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Impact of natural fermentation on *Solanum Anguivi* Lam "Gnagnan" Berries

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Abstract
Solanum anguivi Lam is a bitter eggplant from the Solanaceae family. Its perishability has led us to explore new preservation methods including spontaneous fermentation. The objective of this work is to study the influence of natural fermentation on the nutritional properties of these berries. The experiment consisted in fermenting batches of berries at different stages of ripening.
These berries were put in 3% salt brine and fermented at room temperature (25˚C) for 3 and 6 months. The berries were then oven dried and crushed to obtain berry powders fermented. The analyzes were carried out according to conventional methods. The results generally showed an increase in mineral, in fiber (12.17 to 24.90 mg / 100g), protein (13.42 to 26.89 mg / 100g), ash (6.17 to 9.42 mg / 100g) and decrease of reducing and total sugar contents. Fermentation in general has helped to improve the nutritional quality of the berries.

Keywords: *Solanum anguivi* Lam, Ivory Coast, spontaneous fermentation, nutritional properties

Introduction
In Africa, many plant species are not sufficiently exploited, despite their undeniable edible values. Among these plants are the bitter eggplants *Solanum anguivi* Lam commonly called "gnagnan" in Côte d'Ivoire (Dan *et al.,* 2021) [12]. They are appreciated for nutritional value and their therapeutic virtues. Indeed, berries are rich in phenolic compounds (quinones, flavonoids and coumarins) and vitamin C, compounds capable of fighting against stress. In addition, the fruits and leaves are used in traditional medicine to treat malaria, high blood pressure and diabetes (Dan *et al.,* 2017) [11]. Also, berries contain glucose, ribose, xylose, arabinose and fructose (Dan *et al.,* 2014) [10]. Because of its nutritional and therapeutic importance, berries are prone to rotting due to a lack of fresh storage. Generally, the berries of *S. anguivi* Lam can be stored by drying in the sun, with or without cooking in water or steaming water. But storage in the fresh state helps preserve the taste and nutritional qualities of the berries better (Dan *et al.,* 2017) [11]. It would therefore be useful to find ways of keeping the berries fresh. One of the ways to keep vegetables fresh is natural fermentation.
Natural fermentation is a process for preserving food. It can be defined as a fermentation process in which a group of Gram-positive, non-sporulating, immobile, catalase-negative bacteria takes place, which grow under anaerobic conditions and use the carbon sources to produce lactic acid as the acid major organic (Yao *et al.,* 2009) [37]. Fermentation is therefore an interesting preservation process for food insofar as the main functions of lactic acid bacteria include the production of organic acids, aromatic compounds, stimulation of yeasts, inhibition of pathogenic microorganisms, improvement nutritional quality, probiotic activity, texture development and degradation of toxic compounds can also be observed (Yao *et al.,* 2009) [37]. Thus, the practice of natural fermentation on the berries of *S. anguivi* Lam could help to enhance these berries by improving their nutritional and biological quality. However, to our knowledge, there is little data regarding the nutritional composition of fermented berries.
Thus, the general objective of this research is to contribute to the nutritional enhancement and conservation of *S. anguivi* Lam berries in Côte d'Ivoire. More specifically, it will be a question of evaluating the biochemical characteristics of these berries after spontaneous fermentation.

Materials and Methods
Samples collection
The berries of *S. anguivi* Lam were collected at the stage of Green maturity from cultvated farmlands located at Agboville (100 km) from Abidjan.

Berries were harvested as follow (N'dri *et al.*, 2010) [25]: Green berries at 90 days after growth, Yellow berries about 6 days after green stage, Orange berries about 3 days after yellow stage, and red berries about 2 days after Orange stage. They were conveyed to the laboratory at Nangui Abrogoua University where they were stores on a bench at room temperature (25º C ± 3º C). The berries are previously identified and authenticated at the Departement of National Center of Floristic Research (Felix Houphouët-Bobigny University, Cocody-Abidjan.

Samples processing

Upon arrival at the laboratory, the berries were sorted, cleared of debris, detached from their stems and thoroughly rinsed with distilled water. They were then drained at laboratory temperature (20 °C) and subdivided into 4 batches of 900 g according to the stage of maturity (green berries, yellow berries, orange berries, red berries) (figure 1). Each batch was split into three 300g sublots, two of which were fermented in saline brine for three and six months according to the method described by Don (2019) [13] and then oven dried. As for the third, it was directly oven dried to serve as a control. The different batches of dried berries were crushed using a blender. The resulting flour was sifted through a 100 µm diameter mesh sieve.

