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Influence of maturity stage on nutritional and therapeutic potentialities of *Solanum anguivi* Lam berries (Gnagnan) cultivated in Côte d'Ivoire

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Abstract: *Solanum anguivi* Lam, collectively called Gnagnan in Côte d'Ivoire is an eggplant with nutritional and therapeutic potentialities. The present study was undertaken to analyze the chemical composition of berries at different stages of maturity. Data showed that at the first stage of maturity, green berries are rich in ascorbic acid (34.5 ± 1.7 mg / 100 g DM), phenolic compounds (956.7 ± 71.1 mg / 100 g DM), iron (467.7 ± 1.8 mg / 100 g DM), magnesium (404.6 ± 16.3 mg / 100 g DM) and potassium (2059.7 ± 22.3 mg/100 g DM). However at the last stage of maturity, red berries are rich in proteins, cellulose, total sugars, fat and potassium with values of 22.53 ± 2 g/100 g DM, 19.12 ± 0.4 g/100 g DM, 3.7 ± 0.2 g/100 g DM, 2.7 ± 0.2 g/100 g DM and 2290.8 ± 22.2 mg / 100 g DM respectively. Thin layer chromatography revealed the presence of glucose, ribose, xylose, arabinose and fructose at all maturity stages. Excepted alkaloids and gallic tannins, the phytochemical sorting revealed that Gnagnan contain several pharmacological components. According to the maturity stages, orange and red berries showed a higher content in sterols and polyterpens, flavonoids and saponins. The green berries contain most of polyphenols, catechin tannins and quinons. As to yellow berries, they are rich in polyphenols and catechin tannins. Data of our study may enhance clinical research on the nutritional and pharmacological properties of *S. anguivi* Lam.

Keywords: Gnagnan, Maturity Stage, Chemical Composition, Thin Layer Chromatography, Phytochemical Sorting

1. Introduction

Solanaceae is a plant family comprising about 2300 species, nearly one-half of which belong to the genus *Solanum* [1]. *Solanum anguivi* Lam a native of Africa, is a medicinal plant that has improved health both in ancient and modern times. The ethnobotanical and clinical surveys have revealed that *S. anguivi* Lam berries are used in the treatment of many diseases which are of public health concern [2-7]. It is one of the non-tuberous *Solanum* species which is widely distributed in non-arid areas of Africa notably in West Africa, Central Africa, East Africa as well as Southern Africa [3]. *S. anguivi* Lam is polymorphic with wide diversity in forms and agronomic characteristics [8] as shown with the wide diversity in local cultivars including fruit sizes, shapes, taste, color, plant height and branching ability [9]. It has the potential for wide cultivation and increased demand in Côte d'Ivoire due to the cultural importance involving the welcome of visitors into family houses especially in the Central geographical zone of the country. Currently, this preference extends increasingly in all regions of the country. In literature, no consensus exists on maturity stage of *S. anguivi* Lam berries. *S. anguivi* Lam berries or Gnagnan assumes different colors, from green to yellow and finally red during its ripening period [4]. But, other authors noticed that *S. anguivi* Lam globular green berries successively change color into yellow, orange to red after ten days [3]. The berries of *S. anguivi* Lam are collected and consumed as a vegetable and seem to contain many nutrients like most of vegetables and fruits [2]. The berries can be consumed fresh, semi-ripe, ripe, dried or ground into flour. *S. anguivi* Lam berries are especially characterized by their bitterness due to the presence of various phenolic compounds conferring them antioxidant properties. The antioxidant profile (ascorbic acid, carotenoids and polyphenols) and antioxidant capacity of Gnagnan vary at three ripening levels (green, yellow and red) in Côte d'Ivoire [4]. Apart from this information on antioxidant properties of Gnagnan, little is known about its other chemical constituents. This complementary study was undertaken to determine nutritional and therapeutic potentialities of Gnagnan according to four maturity stage (green, yellow, orange and red).

