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Proximate Composition and Nutritional Potential of *Saba Senegalensis* Fruit from Three Climatic Regions in Burkina Faso

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Abstract

Non-timber forest products such as lianas provide essential nutrients for human health and should be exploited in Burkina Faso. In order to better valorization, this study aimed to investigate the nutritional potential of *Saba senegalensis* fruit. The samples of fruit were obtained from three climatic regions then biochemical composition and nutritional content of it pulp were analyzed according to standard methods.

The results showed that pulps were acidic with pH varying from 2.85±0.12 to 3.16±0.70 and titratable acidity 4.52±0.20% to 4.89±0.40%. Brix degree, moisture content, and ash were ranged respectively from 20.11±1.50% to 23.50±1.10%, 84.50±3.15% to 86.50±4.25%, 4.44±0.30 g/kg to 5.85±0.40 g/kg. Macronutrients contents were 3.89±0.10 to 3.89±0.10 g/kg, 4.65±0.70 to 7.78±0.50 g/kg, 19.44±1.80 to 23.80±1.40 g/kg, 146.40±11.25 to 155.70±14.50 g/kg respectively for lipids, proteins, total fibers and total carbohydrates. Vitamines rates of pulps were respectively 15.50 ± 1.91 to 17.14 ± 1.90 mg/kg, 0.25 ± 0.05 to 0.55 ± 0.08 mg/kg, and 22.6 ± 2.30 to 27.8 ± 2.90 mg/kg for vitamins B6, A and C. Pulp contain of phytonutrient and anti-nutritional factors were 105.18 ± 10.14 to 132.80 ± 15.00 mg/100g and 19.17 ± 1.16 to 39.60 ± 1.10 mg/100g for total polyphenols and flavonoids and yet ranged 105.25 ±5.15 to 121.80 ±2.20 mg/100g, 78.51 ±0.13 to 80.30 ±1.50 mg/100g, and 20.57 ±3.50 to 26.49 ±1.30 mg/100g respectively for phytates, tannins and oxalates.

The mineral composition exhibited higher Mg, Ca, and P content as presented in the results. Principal component analysis (PCA) revealed specific variation on nutritional composition of pulp according to climatic zone. The study demonstrates that *S. senegalensis* is good nutritional source and could contribute to food security.

Keywords: forests products, *Saba senegalensis*, nutritional content, climatic zones, Burkina Faso

1. Introduction

Burkina Faso's economy is predominantly agrarian, with agriculture contributing approximately 18.4% of the country's total gross domestic product (GDP) in 2020 and employing around 80% of the workforce (PNUD, 2022). The country's food policy prioritises a limited number of crops commonly referred to as "main crops," including cereals and legumes. Market garden crops are classified as secondary crops, whereas non-timber forest products are rarely considered food crops (Loubelo, 2015). Yet, their significance with regard to nutritional intake and their role in maintaining a balance of nutrients and achieving self-sufficiency in food cannot be overlooked (Loubelo, 2015). Consumption of non-timber forest food species in their natural state helps enhance the quality of food by adding micronutrients.

Non-timber forest products (NTFPs) play an important role in the lives of people, especially in rural areas. They are used by these populations to meet subsistence needs (food and health) or as sources of additional income and employment. Around 1.2 billion people in developing countries use the trees on their farms (fields) for food and income (FAO, 1996). The importance attached to these non-timber forest products (NTFPs) is linked above all to the major role they play in human nutrition as one of the main sources of micronutrients: vitamins and minerals (Sambou et al., 2016).

Saba senegalensis is a climbing fruit species that grows wild and remains unvalued and undomesticated (Kabré et al., 2020). Additionally, its year-round unavailability and perishable nature further constrain its valorisation (Sarr et al., 2018). The orange-yellow pulp covering the seeds contains important minerals as Fe, Mg, Zn, Ca and K (Parkouda et *al*., 2018, Tiendrebeogo et al., 2020). Also fruit contains carotenoids, anthraquinones, sterols, triperpenes anti-nutritional substances as phytates, tannins, and oxalats (Kini et al., 2008, Diabagaté et al. 2019).

Adding value to non-timber forest products remains the most sustainable solution for combating malnutrition, the degradation of forest resources and the prevalence of certain diseases. forest resources and the prevalence of certain diseases. Despite the importance of forest fruits the nutritional quality of these fruits is poorly known by those involved in the sector (FAO, 2012).

Figure 1. Saba senegalensis: a) *Saba Senegalensis* fruit species b) *Saba senegalensis* fruits c) Pulp-coated seeds

Studies conducted by Semdé et al. (2019) have highlighted the variability in fat, total sugar, protein, and mineral contents of stump tubers harvested in different locations in Burkina Faso. These nutritional variations are similar to the research of Abalokoka et al. (2018), who discovered differences in the mineral values across three areas in Togo. According to Bourque (2000), ongoing global warming is resulting in climatic changes which may impact agriculture, specifically fruit production. As reported by Basson et al. (2020), Burkina Faso possesses three climatic zones - the Sudanian, Sahelo-Sudanian, and Sahelian zones - and climate variability has a detrimental effect on their agroforestry production. The research by Diouf et al. (2019) indicates that populations of goose liana display morphological variability in leaves, fruits, and seeds based on their respective climatic zones. The study by Bationo-Kando et al. (2009) further suggests that climate change can cause variations in the biochemical makeup of the species' fruits.

Most studies on of *Saba senegalensis* fruit in Burkina Faso focused only on its physicochemical characteristics (Parkouda et al., 2018; Tiendrebeogo et al., 2020) but not looking to climatic impact. For better valorisation of this Non-timber forest products (NTFPs) the influence of climatic factors on the fruit's potential needs to be checked. The main objective of this study was investigate the nutritional characteristics of S. senegalensis pulp according climactic zones of Burkina Faso.

2. Material and Methods

2.1 Sampling and Samples Preparation

2.1.1 Sampling Collect

This study uses pulps extracted from ripe *Saba senegalensis* fruits collected from multiple localities according different climatic zones in Burkina Faso. For the Sudanian zone, the fruits were gathered from Orodara, Wempea, and Gaoua, whereas Balongen, Passakongo, and Guirgho were selected for the Sudano-Sahelian zone, and Bourbo, RiguiRigui, and Bougouré for the Sahelian zone (Figure 2). The samples were collected between May and August 2022, with 25 samples per locality in the same climatic zone, resulting in a total of 75 fruit samples per climatic zone. Each sample weighed 1 kg, and a total of 225 samples were transported to the laboratory.