As for the saline brine, it was prepared with distilled water and sea salt in the proportions of 30 g of salt per liter of water. For fermentation, the berries were placed in jars so as to fill them to 2/3 of the jar and cover the berries with the saline brine. Subsequently, the jars with seals were hermetically sealed and spontaneous pre-fermentation was carried out for one week at laboratory room temperature (25 °C) and protected from light. After the first week, the jars containing the pre-fermented berries were left to ferment in the open air, away from moisture and heat for up to six months. During this fermentation process, samples were taken aseptically from the brines for analysis.

Proximate analysis

Ash, proteins and lipids were determined using official methods (AOAC, 1990) [1]. For crude fibres, 2 g of dried powdered sample were digested with 0.25 M sulphuric acid and 0.3 M sodium hydroxide solution. The insoluble residue obtained was washed with hot water and dried in an oven (Memmert, Germany) at 100 °C until constant weight. The dried residue was then incinerated, and weighed for the determination of crude fibres content. Reducing sugar content was determined by extracting with 80% natural aqueous ethanol followed by evaporation of the ethanol and subsequent measurement using the dinitrosalicylic acid method according to Bernfeld (1955) [7]. Total soluble sugar content in ethanolic extract was assessed using the phenol-sulfuric acid method according to Dubois *et al.* (1956) [15]. The results of ash, fibres, proteins and lipids contents were expressed on dry matter basis.

Minerals including calcium, magnesium, iron, zinc, manganese, phosphorus, sodium, copper and potassium were determined using an Atomic Absorption spectrophotometer, AAS (Model 372, Perkin-Elmer, Beaconsfield, UK) by wet digestion while phosphorus level was determined using the phosphovanado molybdenate method (AOAC, 1995) [2].

Stastical analysis

Two ways analysis of variance (ANOVA) was conducted on each of the variables and the Duncan test at significant level P < 0.05 was performed using STATISTICA 7.1 software to compare the difference between treatment means. Results were expressed as the mean ± standard deviation of triplicate determination.

Results

1. Biochemical composition of fermented berries "Gnagnan" eggplant

Table I shows the biochemical composition of fermented berries of "Gnagnan" eggplant from the green, yellow, orange and red stages of ripening. Compared to unfermented berries, a significant increase (at the 5% threshold) in crude protein levels is observed after three and six months of fermentation of berries in the green, yellow, orange and red stages of ripening. Indeed, the initial levels of crude proteins recorded (from 13.42 ± 0.30 to 14.02 ± 0.03%) in these different berries reach values between 19.36 ± 0.10% and 25.54 ± 0.14% (after three months of fermentation) and between 19.52 ± 0.27% and 26.89 ± 0.20% (after six months of fermentation). In addition, such a significant increase (at the 5% threshold) in rate is observed at the level of raw fibers or after three and six months of lactic fermentation, with values oxidizing from 21.67 ± 0.02 to 24.90 ± 0.23%, from 18.42 ± 0.02 to 21.05 ± 0.47%, from 14.00 ± 1.00 to 17.79 ± 0.23% and from 12.17 ± 0.03 to 19.95 ± 0.06% respectively for the berries of the green, yellow, orange and red stages. In addition, the ash and fiber contents of the berries increase during fermentation. Thus, after six months of lactic fermentation, the ash contents vary from 06.90 ± 0.01 to 19.42 ± 0.02% for green berries; from 06.74 ± 0.04 to 14.06 ± 0.03% for yellow berries; from 06.32 ± 0.02 to 12.19 ± 0.02% for orange berries and from 06.17 ± 0.02 to 11.52 ± 0.02% for red berries. Lipid content also increase during fermentation time. The lipid content fluctuates between 1.37±0.03 and 1.78±0.32% for green berries, between 1.49±0.02 and 1.95±0.15 for yellow berries, between 2.39±0.04 and 2.80±0.26 for orange berries, between 2.67±0.05 and 03.95±0.25 for red berries.

