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EFFECT OF RIPENING ON NUTRITIONAL VALUES OF *SOLANUM ANGUIVI* LAM BERRIES "GNAGNAN"

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Abstract: *The purpose of this paper is to evaluate the effect of ripening at different stages on nutrient properties in Solanum anguivi Lam berries at different stages. Fresh berries were collected at Agboville (100 km from Abidjan). Nutritional values were investigated using standard methods, while minerals profiles were performed by using an Atomic Absorption Spectrophotometer. Results showed that green berries had the highest content in ash (06.90 ± 0.01 %) and in fiber (21.67 ± 0.02 %) while red berries had the highest content in protein (14.02 ± 0.03 %). Ash and protein content decreased during boiling, but the fiber content increased. The losses registered after 15 min of boiling were the following: protein (10.35 – 10.41 %) and ash (1.62 – 3.04 %). During ripening, calcium, potassium, phosphorus and zinc amount increased whereas magnesium, manganese and iron quantity decreased. Generally, all minerals decreased during boiling times. In this view, these berries constitute good source of nutrients and could contribute efficiently to the nutritional requirement and food security of Ivorian populations.*

Keywords: *Solanum anguivi Lam, boiling, proximate composition, minerals.*

1. Introduction

Native fruit vegetable, *Solanum anguivi* Lam is part of the family Solanaceae, [1]. It is a spontaneous food plant widespread in the tropical and temperate zones [2]. Commonly called "gnagnan", these berries of S. anguivi Lam are highly appreciated by the Ivorian population specifically that of central Côte d'Ivoire. They are characterized by a bitter aftertaste due to the presence of various phenolic compounds that give them antioxidant properties and are able to fight against stress and cell aging [3]. At physiological maturity, the berries of S. anguivi Lam change color successively over time. They pass from the green state to the red state (optimum ripening) by passing through the yellow state, then orange. The green berries contain a lot of vitamin C, phenolic compounds, iron and magnesium. However, red berries are rich in protein, cellulose, total sugars, lipids, potassium [4]. In addition, fruits, leaves, roots and even seeds are used in traditional medicine to treat various pathologies including malaria, high blood pressure, prostate, abdominal pain, diabetes etc [5]. Traditionaly, in Côte d'Ivoire, berries are eaten raw, boiled or are preserved by drying at sun preceded or not by cooking with water or steam of water [3]. However, various studies have shown that cooking caused negative impact by reducing nutritive value but positive impact by increasing some nutrients. Thus, cooking with water causes a drop in minerals (Ca, Mg, P, K, Na, Zn, Fe) in vitamin C, in ash, in protein yet raises fiber content [6-7]. Earlier reports have high lighted the nutritive potential of these fresh berries but there is a lack of scientific data with regards to the effect of cooking.

2. Matherials and methods

Samples collection

S. anguivi Lam berries at different stage of ripening were collected from cultivated farmlands located at Agboville (5°55'40" N and 4°12'47" W), and authenticated at the Departement of National Center of Floristic Research (Felix Houphouët-Boigny University, Cocody-Abidjan. They were analysed in the Laboratory at Nangui Abrogoua University. Berries (green, yellow, orange and red) were directly dried into an oven at 45ºC for 72 hours.

Samples Preparation

Berries were harvested as follows [8]: 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. The fruits were stored at a temperature of 28°C ± 3 °C.

Color analysis was done using a Chroma meter (Konica Minolta, Inc. Color Reader CR_ 10 (Japon). After harvesting at different stages of ripening, fresh berries were washed with deionised water and allowed to drain at ambient temperature. Each sample was divided into two lots. The first lot (raw) was dried in an oven (Memmert, Germany) at 45ºC for 72 h according to Chinma and Igyor [9]. Then, the dried berries were ground with a Moulinex-type mixer. The powder obtained was sieved (100 µm) and samples were stored in clean dry air-tight bottles at 4ºC until required for analyses. The second lot was cooked by using the method of Randrianatoandro, [10] modified as follow: 250 g of berries were immersed in 1.5 L of boiled water in stainless steel container for 10 and 15 min. The boiling solution was discarded and the boiled samples were cooled, drained at ambient temperature and subjected to the same treatment using for raw samples.

Proximate analysis

The dry matter contents were determined by AOAC [11]. Ash, proteins, lipids and minerals were determined using standard methods AOAC [12]. For total fibers, 2 g of dried powdered sample were digested with a solution of 0.25 M sulphuric acid and 0.3 M sodium hydroxide.