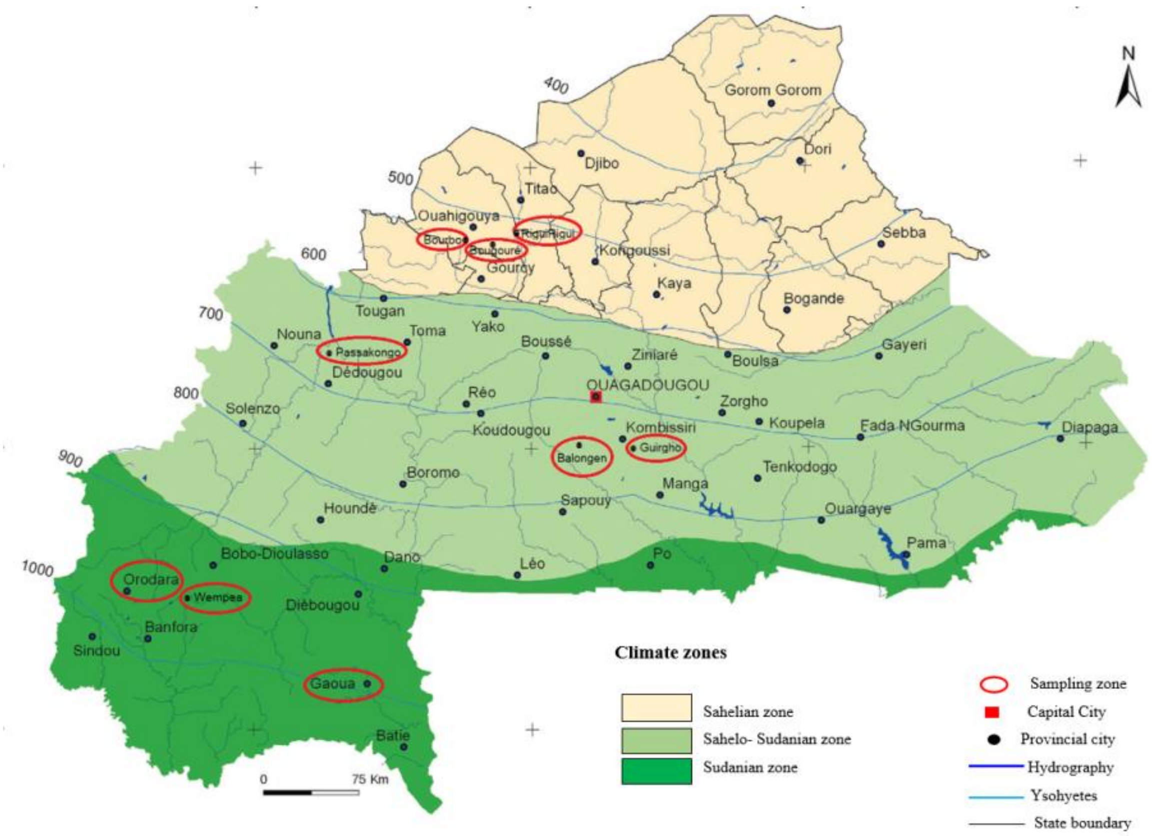

Figure 2. Three climatic zones in Burkina Faso (adapted to Kambire et *al.,* 2015)

Sahelian zone and GPS coordinates:

RiguiRigui :13° 27’ 29.794 ‘’ N 2° 15’ 18.648” W: Bourbo: 13° 27’ 13.298’’N 2° 23’ 53.286” W:

Bougoure: 13 °23.8080 ‘’N 2° 15’ .1250” W.

Sudano-sahelian zone and GPS coordinates:

Balongen: 1 2° 2’ 57.077’’ N 1° 29’ 56.713” W: Passakongo: 12° 29’ 24.536 ‘’N 3° 25’ 53.533’’W; Guirgho: 11° 54’ 10.48’’ N 1° 21’ 33.606” W.

Sudanian zone and GPS coordinates

Orodara :10° 58’ 0.001’’ N 4° 54’ 0” W; Wempea I: 10° 49’ 50.03’’ N 4° 36’ 41.281” W;

Gaoua : 10° 19’ 0.001’’ N 3° 10’ 0.001’’ W.

2.1.2 Pulp Extraction and Preparation

The fruit batches were washed using potable water and soap before being disinfected in a water solution containing a few drops of sodium hypochlorite. The pulps were extracted using a knife and spoon method and then blended using a Nasco 500 W5 blender (refer to Figure 3: A, B, C). For analysis, samples of 500g mixed pulp, without seeds per locality in the climatic zones, were taken and then dried in an oven at 40 ℃ for 14 days. A part of pulp obtained was stored at + 4 ℃ in freezer bags and kept frozen for analysis. The dried pulp was powdered using a MINA MIQABO electric grinder (Figure 3D). A composite sample of pulp extracted from each area was monitored.

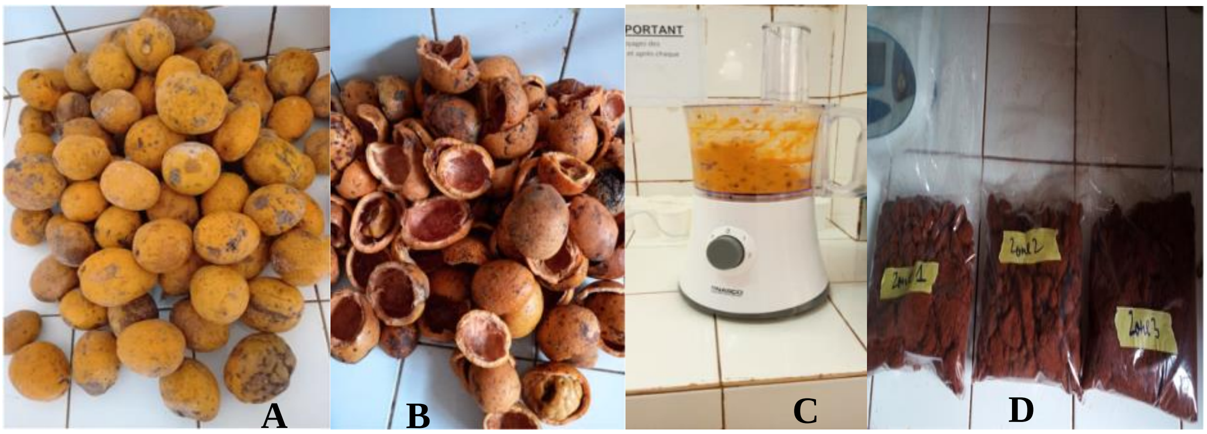

Figure 3. Preparation steps of dried pulp powders: A) fruit, B) fruit hulls ~~and~~ C) pulp extraction D) dried pulp