Regarding the levels of total soluble sugar and reducing sugars, a decrease is observed in the berries of "Gnagnan" eggplant after six months of fermentation. Thus, the resulting values of the fresh state vary from 2.35±0.05 to 0.35±0.11%, from 24.18 ± 0.03 to 16.43 ± 0.63%; from 23.67 ± 0.05 to 17.88 ± 0.49% and from 22.75 ± 0.03 to 19.95 ± 0.06% respectively for green, yellow, orange and red berries after six months of fermentation. For reducing sugars, the contents vary from 01.06 ± 0.0 3 to 0.04 ± 0.01 % for green berries, from 1.07 ± 0.11 to 0.08 ± 0.01 % for yellow berries, from 01.09 ± 0.02 to 0.07 ± 0.01 % for orange berries and from 01.25 ± 0.05 to 0.13 ± 0.01 % for red berries.

Table 1: Biochemical composition of fermented berries of "Gnagnan" eggplant

Parameter	Stages	fermentation time (months)		
		0	3	6
Ash (%)	G B	6.90±0.01^{c}	9.42±0.17^{a}	7.16±0.15^{bc}
	Y B	6.74±0.04^{c}	7.06±0.17^{b}	7.98±0.11^{a}
	O B	6.32±0.02^{bc}	7.19±0.06^{a}	6.27±0.15^{c}

	R B	6.17±0.02^{Ab}	6.52±0.07^{g}	6.80±0.11^{f}
Fiber (%)	**G B**	21.67± 0.02^{g}	22.79±0.38^{k}	24.90±0.23^{l}
	Y B	18.42± 0.02^{e}	19.56±0.21 ^{h}	21.05±0.47^{i}
	O B	14.00 ± 1.00^{b}	15.00±1.28^{d}	17.79±0.23^{f}
	R B	12.17 ± 0.03^{a}	14.23±0.35^{c}	16.03±0.22^{e}
Proteins (%)	**G B**	13.42±0.02^{a}	17.12±0.13^{c}	19.52±0.27^{f}
	Y B	13.76±0.02^{b}	19.36±0.10^{e}	22.06±0.51^{h}
	O B	13.94±0.20^{d}	20.71±0.79 ^{g}	23.54±0.12^{j}
	R B	14.02 ± 0.03^{i}	25.54±0.14^{k}	26.89±0.20^{l}
Lipids (%)	**G B**	1.37±0.03^{b}	1.75±0.19^{a}	1.78±0.32^{a}
	Y B	1.49±0.02^{b}	1.83±0.09 ^{a}	1.95±0.15^{a}
	O B	2.39±0.04^{c}	2.52±0.08^{b}	2.80±0.26^{a}
	R B	2.67±0.05^{c}	03.53±0.26^{b}	03.95±0.25^{a}
Reducing sugar (%)	**G B**	1.06±0.03^{a}	0.13±0.01^{b}	0.04±0.01^{c}
	Y B	1.07±0.01^{a}	0.14±0.03^{b}	0.08±0.01^{c}
	O B	1.09±0.02^{a}	0.15±0.01^{b}	0.07±0.01^{c}
	R B	1.25±0.05^{a}	0.16±0.01^{b}	0.03±0.01^{c}
Total soluble sugar (%)	**G B**	2.35±0.05^{a}	1.06±0.03^{b}	0.35±0.11^{c}
	Y B	2.78±0.02^{a}	1.04±0.11^{b}	0.78±0.18^{c}
	O B	3.04±0.02^{a}	1.76±0.42^{b}	0.42±0.12^{c}
	R B	3.42±0.02^{a}	1.50±0.08^{b}	0.80±0.54^{c}

Data are represented as means ± SD (n=3). Means in the column with no common superscript differ significantly (p‹0.05).
GB : Green Berries ; YB : Yellow Berries ; OB : Orange Berries ; RB : Red Berries ; DM = Dry matter

2. Mineral composition of fermented berries of "Gnagnan" eggplant

The mineral composition of fermented berries of "Gnagnan" eggplant are shown in Table II. Minerals such as calcium, magnesium, phosphorus, potassium, iron, sodium, copper, zinc and manganese have been recorded. The most abundant minerals are potassium, calcium, iron and magnesium. Overall, the mineral content increases significantly (p <0.05) during fermentation.