2. Materials and Methods

2.1. Plant Materials

The berries of *S. anguivi* Lam were collected at the stage of green maturity from Yamoussoukro, political capital of Côte d'Ivoire, identified and authenticated at the Department of National Center of Floristic Research (Felix Houphöuet-Boigny University, Cocody-Abidjan). They were conveyed to the laboratory at Nangui Abrogoua University where they were stored on a bench at room temperature (27 ° C ± 3 ° C) with a relative humidity of 70 ± 5% for 10 days. The first day, the ¼ of green berries collected were directly dried into an oven at 45 ° C for 72 h. During the 10 days, the berries were sorted everyday by visual observation in regards to their color (yellow, orange and red) and stored in an oven under the same conditions. All the dried berries were grounded into a powdery (Grinder branded GLEN CRESTON) fine texture (100 µm) according to their color and stored at room temperature in air tight polythene bag prior to use for analysis.

2.2. Methods

2.2.1. Quantitative Evaluation of Nutritional Components

Five grams of the fresh sample of *S. anguivi* Lam was placed in an oven at 105°C until constant weight was attained. The percentage of dry matter was calculated as 100 % moisture. Ash, crude protein; fat and minerals were determined according to AOAC [10]. Phosphorus was determined as mentioned by Taussky and Shorr, 1953 [11]. Total sugars, fibers, phenolic compounds and ascorbic acid were carried out as described elsewhere [12-15].

2.2.2. Qualitative Evaluation of Sugars and Pharmacological Components

Sugars were revealed by thin layer chromatography as described by Bruckner [16]. The phytochemical sorting of pharmacological substances were determined according to previous studies [17]. Substance extractions were made with methanol. Sterols and polyterpens were highlighted by Libermann's reaction. Polyphenols were proved by the reaction of iron chloride ($FeCl_3$). Flavonoids highlighting was made by reacting with cyanidin. Catechol tannins were detected with Stiasny's reagent. Searching of gallic tannins was performed by reaction with sodium acetate. Quinonic substances were sought with Bornsträeger's reagent. Alkaloids were highlighted by Bourchardat, Dragendorff, Mayer-Valser reagent and picric acid. Saponins have been identified by the foam reaction. Coumarins detection was performed by reaction with sodium hydroxide.

2.2.3. Statistical Analysis

Data analyzes were performed using the software STATISTICA 7 (Statsoft Inc, Tulsa, USA Headquarters) and XLSTAT- Pro7.5.2 (Addinsoft Sarl, Paris, France). Comparisons between the dependent variables were made by using analysis of variance (ANOVA) and Duncan's test at 5% level.

3. Results

3.1. Quantitative Evaluation of Nutritional Components

Results showed that maturity significantly ($p \leq 0.05$) influenced the nutrients in *S. anguivi* Lam berries (Table 1). The dry matter, polyphenol, ascorbic acid and ash decreased with maturation while protein, total sugars, fat and fibers increased with Gnagnan maturation. Dry matter content of Gnagnan varied between 33.3 % DM (Green berries) to 22.1 % DM (Red berries). However, no statistically significance difference was observed between yellow and orange maturation stages in dry matter. During maturation proteins, fat, fiber, ash and polyphenols contents did not differed significantly between green to yellow berries and orange to red berries respectively. Ascorbic acid content (DM) decreased in all the maturation stages with the values of 34.5 ± 1.7 %, 25.6 ± 1.4 %, 20.7 ± 1.1 % and 13.8 ± 0.7 % at green, yellow, orange and red stages respectively. In Gnagnan, only red berries have higher total sugars contents (3.7 ± 0.2 % DM).

S. anguivi Lam berries contained several minerals in which potassium has a higher content with the values of 2059.7 ± 22.3 mg / 100 g DM, 2189 ± 25.7 mg / 100 g DM, 2218.8 ± 23.7 mg / 100 g DM and 2290.8 ± 22.24 in green, yellow, orange and red berries respectively (Table 2). Potassium content increased during maturation but did not differ significantly between yellow berries to orange with the values of 2189 ± 25.7 mg / 100 g DM and 2218.8 ± 23.7 mg / 100 g DM respectively. No difference was observed in zinc and phosphorus in berries during maturation. Calcium, sodium and copper contents increased with maturation while magnesium, iron and manganese decreased with Gnagnan maturation.

3.2. Qualitative Evaluation of Sugars and Pharmacological Components

Development of sugars in *S. anguivi* Lam berries during ripening are presented in Figure 1. Data showed that Gnagnan contain many sugars such as glucose, ribose, arabinose, xylose and fructose. Fructose appears in yellow and orange berries while ribose and xylose are replaced by arabinose in red berries. There were no melibiose, raffinose and lactose in Gnagnan whatever the stage of ripening was.