2.2 Determination Physicochemical Parameters of Pulp

The pH and titratable acidity were measured using a pH Metro Digital pH-2005.4120500 model pH meter and titrimetry, respectively, at a ratio of 1/10 (m/v) following the AOAC (1990) method. The results of tritratable acidity were expressed as the percentage (%) of citric acid in the juice. The Brix level was measured using the ATAGO PACKET refractometer according to the AOAC (1990) method. Moisture was determined according to the method of AOAC (1990). A quantity of 0.5 g of pulp was dried oven at 105 ℃ for 24 hours, and the dry matter was determined. Ash content was determined by calcining samples in a muffle furnace (JP Selecta SA 313066) at 550 ℃ for 6 hours, as per the AOAC (1990) method.

2.3 Determination of Macronutrients

The pulp proximate macronutrients were determined using the methods of AOAC.

Carbohydrates were determined using the liquid chromatographic sugar separation method as outlined in (A.O.A.C, 1984). A sample (10 g) was used to determine lipids by extracting with n- hexane (40-60 ℃) in a Soxhlet apparatus (A.O.A.C, 1995).

Protein was estimated using the macro- Kjeldahl method, then calculated by multiplying the measured nitrogen by a factor of 6.25. The crude fiber was evaluated by digesting the defatted sample (2 g) in 1.25% HCl and 1.25% NaOH (A.O.A.C, 1990).

2.4 Determination of Phytonutrients and Anti-nutritional Components

Total polyphenols content was evaluated by method using Folin-Ciocalteu (Joshi et al. 2015).

Phenolic content was measured using Folin-Ciocalteu according to Joshi et al. (2015) method. The pulp extracted by ethanolic solution were treated with Folin-Ciocalteureagent (500 µL, 1 N) followed by saturated sodium bicarbonate (100 µL). The final volume was made up to 25 mL using distilled water. The reaction mixture was then incubated at room temperature for half hour. Absorbance was readed at 730 nm against blank using UV-Vis spectrophotometer (Eppendorf). Gallic acid was used as the standard and expressed in mg gallic acid equivalents (GAE) per g extract.

Flavonoids were are determined at 415 nm using the method described by (Meda et al., 2005). Flavonoids react with aluminum chloride in the presence of potassium acetate to give a yellow complex whose intensity is proportional to the amount of flavonoid present in the medium.

Phytate quantification was based on an indirect method that involves complexing phytates with iron (phytates-ferric), followed by spectrophotometric determination of the iron. (Mohamed et al., 1986). The concentration of tannins in pulp was measured using the method described by Bainbridge et al. (1996). The oxalic acid content was evaluated following to the AOAC (1995) as adapted by Sotomayor et al. (2001).

2.5 Determination of Micronutrients

Vitamines (A, B6 and C) contents were determined in accordance with standard method EN 12823-1: 2014 using high-performance liquid chromatography (HPLC) with fluorometric detection (F). This method was described by Albalà-Hurtado et al (1997). The retinol molecule was used as the standard for vitamin A. Vitamin B6 is the mass fraction of the sum of pyridoxine, pyridoxal, pyridoxamine including their phosphorylated derivatives determined as pyridoxine.

Minerals content were carried out according the method of AOAC (2005). using inductively coupled plasma atomic emission spectrometer (ICPE 9000, Shimadzu, Japan). Sample The concentrations of Calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), iron (Fe), zinc (Zn), and manganese (Mn) were determined by comparing their absorbance to a standard linear regression curve from standard solutions.

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2.6 Statistical Analysis

The data obtained after analysis were subjected to an analysis of variance (ANOVA) at the 0.05 significance level using XLSTAT software (Version 2016). The Fischer LSD test was used to determine significant differences between samples. Principal Component Analysis (PCA) was performed to explicitly determine parameter variations between climatic zones.

3. Results and Discussion

3.1 Proximate Biochemical Composition of Pulp Related To the Region

3.1.1 pH, Titratable Acidity, Brix degree, Moisture, Ash

The physico-chemical parameters of fruit pulp from three regions were presented in the the table 1. Results showed no statistically significant differences (p>0.05) in the pulp among the regions concerning pH, Titratable acidity, Brix degree, moisture. However, a significant difference was observed for Ash.

Table 1. Physico-chemical parameters of fruit pulp of *S. senegalensis*

Samples	**pH**	**Tritratable acidity (%)**	**Brix degree (%)**	**Moisture (%)**	**Ash (g/kg)**
Z1	2.85±0.12 [a]	4.52±0.20 [a]	20.11±1.50 [b]	84.50±3.15 [a]	4.44±0.30 [b]
Z2	3.10±0.25 [a]	4.64±0.15 [a]	23.50±1.10 [a]	86.50±4.25 [a]	5.85 ± 0.40[a]
Z3	3.16 ±0.70 [a]	4.89±0.40 [a]	22.20±1.50 [ab]	86.11±3.70 [a]	5.30±0.60 [ab]
P value	0.670	0.308	0.061	0.79	0.024

For the same column, values (means ± SEM) followed by the same letter are not significantly different.

Z1: Sudanian zone , **Z2:** Sahelo-Sudanian zone, **Z3 :** Sahelian zone

The pH values of liana fruit pulp ranged 2.85±0.12, 3.1±0.25 and 3.16±0.70 while tritratable acidity ranged 4.52±0.2%, 4.64±0.15% and 4.89±0.40% respectively for Sudanian zone, Sudanian, Sahelo-Sudanian and Sahelian zone. The pH values indicated that *S. Senegalensis* fruit is acidic. These values were closed to those of Parkouda et al. (2015) in Burkina Faso, who obtained pH values of 2.76 ± 0.1. Similarly, Kouakoua et al. (2019) and Diabagaté et al. (2019) in Côte d'Ivoire found similar pH values of 2.85 ± 0.21 and 3.03 ± 0.01 respectively. In Senegal, Gaye et al. (2022) also obtained similar results with a pH of 2.79 ± 0.05.