After six months of fermentation, the calcium content fluctuates between 517.05 ± 0.04 and 531.12 ± 0.02 mg / 100 g (green berry), between 531.38 ± 0.02 and 545.52 ± 0.02 mg / 100 g (yellow berry), between 551.53 ± 0.03 and 566.07 ± 0.02 mg / 100 g (orange berry) and between 647.42 ± 0.02 and 665.09 ± 0.30 mg / 100 g (red berry). For magnesium, the contents vary between 421.36 ± 0.01 and 540.01 ± 0.01 mg / 100 g, between 339.11 ± 0.01 and 370.20 ± 0.01 mg / 100 g, between 269.78 ± 0.02 and 286.14 ± 0.01 mg / 100 g and between 257.59 ± 0.01 and 270.32 ± 0.02 mg / 100 g respectively for the berries of the green, yellow, orange and red stages. Concerning phosphorus, the rates are from 120.44 ± 0.04 to 141.39 ± 0.04 mg / 100g (green berries), from 123.22 ± 0.02 to 130.01 ± 0.01 mg / 100 g (yellow berries), from 125.96 ± 0.03 to 133.67 ± 0.02 mg / 100g (orange berries) and 122.06 ± 0.03 to 132.21 ± 0.01 mg / 100g (red berries) from the initial state at 6 months. As for potassium, the most abundant mineral of the macro-elements, its content varies between 1925.79 ± 0.02 and 1972.53 ± 0.02 mg / 100g, between 2046.26 ± 0.06 and 2069.41 ± 0.01 mg / 100g, between 2296.05 ± 0.01 and 2313.46 ± 0.01 mg / 100g and between 2304.58 ± 0.08 and 2347.04 ± 0.01 mg / 100 g respectively for green, yellow, orange and red berries. It should also be noted that this content

increases with the fermentation time. Sodium also increases with the time of fermentation. Its content goes from 256.70 ± 0.02 to 263.39 ± 0.02 mg / 100 g, from 310.20 ± 0.01 to 327.00 ± 0.03 mg / 100 g, from 356.12 ± 0.02 to 362.52 ± 0.02 mg / 100 g and from 338.12 ± 0.02 to 350.01 ± 0.01 mg / 100 g respectively for green, yellow, orange berries and red berries. Iron is the most common trace element. Its value oscillates between 454.45 ± 0.02 and 476.26 ± 0.06 mg / 100g for green berries, between 443.96 ± 0.01 and 452.91 ± 0.01 mg / 100g for yellow berries, between 356.46 ± 0.03 and 362.52 ± 0.02 mg / 100g for orange berries and between 338.12 ± 0.02 and 350.01 ± 0.01 mg / 100g for red berries. The copper, zinc and manganese contents are the lowest. Thus, for green berries, the copper content varies from 0.05 ± 0.02 to 0.07 ± 0.02 mg / 100g, from 0.08 ± 0.02 to 0.11 ± 0.01 mg / 100 g for yellow berries, from 0.14 ± 0.02 to 0.17 ± 0.02 mg / 100g for orange berries and 0.41 ± 0.01 to 0.45 ± 0.01 mg / 100g for red berries. Regarding zinc, the values range from 20.70 ± 0.01 to 23.65 ± 0.04 mg / 100g, from 8.08 ± 0.02 to 11.01 ± 0.01 mg / 100g, from 12.64 ± 0.02 to 14.83 ± 0.03 mg / 100g and from 6.17 ± 0.02 at 7.92 ± 0.01 mg / 100g respectively for green, yellow, orange and red berries.

Finally, concerning manganese, the values oscillate between 0.17 ± 0.02 and 0.21 ± 0.01 mg / 100g (green berries), between 0.11 ± 0.01 and 0.18 ± 0.02 mg / 100g (yellow berries), between 0.09 ± 0.03 and 0.11 ± 0.01 mg / 100g (orange berries) and between 0.10 ± 0.03 and 0.14 ± 0.01 mg / 100g (red berries).