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 fiber content.

Glucids and calorific value were calculated using the following formulas FAO [13]:

Glucids: 100 – (% moisture + % proteins + % lipids + % ash).

Calorific value: (4 x % proteins) + (4 x % glucids) + (9 x % lipids).

The results of ash, fibres, proteins, lipids and glucids contents were expressed on dry matter basis.

Minerals including calcium, magnesium, iron, zinc, manganese, phosphorus, sodium and potassium were determined using an Atomic Absorption Spectrophotometer, AAS (Model 372, Perkin-Elmer, Beaconsfield, UK) by wet digestion while phosphorous level was determined using the phosphovanado molybdenate method [11].

Statistical analysis

All experiments were carried out in triplicate and data were expressed as mean ± standard deviation (SD) or standard error of mean (SEM).Two ways analysis of variance (ANOVA) and the Duncan test at significant level $P = 0.05$ was conducted to compare treatment means using STATISTICA 7.1 software. Principal component analysis (PCA) was also used to distribuate samples in terms of nutritional parameters.

3. Results and discussion

Nutritional values

Mineral content is an essential component of the nutritive value of vegetable. Table 1 showed the effect of cooking on mineral composition of S. anguivi Lam during ripening. Green berries of S. anguivi Lam had the highest levels of magnesium, manganese and iron while red berries are higher in calcium, potassium and zinc. After boiling, all mineral content decreased significantly ($p < 0.05$). The registered losses were as follow: calcium (66.81 – 75.34 %), magnesium (56.99 – 61.9 %), phosphorus (51.51 – 60.53 %), potassium (28.53 – 57 %), iron (63.90 – 72.07), zinc (66.95 –77.47 %) and manganese (50 – 70.58 %). These observed reductions may be due to leaching of the mineral compounds into the boiling water [14]. This finding is in line with the report of Davidson and Monulu [15] who observed significant reduction in the mineral concentration of boiled and steamed eggplant leaves (Solanum macrocarpon).

It is known that calcium and phosphorus play a major rôle in ossification and dentition and has a preventive effect on artériel hypertension in the elderly [16].

Concerning magnesium, this mineral prevents cardiomyopathy, muscle degeneration, growth retardation, congenital malformations and bleeding disorders [17]. Potassium is an essential mineral and a major electrolyte found in the human body. Potassium and sodium are involved in membrane and cellular exchange, thus contributing to the regulation of plasma volume, acid-base balance and muscles contraction [18]. Iron plays important role in prevention of anemia which affects more than one million people worldwide [19]. Considering the recommended dietary allowance (RDA) for iron (8 mg/day), consumption of 15 min boiling, berries could cover RDA [19, 20]. Zinc is metal present in all cells. It is co-factor for morethan 300 enzymes, and it is necessary for wide variety of biological functions. It is also required for synthesis of DNA, normal growth, gene expression, gene regulation, cell division and immunity [21].

Nutritional content during the ripening and cooking berries of S. anguivi Lam were shown in Table 2. During boiling time, dry matter, ash, protein, fat and calorific energy contents decreased significantly ($p < 0.05$) while fiber and glucids quantity increased.

The decline of dry matter content is provoked by the weakness of the berries tissues and movement of water in the cell walls [22]. A similar reduction in dry matter content was reported by Lo Scalzo and al. [23] in three boiled eggplants (7.8 - 5.6 %; 9.18 - 6.2 % and 8 – 5.2 %) respectively in Tunisia, Buia and L 305 after 10 min. In green berries, after 15 min of boiling, dry matter (24.97 ± 0.03 %) were higher than red berries (22.23 ± 0.01%).

Quantity of ash varied from 6.90 ± 0.01 to 6.69 ± 0.02 % in green berries and from 6.17 ± 0.02 to 6.07 ± 0.03 % in red berries. The lowering of ash content in these studied berries may be a result of minerals leaching into the boiling water [24]. In spite of ash losses, S. anguivi the studied berries may be considered as good sources of minerals after cooking at 15 min when compared values of boiled leaves of Solanum nigrum (1.24 %) [14] and boiled yam (1.53 %) [25].