The acidic pH in the fruit may be attributed to the existence of organic acids as citric acid, tartaric acid, malic acid and succinic acid, which are commonly present in fruits such as oranges and lemons (Ouchemoukh et al., 2007). According to Vondruskova et al. (2010), organic acids have the ability to lower pH and thereby reduce the growth of certain pathogenic bacteria. Only acidophilic microorganisms can survive in such an environment (Yeo et al., 2021).

Titratable acidity values exceed those reported by Parkouda et al. (2015) in Burkina Faso, Kouakoua et al. (2019) and Diabagaté et al. (2019)in Côte d'Ivoire, with values of 1.35%, 2.2% and 0.28% respectively. Acidity is crucial in prolonging the shelf life of food (Li et al., 2022).

The Brix values obtained for the Sudanian, Sahelian, and Sahelo-Sudanian zones were gradually 20.11±1.50%, 22.20±1.50%, and 23.50±1.10%, respectively. Statistical analysis revealed no significant difference (p>0.05) in Brix values between the three climatic zones of Burkina Faso. Brix degree was higher than those obtained by Tiendrebeogo et al.(2020) in liana pulp (18.74±0.00%) in Burkina Faso, and Kouakoua et al. (2019) in Cote d'Ivoire (19.60±0.1%) then to those of Boamponsem et al. (2013) in Ghanaian goïne liana fruit pulps (14.1%). In contrast, Parkouda et al. (2015) in Burkina Faso found higher values (26.62±1.08%). The Brix level depends on the sugar content of the fruit. According to Piard et al. (2014), the sweetness of a sample increases with its

Brix level. The composition of fruit sugar varies considerably during the development stage based on crop management and climatic factors (Taghavi et al., 2019).

The pulp moisture content from liana fruits ranged with no significant difference (p>0.05) 84.50±3.15, 86.11±3.70, 86.50±4.25 respectively for Sudanian, Sahelian, Sahelo-Sudanian zones. These values were found to be closed to those reported by Tiendrebeogo et al.(2020) in Burkina Faso, which were 83.23±2.39%. The pulp moisture content is high when compared to other authors as Gaye et al. (2022) in Senegal and Boamponsem et al. (2013) in Ghana, who have reported 74.77±0.48% and 70.90%, respectively.

The variable moisture content in the pulp of three zones can be attributed to agromorphologic conditions and other factors such as sunlight and wind exposure contributing to fruit pulp dryness (Ruiz-Rodríguez et al., 2011). On the other hand, Ash values ranged gradually 4.44±0.30 g/kg, 5.85±0.40 g/kg and 5.30±0.60 g/kg for Sudanian, Sahelian, Sahelo-Sudanian zone. The ash was found to be significantly different between the three climatic regions (p<0.05).

The mean value obtained of 5.19±0.71 g/kg was similar to those of Tiendrebeogo et al. (2020), who reported 5.9 ± 3.1 g/kg for fruit pulps sourced in Burkina Faso, moreover was higher to those reported by Diabagaté et al. (2019) in Côte d'Ivoire (0.46 ± 0.01%) and Boamponsem et al. (2013) in Ghana (2.8%). The difference of ash contents obtained in this study and those of the literature could be explained either by the different varieties, the geographical locations of the plant studied. According to Diabagaté et al (2019) difference could provide to the nature of the climate and the property of the soil on which the plant grows and technological treatments applied. The ash content is a reflection of the inorganic matter and of minerals of the pulp (Muthai et al., 2017).

3.1.2 Macronutrient Content

The results of macronutrient content were mentioned in the table 2. Results showed statistically significant difference (p<0.05) for fat, protein and total fiber according the three regions. And yet no significant difference was found for total carbohydrates content.

Table 2. Macronutrient compositions of fruit pulp of *S. senegalensis*

Samples	Protein (g/kg)	Fat (g/kg)	Total Fiber (g/kg)	Total carbohydrates (g/kg)
Z1	4.65 ±0.70^{b}	3.89±0.10^{b}	19.44±1.80^{b}	146.40±11.25^{a}
Z2	7.78±0.50^{a}	11.56±0.20^{a}	23.80±1.40^{a}	155.70±14.50^{a}
Z3	5.65±0.30^{b}	4.10±0.24^{b}	20.17±1.32^{b}	151.18±13.00^{a}
P value	0.001	0.001	0.026	0.696

For the same column, values (means ± SEM) followed by the same letter are not significantly different.

Z1: Sudanian zone , **Z2:** Sahelo-Sudanian zone, **Z3 :** Sahelian zone

The mean crude protein content ranged gradually 4.65±0.70 g/kg, 5.65±0.30 g/kg, 7.78±0.50 g/kg for Sudanian, Sahelian, Sudano-Sahelian zones. There was specific regional trend across the regions. The results showed that there were statistically significant differences (p < 0.05) among the regions for protein content.

The mean value recorded in this study was comparable to results of previous studies on *S. senegalensis* fruit pulp conducted by Tiendrebeogo et al. (2020) in Burkina Faso (5.9 ± 1.2 g/kg), Boamponsem et al. (2013) in Ghana (5.3 g/kg). However, it was lower than those obtained by Diabagaté et al. (2019) in Côte d'Ivoire (29.1± 5.1 g/kg).

Fat content gradually ranged 3.89 ± 0.10g/kg, 4.10 ± 0.24g, 11.56±0.20g/kg for Sudanian, Sahelian, Sahelo-Sudanian zone. Fat content in the Sahelo-Sudanian zone exceeded those in the Sudanian and Sahelian zones. The results showed that there were statistically significant differences (p < 0.001) among the regions for fat content. Tiendrebeogo et al (2020) reported values of 11.5 ± 0.2g/kg in Burkina Faso, similar to those in the Sahelo-Sudanian zone. Gaye et al. (2022) found levels ranging from 9.6 ± 3g/kg to 16.59±5.1g/kg in Senegal, which were comparable to those observed in Burkina Faso. Diabagaté et al. (2019) found 14.8 ± 2.1g/kg in Côte d'Ivoire. Sarr et al. (2018) obtained a lipid content of 2g/kg from fruit pulps harvested in Senegal.

The Sudanian zone exhibited a crude fiber content of 19.44±1.80g/kg, while the Sahelo-Sudanian zone and Sahelian zones displayed 23.80±1.40g/kg and 20.17±1.32g/kg, respectively. Notably, the Sahelo-Sudanian zone recorded the highest content levels in comparison to the other two zones. Mean pulp crude fiber content showed lower value than those of Boamponsem et al. (2013) in Ghana 13.52g/kg. This finding showed that the influence of environment on pulp crude fiber content was very minimal. This experiment demonstrated for the first time that the pulp fiber content of liana was influenced by the provenance of origin.