Table 2: Mineral contents of fermented eggplant « Gnagnan »

Mineral (mg / 100 g DM)	**Stages**	**Fermented time (month)**		
		0	**3**	**6**
Calcium	**G B**	517.05 ± 0.04^{i}	526.08±0.03^{b}	531.12±0.02^{c}
	Y B	531.38±0.02^{j}	540.13±0.02^{e}	545.52±0.02^{g}
	O B	551.53±0.03^{k}	559.29±0.02^{h}	566.07±0.02^{i}
	R B	647.42±0.02^{l}	660.31±0.01^{k}	665.09±0.30^{l}
Magnesium	**G B**	421.36±0.01^{l}	532.21±0.03^{k}	540.01±0.01^{l}
	Y B	339.11±0.01^{j}	367.29±0.03^{h}	370.20±0.01^{i}
	O B	269.78±0.02^{i}	284.14±0.02^{e}	286.14±0.01^{f}
	R B	257.59±0.01^{h}	268.52±0.02^{b}	270.32±0.02^{d}

Phosphorus	**G B**	120.44±0.04^{i}	141.30±0.04^{k}	141.39±0.04^{l}
	Y B	123.22±0.02^{k}	129.90±0.05^{f}	130.01±0.01^{g}
	O B	125.96±0.03^{l}	131.53±0.03^{h}	133.67±0.02^{j}
	R B	122.06±0.03^{j}	127.91±0.01^{e}	132.21±0.01^{i}
Potassium	**G B**	1925.79±0.02^{i}	1963.54±0.02^{b}	1972.53±0.02^{c}
	Y B	2046.26±0.06^{j}	2067.10±0.01^{e}	2069.41±0.01^{f}
	O B	2296.05±0.01^{k}	2309.10±0.01^{i}	2313.46±0.01^{j}
	R B	2304.58±0.08^{l}	2338.31±0.01^{k}	2347.04±0.01^{l}
Sodium	**G B**	256.70±0.02^{e}	261.10±0.03^{b}	263.39±0.02^{c}
	Y B	310.20±0.01^{g}	322.29±0.02^{e}	327.00±0.03^{f}
	O B	356.12±0.02^{c}	368.31±0.01^{h}	371.15±0.02^{b}
	R B	460.17±0.02^{d}	474.23±0.03^{k}	474.56±0.03^{c}
Iron	**G B**	454.45±0.02^{l}	473.01±0.01^{k}	476.26±0.06^{l}
	Y B	443.96±0.01^{k}	449.04±0.01^{h}	452.91±0.01^{i}
	O B	356.46±0.03^{j}	361.35±0.05^{e}	362.52±0.02^{f}
	R B	338.12±0.02^{i}	347.02±0.02^{b}	350.01±0.01^{c}
Copper	**G B**	0.05±0.02^{ab}	0.06±0.10^{a}	0.07±0.02^{a}
	Y B	0.08±0.02^{bc}	0.10±0.02^{b}	0.11±0.01^{b}
	O B	0.14±0.02^{d}	0.15±0.02^{cd}	0.17±0.02^{d}
	R B	0.41±0.01^{f}	0.44±0.02^{f}	0.45±0.01^{f}
Zinc	**G B**	20.70±0.01^{l}	23.34±0.03^{k}	23.65±0.04^{l}
	Y B	8.08±0.02^{h}	10.11±0.01^{e}	11.01±0.01^{f}
	O B	12.64±0.02^{j}	14.27±0.02^{h}	14.83±0.03^{i}
	R B	6.17±0.02^{f}	7.38±0.02^{b}	7.92±0.01^{c}
Manganese	**G B**	0.17±0.02^{e}	0.19±0.02^{a}	0.21±0.01^{a}
	Y B	0.11±0.01^{d}	0.15±0.01^{a}	0.18±0.02^{a}
	O B	0.09±0.03^{cd}	0.10±0.01^{a}	0.11±0.01^{a}
	R B	0.10±0.03^{cd}	0.13±0.01^{a}	0.14±0.01^{a}

Data are represented as Means ± SD (n=3). Means in the column with no common superscript differ significantly (p‹0.05), as analyzed by Duncan's test.