Fibers revealed a significant slight increase with 15.37 ± 0.02 % and 27.12 ± 0.02 % after 15 min. This finding is in agreement with some reports that cooking caused increase in soluble fiber content [26]. With regard to their fibers content at 15 min, Fiber intake has a number of health benefits, including maintenance of healthy laxation and the reduced risk of cardiovascular diseuse and cancer [27, 28]. These results are in agreement with those of Oulai and al. [6] who observed an increase in the fiber content when leafy vegetables were cooked with water (H. Sabdariffa (14.27 - 14.55 %), A. digitata (12.56 – 13.10 %)).

Table 1

Mineral composition of raw and cooked of *Solanum anguivi* Lam at differents stages of ripening

Minerals (mg/100g MS)	Berries	Cooking time (min)		
		0	10	15
	Green	517.05±0.04[i]	289.50±0.05[g]	171.57±0.02[d]
Calcium	Yellow	531.38±0.02[j]	290.17±0.02[h]	142.14±0.02[a]
	Orange	551.53±0.03[k]	248.29±0.02[f]	144.44±0.02[b]
	Red	647.42±0.02[l]	235.39±0.02[e]	159.64±0.05[c]
	Green	421.36±0.01[l]	364.57±0.02[k]	163.53±0.01[g]
Magnesium	Yellow	339.11±0.01[j]	152.03±0.01[f]	130.08±0.01[c]
	Orange	269.78±0.02[i]	141.70±0.02[e]	136.22±0.02[d]
	Red	257.59±0.01[h]	125.05±0.02[b]	110.79±0.01[a]
	Green	120.44±0.04[i]	94.29±0.04[g]	47.53±0.03[a]
Phosphorus	Yellow	123.22±0.02[k]	97.87±0.03[h]	91.42±0.02[f]
	Orange	125.96±0.03[l]	84.34±0.01[e]	78.51±0.01[d]
	Red	122.06±0.03[j]	70.56±0.03[c]	59.18±0.02[b]
	Green	1925.79±0.02[i]	1780.43±0.03[f]	1540.06±0.03[d]
Potassium	Yellow	2046.26±0.06[j]	1869.97±0.02[h]	1647.01±0.01[e]
	Orange	2296.05±0.01[k]	1781.31±0.01[g]	1484.99±0.02[b]
	Red	2304.58±0.08[l]	1516.56±0.04[c]	827.95±0.04[a]
Sodium	Green	256.70±0.02[e]	140.58±0.02[b]	100.28±0.02[a]
	Yellow	310.20±0.01[g]	189.18±0.03[c]	151.10±0.03[b]
	Orange	356.12±0.02[h]	300.07±0.02[f]	223.03±0.03[d]
	Red	460.17±0.02[j]	371.13±0.03	235.06±0.03[d]
	Green	454.45±0.02[l]	204.15±0.05[f]	116.02±0.02[c]
Iron	Yellow	443.96±0.01[k]	213.60±0.10[h]	100.29±0.02[b]
	Orange	356.46±0.03[j]	206.21±0.01[g]	164.06±0.03[e]
	Red	338.12±0.02[i]	133.22±0.02[d]	94.43±0.03[a]
	Green	20.70±0.01[l]	12,88±0,02[k]	4,68 ± 0,20[d]
Zinc	Yellow	8.08±0.02[h]	5,28 ± 0,02[e]	3,94 ± 0,01[c]
	Orange	12.64±0.02[j]	9,40 ± 0,02[i]	6,84 ± 0,04[g]
	Red	6.17±0.02[f]	2,45 ± 0,04[b]	1.82 ± 0.02[a]
Manganese	Green	0.17±0.02[e]	0.08±0.00[bcd]	0.05±0.02[ab]
	Yellow	0.11±0.01[d]	0.08±0.02[bcd]	0.04±0.01[a]
	Orange	0.09±0.03[cd]	0.05±0.02[ab]	0.04±0.02[a]
	Red	0.10±0.03[cd]	0.07±0.02[bc]	0.05±0.01[ab]

Values are expressed as mean ± SD. (n =3). Means assigned to the same letter for the same parameter are not significantly differents ($p \leq 0.05$)

As concern proteins content, cooking processing used in this study caused 10.35 – 10.41 % reduction after 15 min. These losses of protein during heat treatments of food could be due to heat destruction of protein peptide bonds [29]. According to Oulai and al. [6] cooked leafy vegetable are poor in crude protein compared to raw leafy. However, after 15 min of cooking, S. anguivi Lam berries could be considered as a significant source of protein because the minimum value recommended for protein-rich foods is 12% [30]. It could play a significant role in providing cheap and available proteins for rural communities. In fact, proteins were also essential for the growth of children and adolescents, as well as for the formation of the fetus in pregnant women [6].