These variations according of the climatic regions could potentially be explained by the effects of soil and climatic conditions within the particular zones (Dabbou et al., 2010).

Total carbohydrate levels for the three climatic zones exhibited no significant differences. The Sudanian, Sahelo-Sudanian, and Sahelian zones recorded contents of 146.400 g/kg, 155.7 g/kg, and 151.180 g/kg, respectively. These values were closed to those obtained by Tiendrebeogo et *al*. (2020) (144.2 ± 4.7 g/kg) in Burkina Faso.

Other authors as Diabagaté et al.(2019) in Côte d'Ivoire, reported a lower mean of 84.2±7.4 g/kg. These differences could be attributed to the climatic conditions existing in the countries and the level of ripeness of the fruits at the time of harvest alongside fruit storage circumstances (Gaye et al., 2022).

3.2 Phytonutrients and Anti-nutritional Factors

The phytonutrients and antinutritionals factors content, were examined in the fruit pulps of *S. senegalensis* and the results were mentioned in table 3. Results were significantly different (p<0.05) for flavonoids, phytates and oxalates according to the climatic regions. In addition, no significant difference was observed for polyphenols and tannins.

Table 3. Phytonutrients and anti-nutritional component

	Average (mg/100g)				
Samples	**Total polyphenols**	**Flavonoids**	**Tannins**	**Phytates**	**Oxalates**
Z1	105.18±10.14 [a]	19.170±1.16 c	78.51±0.13 a	105.25±5.15 b	20.57±3.50 b
Z2	132.80 ±15.00 [a]	39.600±1.10 a	80.300±1.50 a	121.800±2.20 a	26.490±1.30 a
Z3	117.35 ±18.00 [a]	25.300±1.40 b	80.100±4.60 a	115.300±4.25 a	20.630±2.50 b
P value	0.150	0.001	0.706	0.007	0.050

For the same column, values (means ± SEM) followed by the same letter are not significantly different.

Z1: Sudanian zone , **Z2:** Sahelo-Sudanian zone, **Z3 :** Sahelian zone

The polyphenol content values in this study ranged gradually 105.18 mg/100g, 117.35 mg/100g and 132.8 mg/100g for Sudanian, Sahelian and Sudano-Sahelian respectively. Statistical analysis indicated ($p > 0.05$) that there was no significant difference in polyphenol levels between the three climatic zones. Statistical analysis reveals that climatic zone does not impact tannin content, while phytate and oxalate content exhibit considerable variations based on the zone ($p < 0.05$).

Polyphenol level reported here are lower than those obtained by several authors as Diabagaté et al. (2019) and Kouakoua et al. (2021) in Côte d'Ivoire (264.76 ± 4.54 mg/100g, 600.94 ± 5.27 mg/100g). Lamien-Meda et al. (2008) and Noba et al. (2020) reported even higher values in Burkina Faso (945.83 ± 14.13 mg/100g, 630 ± 6mg/100g). Baiyeri et al. (2019) reported the highest levels in Nigeria (165.10 ± 11.80mg/100g).

The flavonoid contents were 19.17 ±1.16mg/100g in the Sudanian zone, 39.60 ±1.10mg/100g in the Sudano-Sahelian zone, and 25.30 ±1.40mg/100g in the Sahelian zone. Lamien-Meda et al.(2008) discovered lower values of 5.30 ± 062 mg/100g in Burkina Faso fruit pulp. These levels were inferior to those uncovered by Diabagaté et al. (2019) and Kouakoua et al.(2021) in Côte d'Ivoire, who respectively identified values of 53.44 mg/100g and 245.09 mg/100g. Baiyeri et al.(2019) discovered notably elevated flavonoid levels in Nigeria (24650±2250 mg/100g, i.e. 24.65±2.25%).

The variations in polyphenol and flavonoid concentration across climatic zones may be attributed to the weather conditions in the areas where *Saba senegalensis* fruits were harvested (Baiyeri et al., 2019).

Polyphenols play a significant role in nutrition. Indeed, there is significant epidemiological evidence that a diet abundant in fruits, vegetables, cocoa, and beverages rich in polyphenols protects against the development of cardiovascular disease and type 2 diabetes (Williamson, 2017). Flavonoids are polyphenolic substances of plant origin with significant biological, antioxidant, vasculoprotective, anti-hepatotoxic, anti-allergic, anti-inflammatory, anti-ulcer, and anti-tumor properties (Lahouel et al., 2004; Ghedira, 2005).

Analysis of goïne liana pulps revealed the presence of anti-nutritional factors, including tannins, phytates, and oxalates. Tannin levels were found to be 78.51 ±0.13 mg/100g in the Sudanian zone, 80.30 ±1.50 mg/100g in the Sudano-Sahelian zone, and 80.10 ±4.60 mg/100g in the Sahelian zone. These measurements are lower than those reported by Diabagaté et al.(2019), who found tannin content in fruit pulp harvested in Côte d'Ivoire to be 198.94

± 1.19 mg/100g. These findings closely match those reported by Diabagaté et al. (2019) for *Saba senegalensis* fruit jams made in Côte d'Ivoire at 78.51 ± 0.14 mg/100g. These lower values can be attributed to the dilution effect in the jam's formulation. Tannins have an essential role in nutrition as they hinder the bacterial metabolism by inhibiting their growth Larwence et al.(1984). This process increases the food's shelf life. Tannins are responsible for the therapeutic properties of some plants. The leaves and fruits contain tannins in the range of 6 to 8% (Sereme et al., 2008). Tannins may exhibit antimicrobial effects by binding to cell wall pore proteins, which can alter molecule transport mechanisms, thereby reducing nutrient bioavailability (Mebirouk-Boudechiche et al., 2015).

Phytate levels in the Sudanian zone were 105.25 ± 5.15 mg/100g, whereas in the Sudano-Sahelian zone and Sahelian zone, they were 121.80±2.20 mg/100g and 115.30±4.25 mg/100g, respectively. These values exceed those obtained by Diabagaté et al.(2019) of 31.18±0.13 mg/100g in goïne liana fruit pulp from Côte d'Ivoire and (Diabagate et al., 2020) of 102±6.93 mg/100g in *Saba senegalensis* fruit jams produced in Côte d'Ivoire. Phytates, identified as anti-nutritional factors, hinder mineral absorption like iron (Towo et al, 2003). Their levels in food should be moderated.

