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Physicochemical and Biochemical Characterization, Total Phenolic and Energy Value from Bulbs of Different Onion (*Allium cepa* L.) Varieties in Senegal

Ndeye Adiara Ndiaye[1], Lahat Niang[2], Modou Dieng[1], Ndeye Coumba Kane Touré[3]

[1]Laboratory of Microbiology, Graduate School Polytechnique (ESP)-UCAD, Dakar, Senegal
[2]Water, Energy, Environment and Industrial Processes Laboratory (LE3PI), Graduate School Polytechnique (ESP)-UCAD, Dakar, Senegal
[3]University Sine Saloum El Hadj Ibrahima Niass (USSEIN), Kaolack, Senegal
Email: ndadiara@hotmail.com

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Abstract

The purpose of this study is to investigate the physicochemical properties of some local varieties of onion (*Allium cepa* L.) and compare them with an imported variety, all collected in May 2021. Proteins, reducing sugars, lipids, and polyphenol content were estimated according to the AFNOR standardized methods. The determination of calcium, magnesium, iron, sodium, potassium and phosphorus was performed by atomic absorption spectrophotometer coupled with a CCD detector. The results highlighted an average acidity of 0.377% ± 0.002% lower than the value of the imported variety which is 0.520% ± 0.001%. Local varieties have a pH ranging from 6.35 ± 0.003 to 6.42 ± 0.004, while the variety has a pH of 6.36 ± 0.003. The ash and dry matter contents vary respectively from 4.788% ± 0.004% to 8.253% ± 0.003% and 7.945% ± 0.021% to 11.945% ± 0.007% for the local varieties. Moreover, the imported one has ash and dry matter contents of 5.175% ± 0.007% and 10.035% ± 0.021% respectively. The results show that the protein, reducing sugar and lipid contents in the local onion varieties vary respectively from 2.815 ± 0.000 to 15.634 ± 0.001 g·100 g^{-1}; 4.691 ± 0.001 to 12.596 ± 0.002 g·100 g^{-1} and 0.006 ± 0.001 to 0.050 ± 0.057 g·100 g^{-1}. Furthermore, the imported variety has a protein, reducing sugar and lipid content of 5.649 ± 0.002; 8.565 ± 0.002 g·100 g^{-1} and 0.011 ± 0.010 g·100 g^{-1} respectively. The maximum levels of total polyphenols are obtained in the imported variety, Bellani and Gandiol, respectively 9.973 ± 0.001, 4.535 ± 0.002, and 3.425 ± 0.006 mg EAG/g of dry matter. The local varieties have a significant calorific intake of between 35.451 ± 0.001 and 112.980 ± 0.003 kcal·100 g^{-1} compared

to the imported one with an energy value of 56.953 ± 0.001 kcal·100 g^{-1} of dry matter. The bulbs of different onion varieties studied have a fairly high content of mineral elements. The potassium content of local varieties is between 502.16 ± 0.06 mg·100 g^{-1} and 582.77 ± 0.04 mg·100 g^{-1} while the imported variety has a content of 536.62 ± 1.30 mg·100 g^{-1}. They note that the local varieties have a better calcium content (249.75 ± 0.07 to 434.20 ± 0.57 mg·100 g^{-1}) and magnesium (142.15 ± 0.07 to 162.60 ± 0.42 mg·100 g^{-1}) than the imported variety (229.58 ± 0.04 mg·100 g^{-1}) except for the varieties White Grano (228.29 ± 0.01 mg·100 g^{-1}) and Rouge Amposta (117.00 ± 0.42 mg·100 g^{-1}) respectively. These results reveal that Gandiol, Dayo and Orient F1 are nutritionally found better due to their higher antioxidant property, proteins, carbohydrates, and reducing sugar and should be included in diets to supplement our daily allowance needed by the body.

