid, carbohydrate and fibre contents decreased. This increase could be explained by the propagation of the softening process. Afterwards, from S₃ (day 9) to S₄ (day 12), the variation

of the chemical composition became low and not significant. This low variation would be due to the decline of the softening process and the transition period between maturation and senescence. The moisture content of safou pulp (41.32-41.52%) taken on the day of harvest (S_0) is close to those observed by Kadji *et al.* (2016), which was ranged from 43.02 (*D. edulis* var. *parvicarpa*) to 46.80% (*D. edulis* var. *edulis*). Moisture content of safou pulp increased with softening times from S_1 to S_3 . The perishable nature and the rapid degradation of safou fruits could be explained the significant increase observed in their moisture content (Kadji *et al.*, 2016). The increasing of moisture content during postharvest storage was also observed by Ozdemir and Topuz (2004) in avocado and by Dan *et al.* (2014) in *Solanum anguivi* berry during post-harvesting ripening period. The ash values of the investigated *D. edulis* pulp (2.95-3.33%) were comparable to those reported by Ndindeng *et al.* (2012) (2.7%) and Duru *et al.* (2012) (2.89-4.16%) for the same species. In the current study, the ash content also increased with softening times from S_1 to S_3 . In contrast, Mahmood *et al.* (2013) reported a decrease from 5.91 to 4.23% in cherry fruits at three maturity stages. Ash content gives an indication of mineral element in food and it is very important in many biochemical reactions of metabolic processes in the human body (N'Goran *et al.*, 2015). During softening process, safou pulp would then provide essential minerals for body development. The protein content of freshly harvested safous (S_0) was near those observed by Ndindeng *et al.* (2012) for the same species (about 3%). During postharvest softening period, the protein content of safou pulp was also found to increase from S_1 to S_3 . This would be related to the increase in polysaccharidase activity during ripening (Elhassan and Abu-Goukh, 2016). An increase in protein content (from 4.23 to 5.91%) was also found by Mahmood *et al.* (2013) in cherry fruit at three maturity stages. The high protein content during softening would be beneficial for consumption. The lipid content obtained in this study (S_0) reveals that safou pulp contains high lipid content (37.27% for var. *edulis* and 34.68% for var. *parvicarpa*). The observed high levels of lipid confirm that the safou fruits are good sources of oils and fats as reported by Duru *et al.* (2012) and Kadji *et al.* (2018). However, these lipid levels were found to decrease during postharvest softening period from S_1 to S_3 . Similar results were reported by Ozdemir and Topuz (2004) in avocado and by Silou *et al.* (2007) in *D. edulis* fruits during post-harvest storage. The reduction observed in

lipid content during safou storage would be due to the degradation of triacylglycerol during ripening and senescence. Indeed, triglycerides are catabolized by the action of triacylglycerol lipases, which release fatty acids. Then, these fatty acids are decomposed into acetyl-CoA units through β -oxidation. Acyl-CoA and alcohols are esterified to form a variety of esters which are characteristic volatile flavour components of fruits (Paliyath *et al.*, 2008). The carbohydrate content of the safous studied at S_0 (12.18-15.01%) are comparable to those reported by Kadji *et al.* (2016) (14.66-17.82%) on a related study. A decrease of carbohydrate content was observed from S_1 to S_3 . This may be explained by the breakdown of some carbohydrate components, the metabolism of the polysaccharides in the cell wall and the starch hydrolysis during the softening process (Wordu and Akusu, 2018). Such a decrease was highlighted by Assemmand *et al.* (2012) in *Musa paradisiaca* L. fruit. Concerning the fibre content of fresh safous (S_0), the values obtained in this study (around to 2.7%) are near to those obtained by Kadji *et al.* (2016), which found 2.70 to 3.13% of fibre in safou fruits. The softening process resulted in a decrease in fibre content of safou from S_1 to S_3 . This reduction was also observed in cherry fruits (Mahmood *et al.*, 2013) and in *D. edulis* fruits (Duru *et al.*, 2012) during maturation stage. According to Mamiro *et al.* (2007), the decrease in fibre content could be attributed to a reduction in insoluble pectin during maturation involving the action of enzymes.