Regarding oxalates, Sudanian, Shalian and Sahelo-Sudanian zone respectively had 20.57±3.50mg/100g, 26.49±1.30mg/100g, and 20.63±2.50mg/100g according to pulp analysis. These readings were lower than those found by Diabagaté et al.(2019) of 381.33 ± 12.67mg/100g. However, it should be noted that these values exceed those reported by Diabagate et al. (2020) of 19.87 ± 0.01mg/100g in *Saba senegalensis* fruit jams and 6.62 ± 0.21mg/100g in *Saba senegalensis* syrup both produced in Côte d'Ivoire.

Oxalates, which can hinder the uptake of micronutrients and reduce their bio-availability, are found in the product. It must be elucidated that not all oxalates are eliminated through cooking (Ngombo-nzokwani et al., 2021).

3.3 Vitamins and Minerals Contents

The vitamins and minerals content in the fruit pulps of *S. senegalensis* were shown in table 4 and table 5. Results were significantly different ($p<0.05$) for vitamin A and minerals as Zn and Mn according to the climatic regions. In addition, no significant difference was observed for Vitamins B6, C and minerals as Mg, Ca, P, K, and Fe.

Table 4. Vitamins content of fruit pulp of *S. senegalensis*

	Average (mg/kg)		
Samples	**Vitamin B6**	**Vitamin A**	**Vitamin C**
Z2	17.140 ±1.90 [a]	0.550 ±0.08 a	27.800±2.90 a
Z3	15.770±1.73 [a]	0.420±0.03 b	22.600±2.30 b
Z1	15.500±1.91 [a]	0.250±0.05 c	24.150±1.50 ab
P value	0.542	0.002	0.078

For the same column, values (means ± SEM) followed by the same letter are not significantly different.

Z1: Sudanian zone , **Z2:** Sahelo-Sudanian zone, **Z3 :** Sahelian zone

Table 5. Mineral content

	Average (mg/100g)						
Samples	**Mg**	**Ca**	**P**	**Mn**	**K**	**Zn**	**Fe**
Z2	128.30±11.00 a	192.14±19.60 a	82.10±4.00 a	7.810±0.50 a	3.700±0.90 a	2.620±0.30 a	4.060±0.13 a
Z1	118.150±10.00 a	176.900±16.00 a	81.500±5.50 a	5.680±0.25 b	2.500±0.30 b	2.110±0.20 b	3.920±0.14 a
Z3	115.210±14.98 a	171.770±36.07 a	70.910±8.51 a	5.590±0.23 b	2.800±0.10 ab	1.470±0.22 c	3.780±0.68 a
P value	0.437	0.619	0.125	0.001	0.084	0.004	0.716

For the same column, values (means ± SEM) followed by the same letter are not significantly different.

Z1: Sudanian zone , **Z2:** Sahelo-Sudanian zone, **Z3 :** Sahelian zone

The vitamin B6 rate was ranged gradually 15.50 ± 1.91 mg/kg; 15.77 ± 1.73 mg/kg, 17.14 ± 1.90 mg/kg for Sudanian, Sahelian and Sudano-Sahelian zone the while Vitamin A and C exhibited respectively 24.15 ± 1.50 mg/kg, 22.6 ± 2.30 mg/kg, 27.8 ± 2.90 mg/kg and 0.250 mg/kg, 0.420 mg/kg, 0.550 mg/kg.

These values exceeded those found by Sarr et al (2018) concerning vitamin B6 (0.2 mg/kg). In other studies, Baiyeri and Olajide's (2022) reported higher vitamin B6 content of 27-144mg/kg. Vitamin B6 is essential for maintaining proper bodily function.

The values of vitamin A were lower than those reported by Kouakoua et al.(2021; 2019) and (Diabagaté et al.(2019) who respectively found values of 19.6 ± 0.3 mg/kg; 1.7885 ± 0.0167 mg/kg and 1.8962 ± 0.0133 mg/kg in Côte d'Ivoire. Sarr et al. (2018) found levels of 15.5 mg/kg in Senegal. Baiyeri et al.(2019) found values of 17.2 ± 2.6 mg/kg in Nigerian pulp.

Vitamin A is an essential fat-soluble vitamin that plays a critical role in maintaining the body's overall health. It contributes to maintaining vision, epithelial surface integrity, immunity, reproduction, and growth and development (Pallet and Enderlin, 2011). Adding fruit to your diet can help to maintain sufficient levels of this vitamin.

The values of vitamin C were lower than those obtained by Diabagaté et al.(2019) of 366.7 ± 22.2 mg/kg and by Kouakoua et al.(2019) 240.0±1.0 mg/kg in pulps from Côte d'Ivoire; by Gaye et al. (2022) 328.6 mg/kg to 1982.2 mg/kg in pulps from Senegal; by Boamponsem et al. (2013) 164.1 mg/kg in pulps from Ghana and by Baiyeri et al.(2019) 37.3 ± 1.7 mg/kg in Nigerian pulp. However, they are higher than those obtained by Noba et al. (2020) of 15.11 ± 0.025 mg/kg in pulps from Burkina Faso. Vitamin C is vital for collagen production and is crucial in the immune system's response to infections (Buxeraud and Faure, 2021). Vitamin C has several biochemical functions such as activating hormones, antioxidants, and histamine detoxification, while also stimulating certain enzymes, collagen biosynthesis, phagocyte and leukocyte functions, nitrosamine formation, and proline hydroxylation, among others (Walingo, 2005).

The levels of Magnesium (Mg), Calcium (Ca), Manganese (Mn), Zinc (Zn), Iron (Fe), Potassium (K), and Phosphorus (P) were ranged 118.15 ±10.00 mg/100g, 176.90 ±16.00 mg/100g, 5.68 ± 0.25mg/100g, 2.11 ± 0.20 mg/100g, 3.92 ± 0.14 mg/100g, 2.5 ±0.30 mg/100g, and 81.50 ± 5.50 mg/100g respectively for the Sudanian zone. Tiendrebeogo et al.(2020) found lower values of Mg, Ca, Fe, Zn and P at 107.01 ± 0.43 mg/100g, 130.22 ± 2.51 mg/100g, 2.54 ± 0.03 mg/100g, 0.22 ±0.0mg/100g, and 253.57 ± 27mg/100g respectively in Burkina Faso.