Keywords

Allium cepa L., Characterization, Physicochemical, Biochemistry, Total Phenolic

1. Introduction

The onion (*Allium cepa* L.) is an herbaceous plant of the Amaryllidaceae family. It constitutes an important component of individuals' daily dietary intake. It is a globally significant agricultural commodity due to its substantial economic value. Ranked second among the most extensively cultivated vegetables worldwide, surpassed only by the tomato, the onion (*Allium cepa* L.) stands as the foremost vegetable crop in Senegal [1]. The estimated onion production in 2018 reached 434.11 tons, reflecting a growth rate exceeding 8.5% when compared to the previous year, 2017 [2]. A considerable proportion (135.27 tons or 32.09%) of this notable achievement is generated within the Senegal River Valley, which in conjunction with the Niayes area, are the two main agro-ecological areas producing onion bulbs [3]. They are used as ingredients, for their bulbs and leaves, in various dishes for thousands of years, especially in Africa [4]. Indeed, it has several nutritional and therapeutic virtues [5]. The onion is considered an energetic, protective, and supportive food, as it contains vitamins (B, C, provitamin A), minerals (potassium, sodium, zinc, iron, phosphorus, …), lipids, proteins, carbohydrates, essential oils, organic acids and fibers [6]. It has both antioxidant and phytonutrient properties that make it a beneficial source. Various studies have demonstrated that regular consumption of raw onion affects blood clotting and prevents certain cardiovascular diseases [7]. However, the onion sector encounters a variety of difficulties, including strong competition between local and imported onions, and especially post-harvest losses. The substantial loss rates associated with the long-term conservation of local onions, which are due to their water content and nutritional composition, pose serious problems [8]. Even though the onion is the most prized food of the Senegalese population, it is

the subject of few scientific studies at the national level. Therefore, this study aims to characterize eight varieties of onion (Gandiol, Sakanal, Dayo, Orient F1, Bellani, White Grano, Rouge d'Amposta, Violet de Galmi) cultivated in Senegal and to compare them with the imported variety to better assess their quality and determine their contribution to nutrition and health in the local consumer population.

2. Material and Methods

2.1. Biological Material

Samples of onion (*Allium cepa* L.) were collected during May 2021 from the local field (Gandiol, Sakanal, Dayo, Orient F1, Bellani, White Grano, Rouge d'Amposta, Violet de Galmi) in Thiès (Senegal) and the imported variety was bought at the Dakar market. These varieties have been selected according to their availability and use. After washing with tap water, the samples were peeled and diced and then stored at 4˚C in jars (**Figure 1**) for analysis.

2.2. Physicochemical and Biochemical Analyzes

The following characteristics: titratable acidity, pH, soluble solids content, reducing and total sugars, proteins, lipids, ash content, and energetic value were determined according to the AFNOR standard methods [9]. The energy value is expressed in kilogram of calories per hundred grams of dry matter.

2.3. Determination of Total Phenolic Content

The total phenolic content (TPC) of the sample was estimated by the Folin-Ciocalteu reagent colorimetric method as described elsewhere slightly modified [10]. 50 µL of the extract was diluted to 450 µL with distilled water and standard was added to 2500 µL of ten times diluted Folin-Ciocalteu reagent. Then, after adding 2.5 mL of 0.75% sodium carbonate, (all from Sigma-Aldrich Chemie, Germany), the mixtures were vortexed and incubated at 50˚C in a water bath for 15 minutes. The samples prepared above were kept in the dark at room temperature for 30 minutes. The absorbance of each sample was read at 760 nm against the blank. Gallic acid was used to calibrate a standard curve. TPC was determined as gallic acid equivalents (GAE) and values were expressed as mg GAE/g dry matter (DM) of extract.

2.4. Mineral Analysis

The determination of minerals (K, Ca, Mg, Na, Cu, Zn, Fe) was carried out by atomic absorption spectrophotometer (SAA NOVAA-350, ZEENIT 700P). The results are expressed in milligrams per gram of dry matter.