During boiling times, lipid content decreased significantly ($p < 0.05$) in green berries (1.37 ± 0.03 to 0.94 ± 0.04 %) and in red berries (1.95 ± 0.05 to 1.54 ± 0.02 %). With boiling the fat must have melted into the boiling water thus causing a reduction in the fat content [14]. Lipids of S. anguivi Lam' s berries was in agreement with the results of many authors which showed that vegetables are poor sources of fats [31], [6], [32]. Therefore, the consumption of these berries may be recommended to individuals suffering from obesity [6].

The glucids content in green berries of S. anguivi Lam (4.66 ± 0.01 - 5.31 ± 0.02 %) increased significantly ($p < 0.05$) during boiling time. This result is similar to the most cooked leafy vegetables which are generally not good sources of carbohydrates [32].

In addition, other authors obtained an increase in carbohydrate content in boiled (83.62 - 84.41 %) and steamed bananas (83.62 - 83.76 %) compared to fresh fruits [33].

Energy value generally decreased significantly ($p < 0.05$) during boiling time from 84.65 ± 0.01 to 77.82 ± 0.03 Kcal/100g in green berries and from 76.07 ± 0.04 to 72.34 ± 0.02 Kcal/100g in red berries. The relatively low energy values of S. anguivi Lam berries were consistent with the observations made on vegetables. According to the general observation, vegetables have low energy values because of their low crude fat content and relatively high moisture content [34].

Table 2:
Proximate composition of raw and cooked berries of *Solanum anguivi* Lam at differents stages of ripening

Parameters	**Berries**	**Cooking time (min)**		
		0	**10**	**15**
Dry matter (%)	Green	26.35 ± 0.05^{i}	25.36 ± 0.04^{h}	24.97 ± 0.03^{g}
	Yellow	24.18 ± 0.03^{f}	24.02 ± 0.02^{ef}	23.85 ± 0.02^{de}
	Orange	23.67 ± 0.05^{d}	23.88 ± 0.02^{de}	23.35 ± 0.01^{c}
	Red	22.75 ± 0.03^{b}	22.55 ± 0.02^{b}	22.23 ± 0.01^{a}
Ash (%)	Green	6.90 ± 0.01^{k}	6.78 ± 0.02^{j}	6.69 ± 0.02^{h}
	Yellow	6.74 ± 0.04^{i}	6.61 ± 0.01^{g}	6.58 ± 0.02^{g}
	Orange	6.32 ±0.02^{f}	6.27 ± 0.02^{e}	6.22 ± 0.02^{d}
	Red	6.17 ± 0.02^{c}	6.13 ± 0.03^{b}	6.07 ± 0.03^{a}
Fiber (%)	Green	21.67 ± 0.02^{g}	25.13 ± 0.02^{h}	27.12 ± 0.02^{i}
	Yellow	18.42 ± 0.02^{e}	20.33 ± 0.02^{f}	21.33 ± 0.03^{g}
	Orange	14.00 ± 1.00^{b}	15.10 ± 0.01^{c}	16.17 ± 0.03^{d}
	Red	12.17 ± 0.03^{a}	14.33 ± 0.03^{b}	15.37 ± 0.02^{c}
Proteins (%)	Green	13.42 ± 0.02^{f}	12.18 ± 0.03^{e}	12.03 ± 0.01^{a}
	Yellow	13.76 ± 0.02^{g}	12.33 ± 0.02^{b}	12.22 ± 0.01^{ab}
	Orange	13.94 ± 0.20^{gh}	12.55 ± 0.02^{c}	12.30 ± 0.02^{b}
	Red	14.02 ± 0.03^{i}	12.96 ± 0.04^{d}	12.56 ± 0.02^{c}
Lipids (%)	Green	1.37 ± 0.03^{cd}	1.12 ± 0.05^{ab}	0.94 ± 0.04^{a}
	Yellow	1.49 ± 0.02^{de}	1.15 ± 0.02^{ab}	1.01 ± 0.01^{ab}
	Orange	1.80 ± 0.04^{fg}	1.45 ± 0.05^{de}	1.17 ± 0.01^{bc}
	Red	1.95 ± 0.05^{g}	1.65 ± 0.02^{ef}	1.54 ± 0.02^{de}