In the same country, Parkouda et al.(2007) found lower levels of 9 to 13 mg/100g for Phosphorus (P). In Côte d'Ivoire, Diabagaté et al.(2019) and Kouakoua et al. (2021) obtained lower levels of (14.18 ± 1.48 mg/100g and 37.58 ± 0.63 mg/100g) and (36.61 ± 2.79 mg/100g and 29.19 ± 0. The levels of Magnesium (Mg), Calcium (Ca), Zinc (Zn), and Iron (Fe) were found to be 17 mg/100g, 0.38 ± 0.11 mg/100g, and 0.08 ± 0.01 mg/100g, and 1.04 ± 0.65 mg/100g and 2.51 ± 0.06 mg/100g, respectively. Gaye et al.(2022) also reported lower values of 24 mg/100g to 30 mg/100g, 9 to 13 mg/100g, and 0.9 to 1.7 mg/100g for Magnesium (Mg), Phosphorus (P), and Iron (Fe) in Senegal. However, higher levels of Magnesium (Mg) 239.66 ± 1.06 mg/100g, Calcium (Ca) 1261.08 ± 6.58 mg/100g, Manganese (Mn) 117.66 ± 1.09mg/100g, Potassium (K) 64.842 ± 0.318 mg/100g, Zinc (Zn) 66.39 ± 0.77 mg/100g, and Iron (Fe) 24.95 ± 0.61 mg/100g were measured in Nigeria by Baiyeri et al. (2019).

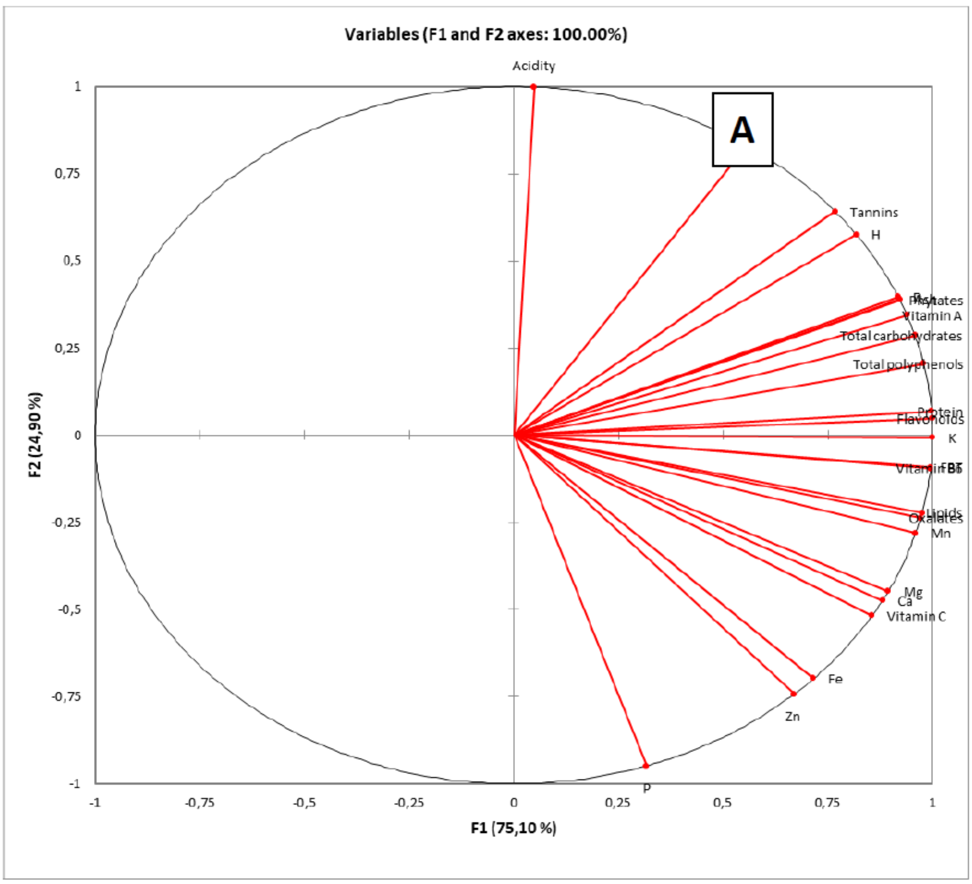
The authors Diabagaté et al. (2019) and Kouakoua et al. (2021) in Côte d'Ivoire; Tiendrebeogo et al. (2020) in Burkina Faso and Gaye et al. (2022) in Senegal also observed elevated Potassium (K) levels ranging from 116.96 ± 2.06 mg/100g to 253.57 ± 27 mg/100g and from 151 mg/100g to 218 mg/100g, respectively. Kouakoua et al. (2021) and Gueye et al. (2022) assert that *Saba senegalensis* fruit pulp from Côte d'Ivoire and Senegal contains no manganese.

The variations in levels across countries can be explained by variances in climatic factors and soil types as documented by Bourque (2000); Amiot and George (2017); Tajini et al. (2020). All of these specific minerals have a crucial function in constructing the body. Magnesium is a vital component in a broad range of primary cellular reactions, and its absence has been linked to pathological conditions in humans (Mazur et al., 2007). The nutritional significance of magnesium's presence in fruit contributes to a well-balanced diet.

Calcium, on the other hand, is an essential element in skeletal development. It is involved in several biological functions, including muscle contraction, blood coagulation, hormone release, and enzyme activation (Katz and Miledi, 1967). Determining its presence in *Saba senegalensis* fruit pulp offers valuable information for nutrition and could aid in balancing the diets of populations. Phosphorus is a crucial element for organisms. It plays a role in various cellular reactions, such as glycolysis and oxidative phosphorylation, which are the primary sources of ATP (Delanaye and Krzesinski, 2005). Its presence in *Saba senegalensis* fruit is nutritionally interesting and can aid in maintaining a balanced diet. Manganese contributes to normal energy metabolism, protects cells against oxidative stress, and participates in skeletal formation within the body (Li and Yang, 2018). Potassium is a crucial mineral in the body, playing a significant role in the normal functioning of the nervous system, proper muscle activity, and the maintenance of normal blood pressure (Turck et al., 2016). Zinc is fundamental to the structure and function of various macromolecules within the body. It is involved in gene expression and stabilises protein structure, and also plays a prominent role in over 300 enzymatic reactions, including spermatogenesis, free radical detoxification via superoxide dismutase, alcohol metabolism via alcohol dehydrogenase (Fallah et al., 2018). Its determination in fruit is also of interest for food. *Saba senegalensis* fruit could be used as a mineral supplement to compensate for certain zinc deficiencies. Iron is crucial for the growth and survival of organisms. It is crucial for several biological processes, particularly the transportation of oxygen by hemoglobin, DNA synthesis (as a ribonucleotide reductase coenzyme) and the redox activity of many mitochondrial enzymes (Cadet et al., 2005).