2.5. Statistical Analysis

The analysis of variance (ANOVA) tests on each factor were carried out with the STATISTICA 7.1 software. The objective was to compare the significance of

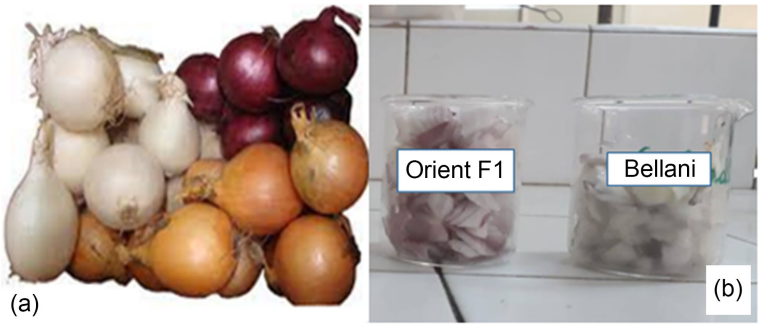

Figure 1. *Allium cepa* L.: Some varieties of onion (a); onion cut in jars (b).

samples analytical results for each parameter. Statistical differences with a probability value less than 0.05 ($P < 0.05$) were considered as significant.

3. Results and Discussion

3.1. Physicochemical Characterisation

The physicochemical and biochemical characteristics of different onion varieties are presented in **Table 1**.

The results show that the titratable acidity varies from 0.278% ± 0.002% for Rouge Amposta (Ra) variety to 0.558% ± 0.001% for Gandiol (Ga) variety. However, the imported variety has a higher acidity (0.520% ± 0.001%) than the local varieties with the exception of the Gandiol variety (0.558% ± 0.001%). Titratable acidity tells us about the amount of organic acids present in the sample [11]. However, the acidity levels obtained are similar to that reported by Kandoliya and al on an Algerian variety with an acidity of 0.37% ± 0.067% [12]. Local varieties have a pH ranging from 6.35 ± 0.003 to 6.42 ± 0.004, while the variety has a pH of 6.36 ± 0.003. Thus, the more or less significant difference in acidity, between varieties, may be due to climatic conditions and the process of plant maturation [13]. The results of analyzes of the dry matter content of the different onion varieties are shown in **Table 1** below. The experimental results showed that the varieties of onion bulbs have more or less high dry matter content with a minimum content of 7.945% ± 0.021% for the Bellani variety and a maximum content of 11.945% ± 0.007% for the bulbs of the onion of the Orient F1 variety. Regarding the imported variety, we notice that the dry matter content of the local varieties is higher than this (10.035% ± 0.021%) except of the Gandiol and Bellani varieties. Some studies have shown that the dry matter content varies from 12% to 13% and can go up to 14.40% [14]. Thus, there is a positive correlation between the storability of the onion and the dry matter content of the bulbs [15]. Indeed, a variety that contains a high dry matter content is a variety whose bulbs keep better. This suggests that the Orient F1 variety is the one that keeps the longest compared to other varieties, especially the imported variety. Onions rich in the dry matter are firmer, and therefore more resistant to lesions caused by transport and handling [16]. These lesions are entry points for parasites or micro-organisms whose actions lead to the rotting of the bulbs. Varieties

Table 1. Physicochemical characteristics of different varieties of *Allium cepa* L.

Parameter	*Ga*	*Sa*	*Da*	*Or*	*Be*	*Wg*	*Ra*	*Vg*	*Iv*
Acidity (%)	0.558 ± 0.001[a]	0.471 ± 0.001[b]	0.336 ± 0.001[c]	0.302 ± 0.002[d]	0.457 ± 0.003[e]	0.297 ± 0.003[f]	0.278 ± 0.002[g]	0.317 ± 0.000[h]	0.520 ± 0.001[i]
pH at 10%	6.35 ± 0.002[a]	6.37 ± 0.003[b]	6.39 ± 0.002[c]	6.40 ± 0.002[d]	6.38 ± 0.003[e]	6.42 ± 0.004[f]	6.41 ± 0.001[g]	6.39 ± 0.001[h]	6.36 ± 0.003[i]
Ashes (%)	5.815 ± 0.021[a]	4.800 ± 0.014[b]	5.065 ± 0.007[c]	4.788 ± 0.004[d]	4.956 ± 0.050[e]	8.253 ± 0.003[f]	5.705 ± 0.007[g]	7.758 ± 0.004[h]	5.175 ± 0.007[i]
Dry Matter (%)	9.08 ±0.014[a]	11.44 ±0.014[a]	11.620 ±0.010[a]	11.945 ±0.007[a]	7.945 ±0.021[a]	10.225 ±0.064[a]	11.615 ±0.007[a]	10.705 ±0.021[a]	10.035 ±0.021[a]