Glucids **(%)**	Green	4.66 ± 0.01^{i}	5.13 ± 0.03^{k}	5.31 ± 0.02^{k}
	Yellow	2.19 ± 0.01^{e}	3.71 ± 0.03^{g}	4.04 ± 0.01^{h}
	Orange	1.14 ± 0.02^{b}	3.26 ± 0.01^{f}	3.86 ± 0.02^{f}
	Red	0.61 ± 0.02^{a}	1.59 ± 0.02^{c}	2.06 ± 0.03^{d}
Calorific energy (Kcal/100g)	Green	84.65 ± 0.01^{j}	79.92 ± 0.02^{i}	77.82 ± 0.03^{h}
	Yellow	77.21 ±0.01^{g}	75.39 ± 0.04^{d}	74.94 ± 0.02^{c}
	Orange	76.52 ± 0.05^{f}	77.93 ± 0.02^{h}	75.17 ± 0.02^{d}
	Red	76.07 ± 0.04^{e}	73.93 ± 0.02^{b}	72.34 ± 0.02^{a}

Values are expressed as mean ± SD. (n =3). Means in the same parameter followed by different letters differed significantly ($p \leq 0.05$)

Classification of *Solanum anguivi* berries samples

The principal component analysis (PCA) based on the nutritional values obtained for the berries at different stages of ripening are presented in Figure 1. The fresh green, yellow and orange berries (gb0, yb0, ob0), green (gb10)) cooked for 10 min and green berries (gb15) cooked for 15 min obtained a high positive score while fresh red berries (Rb0), yellow (yb10), oranges (ob10) and red berries (Rb10) cooked for 10 min and yellow (yb15), oranges (ob15) and red berries (Rb15) cooked for 15 min. had a negative score in PC 2 (FIg 1).

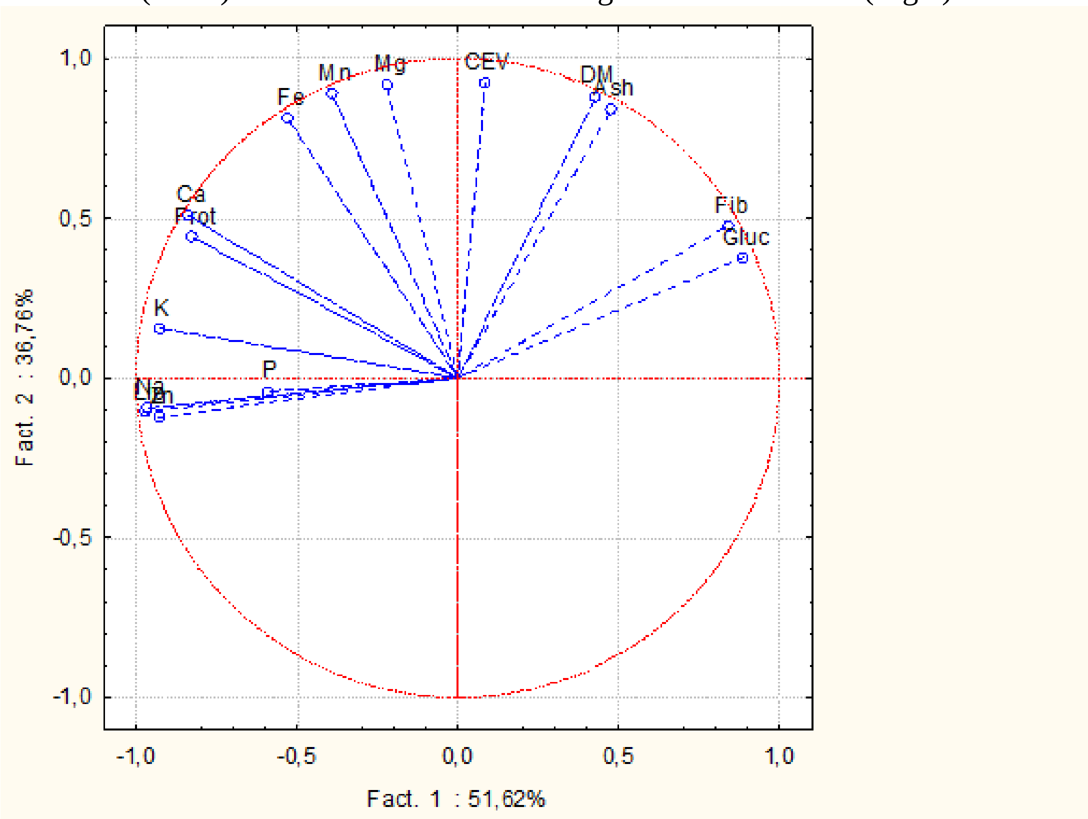

Fig. 1 Circle of correlation of biochemical composition of raw and cooked *Solanum anguivi* lam berries during ripening on axis 1 and 2.