GB : Green Berries ; YB : Yellow Berries ; OB : Orange Berries ; RB : Red Berries; DM = Dry matter

Discussion

The increased protein content of freshly harvested berries during ripening could be attributed to the activation of proteases in biochemical processes such as cell signaling, immune system antibody synthesis, cell adhesion and active transport across cell membranes inducing strong protein synthesis (Dan *et al.*, 2014) [10]. The results obtained are similar to those recorded on the berries of *S. anguivi* Lam by Dan *et al.* (2014) [10]. Also, the results obtained are similar to those recorded on bananas (*Musa paradisiaca* L. "Agnrin variety") by Assemand *et al.* (2012) [5] who indicated an increase in the protein level varying from 3.27 to 4.27% from the green stage to the mature stage (yellow with black dots). Thus, the increase in the protein level testifies to the continuity of the metabolic and physiological activities of the berries of *S. anguivi* Lam after harvest (Dan *et al.*, 2014) [10]. The increase in the protein content of the berries after fermentation is thought to be attributable to a decrease in the carbon content in the total mass (Onyango *et al.*, 2004) [29]. Microorganisms use carbohydrates for energy and produce carbon dioxide as by-products. This causes the concentration of nitrogen in the fermented berries, and thus, the proportion of protein in the total mass increases (Ibrahim *et al.*, 2017) [17]. This increase in the protein content of fermented berries is consistent with previous work by Ibrahim *et al.* (2017) [17] and DON (2021) [14] which demonstrated an increase in the protein level respectively in cashew kernels and "Ahalimancou" type peppers after fermentation. Azoulay (1978) [6] also reported a 15-30% increase in protein content due to fermentation of corn, with a suitable yeast such as *Candida tropicalis*.

Statistical analysis of the results of the lipid content of the powders of the berries of *Solanum anguivi* Lam show a significant increase at the threshold of 5% in the lipid level during ripening. These results are in agreement with those of Dan *et al.* (2014) [10] carried out on the same bays. This increase in lipid content is thought to result from the activity of lipases. In fact, lipases are believed to be at the origin of the synthesis of fatty acids, sterols and triglycerides during the ripening of berries (Weil, 1994) [35]. Also, these results could be explained by the conversion of certain carbohydrates into fatty acids during the Krebs cycle (Dan *et al.*, 2014) [10]. It is possible that the fatty acids synthesized by NADPH during the ripening of the plantain, migrate with water to the pulp as mentioned by Izonfuo and Omuaru (1988) [19]. The berries of *S. anguivi* Lam contain more lipids compared to the turning plantain, cultivar horn 1 whose lipid content is 0.59% (Ibrahim *et al.*, 2017) [17]. However, this lipid content of berries remains much lower than that of cashews, 29.25% (Ibrahim *et al.*, 2017) [17]. As for fermented powders, the increase in lipid content during the fermentation period is justified by the work of Oyarekua, (2013) [30], Ibrahim *et al.* (2017) [17] and Don (2021) [14]. The increase may probably be due to the increased activities of lipases which hydrolyze fat to glycerol and fatty acids (Odunfa, 1983) [27]. Increasing the fat content would promote absorption of minerals and fat-soluble vitamins (Ribaya-Mercado, 2004) [31]. However, this low fat content could contribute to increasing the shelf life of flours by reducing the phenomenon of rancidity (Ibrahim *et al.*, 2017) [17]. Also, lipids perform a structural function on the one hand by enveloping the membranes of the body's cells and on the other hand allow the storage of metabolic energy (Dan *et al.*, 2014) [10]. Regarding the ash content of the berries of *Solanum anguivi* Lam, a significant decrease at the 5% threshold during the ripening stages is observable. These results are similar to those obtained by Dan *et al.* (2014) [10]. This result could be explained by the fact that the decrease in ash is linked to that in dry matter (Tucker and Grierson, 1987) [34]. Also, studies carried out by Monnet (2013) [23] on unripe and ripe *terminalia catappa* fruits show a drop from 5.1 to 4.6

in ash content. In addition, the berries of *S. anguivi* Lam contain more ash content compared to the plantain and cashew kernel (*anacardium Occidentale* l) respectively with values of 2 and 3% (Ibrahim *et al.*, 2017) [17]. These results could be justified by the fact that the berries of *Solanum anguivi* Lam have more dry matter content than these foods. The rate of dry matter and that of ash vary proportionally (Weil, 1994) [35]. After 3 months of fermentation, the berries show an increase in ash content. These results obtained are in agreement with those recorded on fermented cabbage by Arachiche and Ghessab (2018) [3]. This increase in ash content could be explained by the production of certain micronutrients by lactic acid bacteria during fermentation. On the other hand, beyond 3 months of fermentation, a drop in the ash content is observed in the berries of the “Gnagnan” eggplant following the loss in the fermentation medium of certain water-soluble minerals from the berries (Ibrahim *et al.*, 2017) [17].