Changes in chemical parameters of safou pulp oil during natural softening process: The iodine index of the studied safou was found to decrease during softening process from 57.01 to 26.12 mg/100g and from 58.36 to 28.32 mg/100g in *D. edulis* var. *edulis* and in var. *parvicarpa*, respectively. Between S_0 and S_1 , a slight decrease (about 0.95 mg/100g) in the iodine index was observed. This slight variation in the iodine index suggests that the quality of the studied oil remains interesting from S_0 to S_1 . From S_1 to S_4 , a significant decrease in the iodine index was observed. This could be explained by the increasing of oxidative degradation of oil during the storage time (Noumi *et al.*, 2014), thus reducing the amount of double bonds in the oils. Indeed, iodine index is used to quantify the amount of double bonds present in the oil, which reflects the susceptibility of oil to oxidation. It gives information on the unsaturation degree in oil and it is an identity characteristic of native oil. The higher the iodine index, the more unsaturated the oil. In the current study, the observed iodine index after harvest remained in the

range of edible oils, between 9.37 and 145 mg/100g (Tan *et al.*, 2002). Concerning the saponification index, an increase was observed between S_0 to S_4 from 212.26 to 287.85 mg KOH/g and from 198.24 to 259.43 mg KOH/g in *D. edulis* var. *edulis* and in var. *parvicarpa*, respectively. This increase could be explained by the breakdown of unsaturated fatty acid chains following oxidation during postharvest storage (Wolff, 1991). These saponification values of safou pulp oils studied are comparable to those of oils currently used in food diet: soybean (188 - 195), cotton oil (188 - 190), olive oil (184 - 196) and peanut oil (187- 196) (Noumi *et al.*, 2014). The high saponification values in this study are close to those reported by Kadji *et al.* (2018) for Ivorian safou (173.16 to 215.16 mg KOH/g) and suggest the possibility of industrial applications of safou oil. Acid index determine the use of oil for either edible or industrial utility (Kadji *et al.*, 2018). The acid index of fresh safou (S_0) is in accordance with those reported by Kadji *et al.* (2018). Between S_0 to S_4 softening level, there is an increase of acid index. This could be due to the increasing of oxidative degradation of oil during storage (Noumi *et al.*, 2014), resulting in an

increase in the amount of free fatty acids in oil. Similarly, Dandjouma *et al.* (2008) reported an increase of acid index during the storage of *Canarium schweinfurthii* fruits pulp oil. In the current study, the acid index of safou oils (3.51-3.87 mg KOH/g) after 9 days storage (S_3) remain below the recommended value of 4 mg KOH/g. Therefore, these oils are suitable for edible purpose (Codex Alimentarius, 2005). The peroxide index observed in this study at S_0 (around 3.5 meq O_2 /kg) is comparable to those reported by Kadji *et al.* (2018) (3.48-4.46 meq O_2 /kg) and Noumi *et al.* (2011) (4.58 meq O_2 /kg) for safou pulp oils. Between S_0 to S_4 softening level, an increase of peroxide index was observed. This increase was also reported by Dan *et al.* (2014) during the storage of *S. anguivi* berry. Increase in peroxide index would translate high oxidation of unsaturated fatty acids in oil during storage (Dandjouma *et al.*, 2008). However, the relatively low peroxide values at 9 days storage (S_3), which are well below 10 meq O_2 /kg, exhibit the potential use of softened safou oil in food industry (Codex Alimentarius, 1992).

CONCLUSION

This study revealed that the postharvest softening induced significant changes in the physico-chemical quality of safou pulp and oil. The natural softening process of safou grown in Côte d'Ivoire is quickly initiated and it would occur in three phases: initiation (S_0 to S_1), propagation (S_1 to S_3) and decline (S_3 to S_4). In this respect, the nutritional value of softened safou pulp remains satisfactory during 9 days after harvest

(S_3). In addition, the quality of safou pulp oil remain conformed to the recommended standards for edible oils despite its low oxidative degradation during softening up to S_3 . This shows that the fresh fruit of Ivorian safou is a nutritious food, which could be used for industrial purposes and consumed in various forms 9 days after harvest.