S. anguivi Lam berries contain many pharmacological substances which are presented in Table 3. Except gallic tannins and alkaloids, Gnagnan contain sterols and polyterpens, polyphenols, flavonoids, catechin tannins, quinons, saponins and coumarins. Saponins, flavonoids, sterols and polyterpens increased during ripening while polyphenols, catechin tannins and quinons decreased during ripening. No variation was observed in coumarins during berries maturation. Saponins, flavonoids, sterols and polyterpens were rich in orange and red berries while polyphenols and catechin tannins were rich in green and yellow berries (Table 3).

4. Discussion

The dry matter, polyphenol, ascorbic acid and ash decreased with maturation while protein, total sugars, fat and fibers increased with Gnagnan maturation (Table 1). This observation is grandly explained by water variation in berries. Chemical, physiological and organoleptic changes occurring during ripening cause significant movement of water in the cell walls [18]. The decrease of dry matter in *S. anguivi* Lam berries during ripening is due to the loss of solutes (polyphenols, ascorbic acid and ash) provoked by the weakness of the berries tissues. Changes in membranes result in increasing ion permeability, increase leakage of solutes and cell decompartmentalization [19]. Compared to other studies, the dry matter content of *S. anguivi* Lam berries in this study is lower than those reported in *S. aethiopicum* [3] and similar to those of *S. melongena* [20] with the values of 9.4 % and 27.1 % respectively.

Table 1. *Progress of the chemical composition of Solanum anguivi Lam berries during different stages of ripening*

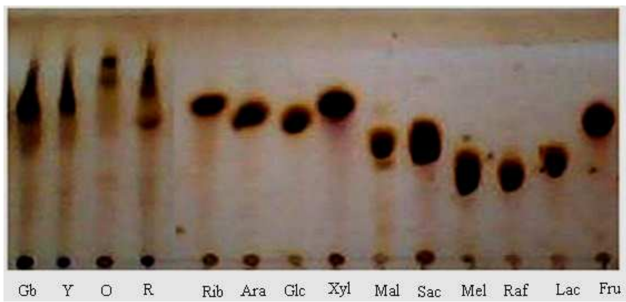
Components	Green berries	Yellow berries	Orange berries	Red berries
Dry matter (%)	$33.3 \pm 0{,}4^{c}$	27.9 ± 0.9^{a}	27.3 ± 1.2^{a}	22.1 ± 1.4^{b}
Proteins (%)	13.4 ± 1.9^{a}	14.1 ± 1.9^{a}	21.5 ± 0.7^{b}	22.5 ± 2^{b}
Total sugars (%)	2.4 ± 0.2^{a}	2.9 ± 0.2^{ab}	3.4 ± 0.3^{bc}	3.7 ± 0.2^{c}
Fat (%)	1.4 ± 0.2^{a}	1.6 ± 0.2^{a}	2.4 ± 0.2^{b}	2.7 ± 0.2^{b}
Fiber (%)	11.8 ± 0.7^{a}	12.6 ± 0.9^{a}	15.8 ± 0.5^{b}	19.1 ± 0.4^{c}
Polyphenols (mg/100 g DM)	956.7 ± 71.1^{b}	883.3 ± 39.2^{b}	666.8 ± 33.2^{a}	546.7 ± 35.4^{a}
Ascorbic acid (mg/100 g DM)	34.5 ± 1.7^{d}	25.6 ± 1.4^{c}	20.7 ± 1.1^{b}	13.8 ± 0.7^{a}
Ash (%)	6.9 ± 0.1^{b}	6.8 ± 0.1^{b}	6.3 ± 0.1^{a}	6.16 ± 0.0^{a}

The means with different superscript letters within the same row indicate significant different at $p<0.05$.