Fib : fiber, Zn : zinc, Lip : lipids, Na : sodium, P : phosphorus, K : potassium, Prot : protein, Ca : calcium, Fe : fer, Mn : manganese, Mg : magnesium, CEV : calorific energy value, DM : dry matters, Glu : glucid

Ob0, Rb0, ob0, yb10, and gb15 were near zero in PC2. Rb0 are near zero in PC1. The correlation circle provides information about correlations between the measured properties (Fig. 2). The observation of the correlation circle shows that the dry matter, ash, fibers, glucide and energy content levels are positively correlated with each other. This group is negatively correlated with the group consisting of proteins, lipids, iron, magnesium, potassium, manganese, sodium, calcium, potassium and zinc.

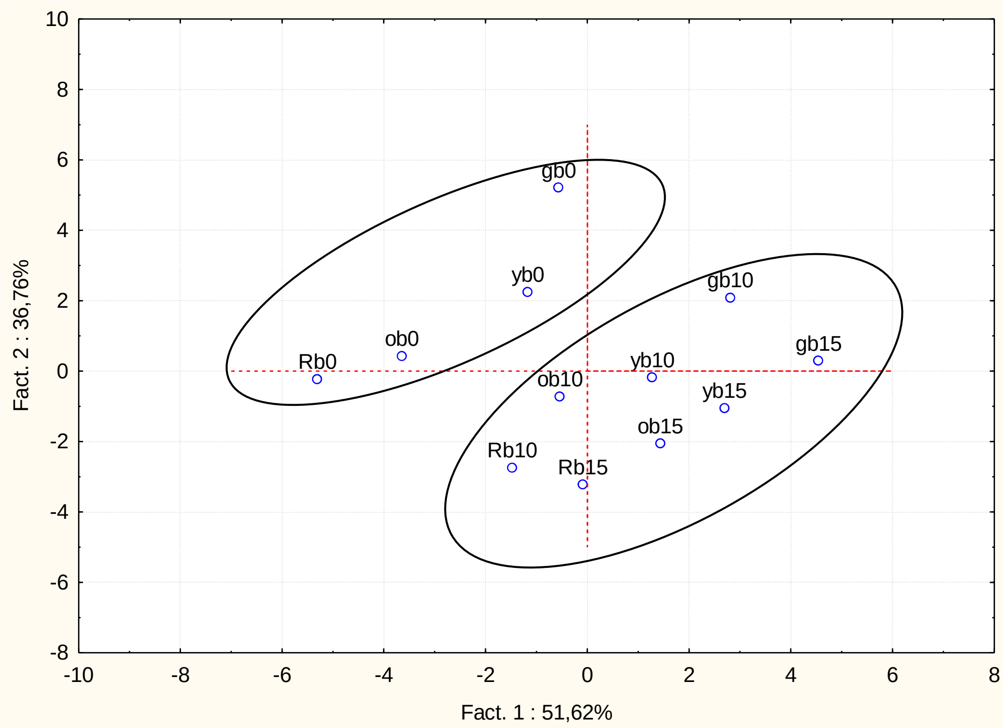

Fig. 2. . Sample plot of principal components 1 and 2 raw and cooked berries of *Solanum anguivi* Lam
gb0: raw green berries, yb0: raw yellow berries, ob0: raw orange berries, Rb0: raw red berries
gb10: green berries boiled during 10 min, yb10: yellow berries boiled during 10 min, ob10: orange berries boiled during 10 min, Rb10: red berries boiled during 10 min
gb15: green berries boiled during 15 min, yb15: yellow berries boiled during 15 min, ob15: orange berries boiled during 15 min, Rb15: red berries boiled during 15 min

4. Conclusion

In conclusion, Green berries contain appreciable amounts of fiber, ash, magnesium, iron and zinc while red berries are rich in protein, calcium, phosphorus, potassium and sodium.
Whatever the stages of ripening, this content decrease during boiling times.Yet, The result of this study revealed that cooked *Solanum anguivi* Lam berries at 10 min preserved more nutrients.

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