Fermentation significantly increased ($p < 0.05$) the mineral content in the berries of "Gnagnan" eggplant. Minerals are important parts of the diet because of their physiological and metabolic role in the body. The mineral profile has shown that the berry powders contain high levels macro-elements (potassium, calcium, magnesium, sodium, phosphorus) and micro-elements (iron, zinc, manganese, copper). They are particularly essential for children, pregnant or breastfeeding women and athletes (Omotoso, 2006) [28]. The mineral content of *S. anguivi* Lam powders is lower than that obtained after fermentation. However, the highest levels are observed after 6 months. Potassium, the most abundant mineral in samples, plays a protective role against increased blood pressure and other cardiovascular risks. Along with sodium (Na), it contributes to maintaining the ionic balance necessary for the functioning of muscles, the heart and for nerve transmission (Tettey-Labi *et al*., 2015) [33].

According to WHO, adequate dietary potassium lowers blood pressure and protects against stroke (WHO, 2003) [36]. The levels recorded in the different berries are higher than those obtained by Kouamé (2018) [20] of fermented sesame seeds (301.29 - 693.35 mg / 100g DM). Since the daily potassium intake is 2000 mg / day for an adult and 1600 mg / day for a child (NRC, 1989) [26], the consumption of fermented berries could cover between 98.15 and 100% of the needs. Calcium and phosphorus are associated for the fortification of bones and the development of teeth (Ijarotimi, 2012) [18]. It is also involved on the one hand in maintaining the normal excitability of the heart, muscles, nerves and on the other hand in cell permeability (Mebdoua, 2011) [22].

The powders of the berries of *Solanum anguivi* Lam fermented for 6 months could be recommended to pregnant women and the elderly to meet the ever-increasing needs for calcium. Magnesium, the concentration of which has increased during fermentation, is involved in the metabolism of carbohydrates and lipids. It is also involved in the regulation of the body's acid-base balance, the maintenance of normal muscle and nerve function and in the body's defense mechanisms against microbial and viral infections (Saris *et al.*, 2000 [32]; Mebdoua, 2011 [22]). The recommended daily intake for magnesium is 400 mg / day for adults (FAO, 2004) [9]. Consuming the various berries would help protect the body from external aggressions and prevent cardiovascular diseasePhosphorus plays an essential role (in the form of ATP) in the metabolism of proteins, lipids and carbohydrates (Mebdoua, 2011) [22]. It is the second most abundant mineral in the body after calcium. Along with calcium, it participates in tooth formation and bone development in children (Makinde *et al.*, 2013) [21]. Fermentation increased the level of phosphorus in the powders. This increase could encourage the use of these powders in the formulation of infant foods.

Iron, copper, zinc, and manganese have increased in content during fermentation. Iron is a trace element that can act as an antioxidant and help prevent cardiomyopathy and stunted growth. It also facilitates the oxidation of carbohydrates, proteins and lipids (Buss *et al.*, 2003) [8]. Iron deficiency causes a drop in hemoglobin levels and leads to anemia (Mourey, 2004) [24]. However, the iron level has increased in the powders of fermented berries. This result is in agreement with that of Kouamé (2018) [20] who also observed an increase in the level of iron in fermented sesame seeds. Also, these powders could be recommended to pregnant women to cover their needs. Zinc is a mineral essential for the synthesis of different nucleic acids, for the regulation of gene expression, metabolism and protein synthesis. To this end, it can play a key role in cell growth which is useful both for the development of the fetus and for the growth of children and adolescents (Arinola, 2008) [4]. The increase in copper content in berry powders is believed to be due to the activation of enzymes during the fermentation process. Indeed, copper plays an essential role in several enzymatic systems comprising cytochrome oxidase and tyrosinase (Garcia-Horsman *et al.*, 1994) [16].

Conclusion

In this study, the effects of fermentation times of 0 months, 3 months and 6 months on some biochemical parameters of "Gnagnan" eggplant berries were evaluated. It emerges from this analysis that the fermentation process of the berries of the "Gnagnan" eggplant significantly increases their nutritional values, particularly in protein, fiber, lipids and minerals, while the levels of reducing and total sugars have decreased. In addition, the berries stored for 6 months revealed a positive impact on the biochemical characteristics of these berries.

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