Table 2. *Progress of minerals (mg/100 g DM) of Solanum anguivi Lam berries during different stages of ripening*

Minerals	Green berries	Yellow berries	Orange berries	Red berries
Calcium	544.8 ± 16.2^{a}	559.9 ± 20.3^{a}	580.4 ± 22.3^{b}	680.9 ± 28.2^{c}
Sodium	268.4 ± 0.5^{a}	324.1 ± 5.6^{b}	352.1 ± 8.1^{c}	451.8 ± 7.2^{d}
Potassium	2059.7 ± 22.3^{b}	2189 ± 25.7^{a}	2218.8 ± 23.7^{a}	2290.8 ± 22.2^{c}
Magnesium	404.6 ± 16.3^{b}	356.8 ± 22.6^{b}	289 ± 14.2^{a}	284.5 ± 21.2^{a}
Phosphorus	107.0 ± 13.4^{a}	107.1 ± 12.7^{a}	107.5 ± 15^{a}	107.5 ± 7.7^{a}
Iron	467.7 ± 1.8^{a}	457.7 ± 4.0^{a}	341.8 ± 8.2^{c}	323.3 ± 6.5^{b}
Copper	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	0.2 ± 0.0^{b}	0.3 ± 0.0^{c}
Zinc	5.3 ± 0.4^{a}	5.4 ± 0.3^{a}	5.5 ± 0.5^{a}	5.6 ± 0.2^{a}
Manganese	0.2 ± 0.0^{b}	0.2 ± 0.0^{a}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}

The means with different superscript letters within the same row indicate significant different at $p<0.05$



Gb:Greenberries;Yb:Yellowberries;Ob:Orangeberries;Rb:Redberries; Rib:Ribose;Ara:Arabinose;Glc:Glucose;Xyl:Xylose;Mal:Maltose;Suc:Sucrose;Mel:Melibiose;Raf:Raffinose;Lac:Lactose;Fru: Fructose.

Figure 1. *TLC of Solanum anguivi Lam berries sugars during ripening with witnesses sugars.*

The loss of dry matter is correlated with the loss of ash. During ripening, ash decrease with dry matter's [18]. The ash obtained is high compared to those of *S. melongena* (2 - 3.2 %) [20]. The ash of *S. anguivi* Lam berries are very rich in minerals such as calcium, sodium, potassium, magnesium, phosphorus and iron (Table 2) which are very important in metabolism and health. That is why, *S. anguivi* Lam is usually considered as fruits or legumes because of its richness in minerals. Its higher content in potassium regardless of ripening (2059.7 ± 22.3 - 2290.8 ± 22.2 mg/100g DM) is important for health. In fact, *S. anguivi* Lam berries could cover the daily needs of potassium which is 2000 mg/100 [21]. Potassium levels are higher than those reported in the literature. In fact, *S. melongena* [20] and *S.*

lycopersicum [3] have potassium content of 238.1 - 245.4 mg/100 DM and 204 mg/100 g DM respectively. During ripening, magnesium declines because it is involved in the synthesis of enzymes required for the release of energy and protein synthesis [22]. Moreover, it decreases because its acts on carbohydrate and lipid metabolism that occur during ripening. *S. anguivi* Lam berries contain high level of magnesium compared to *S. lycopersicum* (10 mg) [3]. Also, it is richer in iron than *S. aethiopicum* [23] and *S. melongena* [3, 20] with the values of 1.5 - 2 and 2.8 mg / 100 g DM respectively.

Table 3. *Development of pharmacological components of Solanum anguivi Lam berries during different stages of ripening*

Components	Green berries	Yellow berries	Orange berries	Red berries
Sterols and Polyterpens	+	+	++	++
Polyphenols	++	++	+	+
Flavonoids	+	+	++	++
Gallic tannins	-	-	-	-
Catechin tannins	++	++	+	+
Quinons	++	+	+	+
Alkaloids	-	-	-	-
Saponins	+	+	++	++
Coumarins	+	+	+	+

Sterols and polyterpens: + purple ring turning to the blue; ++ purple ring turning to the blue more marked
Polyphenols: + coloring blackish blue; ++ coloring blackish blue more pronounced
Flavonoids: + purplish coloring; ++ more marked purplish coloring
Gallic tannins: 羊absence of coloring black blue
Catechic tannins: + presence of flakes; ++ abundance of flakes
Quinons: + red coloring; ++ more marked red coloring
Alkaloids: 羊 absence of tint
Saponins: + foam presence; ++ more foam
Coumarins: + transparent alkaline solution

S. anguivi Lam berries constitute a better source of vegetable protein compared to *S. melongena* with the value of 4.6 % [20] and can be used to prevent protein-energy malnutrition. Moreover, the high fibers content (11.8 ± 0.7 % - 19.1 ± 0.4 % DM) in *S. anguivi* Lam berries play an important role in the digestion. Fibers facilitate food transit through the digestive tract and contribute to limit certain diseases such as appendicitis, diabetes mellitus, arteriosclerosis and some cancers [24].