REFERENCES

- Abu-Goukh AA and Bashir A, 2003. Changes in pectic enzymes and cellulase activity during guava fruit ripening. *Food Chemistry* 83: 213-218.
- Ano AARR, Koffi EN, Adima AA, N'da PK, Anin LA, 2018. Composition biochimique et phytochimique des tourteaux des fruits du safoutier (*Dacryodes edulis*) de Côte d'Ivoire. *International Journal of Biological and Chemical Sciences* 12(6): 2535-2546.
- AOAC, 2000. Official Methods of Analysis of the Association of Analytical Chemists. 17th Edition. Washington, DC, USA.
- Assemmand KE, Camara F, Kouamé F, Konan V, Kouamé PL, 2012. Caractérisation biochimique des fruits de plantain (*Musa paradisiaca* L.) variété « Agnrin » de Côte d'Ivoire et évaluation sensorielle de ses produits dérivés. *Journal of Applied Biosciences* 60: 4438-4447.
- Codex Alimentarius, 1992. Programme mixte FAO/OMS sur les normes alimentaires. FAO, Rome, Italie.
- Codex Alimentarius, 2005. Alinorm 01/17: Norme pour les huiles végétales portant un nom spécifique, Codex-Stan 210, 14 pp.
- Dan CG, Kouassi KN, Ban KL, Nemlin GJ, Kouame PL, 2014. Influence of maturity stage on nutritional and therapeutic potentialities of *Solanum anguivi* Lam berries (Gnagnan) cultivated in Côte d'Ivoire. *International Journal of Nutrition and Food Science* 3(2): 1-5.