3.4 Principal Component Analysis (PCA) of Physicochemical and Nutritional Parameters According to Climatic Zones

The collected data underwent PCA analysis to investigate discriminative qualities between the three climatic zones and to determine the impact of indicators such as the physico-chemical and nutritional analysis results, as well as the production origin of the samples analysed from Zones 1, Zone 2 and Zone 3. The eigenvalues of the correlation matrix were employed to quantify the percentage of variance explained by each factor. In the PCA, the F1 component accounts for 75.10 % of the total variable variation, while the F2 component represents 24.90 %. The histogram of eigenvalues indicates that the F1 and F2 axes constitute the first factorial plane, which explains the entire inertia with a total of 100 %. This adequately explains most of the inertia. Under the given conditions of the three climatic zones, it can be observed that the two main components account for the complete variance. Furthermore, the parameters investigated have a strong correlation with the principal axis (F1 = 75.10 % of the total variance). The screen plot depicted in Figure 3(B) displays the physico-chemical indices such as pH, acidity, brix, water content (H), ash content, lipids, proteins, total carbohydrates and crude fibre, alongside phytonutrients and anti-nutrients, including total polyphenols. Flavonoids, tannins, phytates, and oxalates, along with vitamins B6, A, and C, and mineral composition including Mg, Ca, P, Mn, K, Zn, and Fe, exhibit positive correlation with the principal axis F1, which explains 75.10 % of the variability. The physicochemical and nutritional parameters analyzed are highly correlated with the Sudano-Sahelian zone (Z2) (see Figure 3B). Some authors affirm that this zone is favourable for the development of *Saba senegalensis* species. According to Kabré et al (2020), the Sahelian and Sudanian zones exhibit the highest densities of adult *S. senegalensis*. The nutritional and physicochemical profile obtained may be attributed to the young population in the Sudano-Sahelian zone.



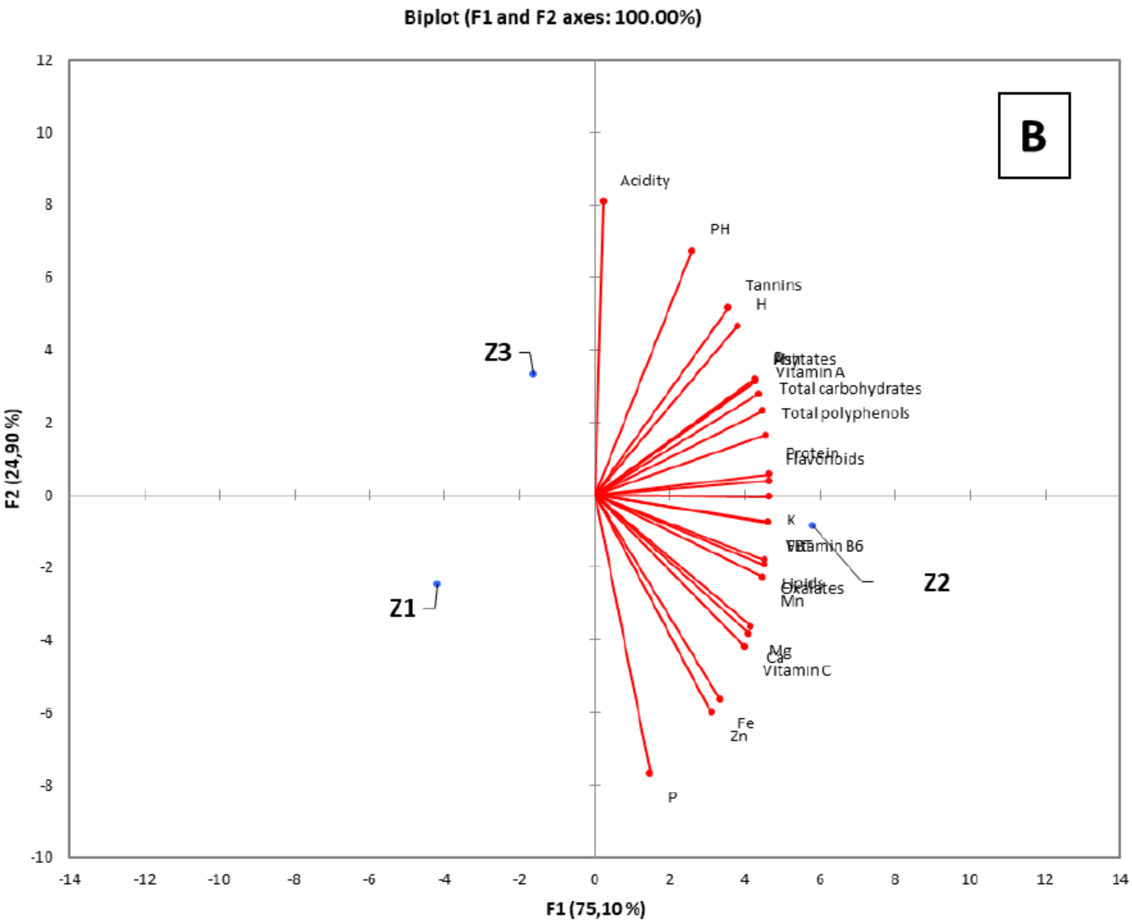


Figure 4. PCA of physico-chemical and nutritional parameters as a function of climatic zone according to the (F1xF2) design: A) factorial map of variables; B) factorial map of variables as a function of climatic zone

4. Conclusion

The study provides insight into the possible nutritional and biochemical content of the pulp of the goïne liana fruit in the three primary climates of Burkina Faso. Based on the nutritional value of the pulp, it is evident that the fruit of *Saba senegalensis* could offer a positive contribution to the dietary balance of populations and serve as a remedy for specific nutritional deficiencies in individuals with a deficiency. The studied parameters reveal that the composite sample from the Sudano-Sahelian zone displays the most optimal biochemical and nutritional profile.

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Authors contributions

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The data used to support this study are provided within the article.

Data sharing statement

No additional data are available.

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