S. anguivi Lam berries are very rich in fibers than those of 1.2 % DM, 1.8 % DM and 2 % DM in tomato (*S. lycopersicum*), oval purple eggplant (*S. melongena*) and scarlet eggplant (*S. aethiopicum*) respectively [20, 23]. Protein and fiber in *S. anguivi* Lam berries are similar to those of Goji berries (*Lycium barbarum*) with the values of 10.6 % and 11.9 %. Fat is less than 3 % during ripening in the berries of *S. anguivi* Lam (Table 1). That is similar to the most of eggplants such as *S. melongena* (1.7 - 2.1 %) and *S. aethiopicum* (0.1%) in studies [3, 20].

Crude protein, fat, fiber, ash and polyphenols contents did not differ significantly between green to yellow berries and orange to red berries respectively (Table 1). Our data confirmed those in the literature in which from the orange stage, the activation of chemical processes takes place induce a high synthesis of many chemical components such as protein and fat [25]. Polyphenols are higher in *S. anguivi* Lam berries with a value of 956.7 ± 71.1 mg/100 g DM. Their formation would be occurred with oxidation reactions producing quinines which are responsible of browning and bitterness [26]. The decrease of polyphenols in *S. anguivi* Lam berries during ripening could be attributed to enzymatic reaction. In fact, post-harvest storage and ripening would be attributed to polymerization and condensation reactions which are responsible of the formation of insoluble polymers [27].

Ascorbic acid in *S. anguivi* Lam decrease from 34.5 ± 1.7 mg/100g DM in green berries to 13.8 ± 0.7 mg/100g DM in red berries. This significant loss of ascorbic acid is due to the loss of chlorophyll [4]. This richness of ascorbic acid in *S. anguivi* Lam berries enhances tone and recovery. That is why its consumption restores patients' appetite [28]. Ascorbic acid content in *S. anguivi* Lam berries is lower than those of *S. aethiopicum* (8 mg/100 FM), *S. melongena* (2 mg/100 FM) [23] and similar to those of *S. lycopersicum* (26 mg/100 FM) [3]. The increase of total sugar in *S. anguivi* Lam berries during ripening is due to starch degradation by amylases [29]. But total sugars (2.4 ± 0.2 - 3.7 ± 0.2 % DM) in berries are lower compared to those of purple eggplants (11.8-15.4 %) of *S. melongena* [3] and scarlet eggplant (7.2 % DM) [20]. These sugars revealed by TLC are ribose, arabinose, xylose and fructose (Figure 1).

Data showed pharmacological substances such as sterols and polyterpens, polyphenols, flavonoids, catechin tannins, quinons, coumarins and saponins (Table 3). That could explain the beneficial effect of the consumption of *S. anguivi* Lam berries for the treatment of several diseases. In fact, *S. anguivi* Lam berries have stimulant, antioxidant, anti-inflammatory and anti-carcinogenic properties because of theses pharmacological substances [30, 4-7].

5. Conclusion

This study has highlighted that *S. anguivi* Lam berries or Gnagnan has high nutritional and pharmacological values. These potentialities depend on the stage of maturation of berries. It allowed showing the more or less important variations of the chemical composition of the berries of *S. anguivi* Lam during the various stages of ripening. Indeed, the rates of dry matter, phenolic compounds, ashes, vitamin C, magnesium, iron and manganese of the green berries are higher compared with those of the red berries. On the other hand, the rates of sugars, proteins, lipids, cellulose, calcium, sodium, potassium and zinc of red berries are superior to those of the green berries. The rates of phosphorus and copper in berries do not vary regardless of the stage of ripening. Besides, the loss of 40 % of vitamin C initial content stays the most important finding. Thin layer chromatography revealed ribose, arabinose, xylose, and fructose. The ribose and the xylose are replaced by the arabinose in red berries. Sterols, polyterpens, flavonoids, saponins and coumarins seem to increase during the ripening contrary to polyphenols, catechic tannins and quinons. Furthermore, the absence of alkaloids in berries indicates that the consumption of this food is not hazardous. Our findings permit guidance on the choice of the berries of *S. anguivi* Lam according to their maturation stage for the prevention or the treatment of malnutrition and some public health diseases. Data elaborates on the attraction of this eggplant as a popular dish in Côte d'Ivoire.

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