- Dandjouma AKA, Tchiegang C, Parmentier M, 2008. Evolution de quelques paramètres de qualité physico-chimique de l'huile de la pulpe des fruits de *Canarium schweinfurthii* Engl. au cours du stockage. *International Journal of Biological and Chemical Sciences* 2(3): 249-257.
- Dossou BR, Missang CE, Baron A, Renard CMGC, Silou T, 2012. Factors affecting postharvest preservation of safou (*Dacryodes edulis* (G. Don) H.J. Lam) fruits. *Forests, Trees and Livelihoods* 21(1): 44-55.
- Dossou BR, Missang CE, Karou SD, Ameyapoh Y, 2018. Relationship between texture and cell-wall components of safou (*Dacryodes edulis* (G. Don) H.J. Lam) fruits at different storage conditions. *Journal of Applied Biosciences* 125: 12566-12580.
- Duru M, Amadi C, Ugbogu A. Eze A, Amadi B, 2012. Phytochemical, vitamin and proximate composition of *Dacryodes edulis* fruit at different stages of maturation. *Asian Journal of Plant Science and Research* 2(4): 437-441.
- Elhassan SYM and Abu-Goukh AA, 2016. Role of cellulase enzyme in fruit softening during muskmelon fruit ripening. *American Journal of Scientific and Industrial Research* 7(4): 98-105.
- ISO 3657, 2003. Animal and vegetable fats and oils. Determination of saponification value. International Organization of Standardization.
- ISO 3960, 2007. Animal and vegetable fats and oils. Determination of peroxide value Iodometric (visual) end point determination. International Organization of Standardization.
- ISO 3961, 2009. Animal and vegetable fats and oils. Determination of iodine value. International Organization of Standardization.
- ISO 660, 2009. Animal and vegetable fats and oils. Determination of acid value and acidity. International Organization of Standardization.
- Kabantu MT and Tshiombe VE, 2011. Quelques constantes physiques de l'huile de safou. Editions Universitaires Européennes. 6 pp.
- Kadji BRL, Kone FMT, Sika AE, Dabonné S, 2016. Physico-chemical properties of Safou (*Dacryodes edulis*) fruits grown in Côte d'Ivoire. *Journal of Applied Biosciences* 105: 10103-10110.
- Kadji BRL, Sika AE, Koné FMT, Dabonné S, 2018. Physicochemical properties and composition of safou (*Dacryodes edulis*) non-conventional oil from Côte d'Ivoire. *Journal of Chemical, Biological and Physical Sciences* 8(1): 168-179.
- Kengué J, 2002. Fruits for the future 3. Safou: *Dacryodes edulis*. Research for Development in Department for International Development. 147 pp.
- Kouamé NMT, Soro K, Mangara A, Diarrassouba N, Koulibaly AV, Boraud NKM, 2015. Etude physico-chimique de sept (7) plantes spontanées alimentaires du centre-ouest de la Côte d'Ivoire. *Journal of Applied Biosciences* 90(1): 8450-8463.
- Mahmood T, Anwar F, Bhatti IA, Iqbal T, 2013. Effect of maturity on proximate composition, phenolics and antioxidant attributes of cherry fruit. *Pakistan Journal of Botanic* 45(3): 909-914.
- Mamiro P, Fweja L, Chove B, Kinabo J, George V, Mtebe K, 2007. Physical and Chemical Mango (*Mangifera Indica* L.) Fruits varieties of Eastern Tanzania. *African Journal of Biotechnology* 6(21): 2477-2483.
- Mayele D, 2010. Biodiversité morphologique et biochimique du safou (*Dacryodes edulis*) de Kinshasa et du Bas-Congo en République Démocratique du Congo. Thèse de doctorat, Université de Kinshasa, République Démocratique du Congo.
- N'Goran NAM, Ahipo DE, Koné FMT, N'Guessan EJPK, Zoro BIA, Kouamé PL, 2015. Physico-chemical properties and mineral composition of four cultivar seed flours from *Citrullus lanatus* (Cucurbitaceae) cultivated in Côte d'Ivoire. *International Journal of Agronomy and Agricultural Research* 6(1): 45-53.
- Ndindeng SA, Talle, Bigoga J, Kengue J, Boffa J-M, 2012. Predictors of organoleptic quality of boiled and dried pulp of safou (*Dacryodes edulis*) and the shelf life of its fresh fruits. *Fruits* 67(2): 127-136.
- Noumi GB, Djounja T, Ngameni E, Kapseu C, 2014. Influence of the storage time on the fats and oil composition of safou (*Dacryodes edulis*) dried pulp. *International Food Research Journal* 21(5): 1837-1841.
- Noumi GB, Njoukam YM, Njiné CB, Ngameni E, Kapseu C, 2011. Effets du séchage sur le rendement et la qualité de l'huile extraite de la pulpe de safou. *Tropicicultura* 29(3): 138-142.

- Nwosuagwu UH, Onuegbu CN, Nkwoala CC, 2009. The chemical properties of African pear pulp at different stages of fruit development. *International NGO Journal* 4(9): 380-385.
- Ozdemir F. and Topuz A., 2004. Changes in dry matter, oil content and fatty acids composition of avocado during harvesting time and post-harvesting ripening period. *Food Chemistry* 86: 79-83.
- Paliyath G, Murr DP, Handa AK, Lurie S, 2008. Postharvest biology and technology of fruits, vegetables, and flowers. Wiley-Blackwell Publishing. 492 pp.
- Silou T, Massamba D, Maniongui JG, Maloumbi G, Biyoko S, 2007. Post-harvest losses by natural softening of safou pulp (*Dacryodes edulis*) in Congo-Brazzaville. *Journal of Food Engineering* 79: 392-400.
- Tan CP and Che Man YB, 2002. Differential scanning calorimetric analysis of palm oil, palm oil based products and coconut oil: effects of scanning rate variation. *Food Chemistry* 76: 89-102.
- Wolf JP, 1991. Analyse et dosage des lipides. In Techniques d'analyses et de contrôle dans les industries agroalimentaires. Analyse des constituants alimentaires. Lavoisier, Techniques et Documentation, France. 221 pp.
- Wordu GO and Akusu MO, 2018. Chemical mineral and anti-nutrient composition of plantain (musa paradisiacal) during ripening process. *International Journal of Food Science and Nutrition* 3(1): 150-153.