On the same line, the means bearing the same letter are not significantly different at the 5% level. *Gandiol*: *Ga*; *Sakanal*: *Sa*; *Dayo*: *Da*; *Orient F*1: *Or*; *Bellani*: *Be*; *White Grano*: *Wg*; *Rouge d'Amposta*: *Ra*; *Violet de Galmi*: *Vg*; *Imported variety*: *Iv*; *Energetic value*: *Ener*. *Value*.

with a high dry matter content can therefore be considered as varieties with long-term storage potential. The results show that the ash contents vary significantly for the nine varieties studied ranging from 4.788% ± 0.004% to 8.253% ± 0.003%. In all varieties, White Grano (8.253% ± 0.003%) and Violet Galmi (7.758% ± 0.004%) show the highest ash content. However, the imported variety has a higher acidity (0.520% ± 0.001%) than the local varieties, with the exception of the Gandiol variety (0.558% ± 0.001%). So these are a good source of minerals.

3.2. Biochemical Characteristics and Energetic Value

The protein contents in the cultivars analyzed are higher with the variety Gandiol (15.634 ± 0.001 g·100 g^{-1}), orient F1 (11.253 ± 0.004 g·100 g^{-1}) and that of Dayo (9.986 ± 0.001 g·100 g^{-1}). These are much higher than the content of 5.649 ± 0.002 g·100 g^{-1} obtained with the imported variety. However, the other local varieties studied (Violet Galmi, *Sakanal*, *Bellani*, *White Grano*, *Rouge Amposta*) have lower protein contents than the imported variety (**Table 2**).

On the same line, the means bearing the same letter are not significantly different at the 5% level.

Thus, these values are similar to those of Nigerian white and red *Allium cepa* varieties [17]. Thus, Gandiol and orient varieties with higher protein content can contribute to the formation of hormones that control various bodily functions such as growth, repair and maintenance of body tissues by providing necessary amino acids [18]. Sugars, biochemically important constituents, are responsible for the flavor of foods [19]. According to **Table 2**, the sugar contents of the nine varieties studied are more or less low. They vary by 4.691 ± 0.001 g·100 g^{-1} for the Sakanal variety to 13.402 ± 0.003 g·100 g^{-1} for the Orient F1 variety. Similarly, there is a total sugar content of 8.565 ± 0.002 g·100 g^{-1} for the imported variety. Among the local varieties, Gandiol, Violet Galmi, Dayo and Orient F1 varieties stand out with higher sugar content compared to the imported variety. Thus these differences can be due to the variety, the geographical origin and the storage conditions according to [20]. Many researchers claim that sugars vary with climate and stage of ripening [21]. The sugar content of plants is a complex

Table 2. Content of protein, reducing sugars, lipids and energy value of *Allium cepa* L.

Parameters	*Ga*	*Sa*	*Da*	*Or*	*Be*	*Wg*	*Ra*	*Vg*	*Iv*
Lipids (g/100 g)	0.006 ± 0.001[a]	0.011 ± 0.001[b]	0.050 ± 0.057[c]	0.044 ± 0.050[d]	0.011 ± 0.010[b]	0.006 ± 0.000[a]	0.011 ± 0.001[b]	0.044 ± 0.050[d]	0.011 ± 0.010[b]
Total sugar (g/100 g)	12.596 ± 0.002[a]	4.691 ± 0.001[b]	7.560 ± 0.001[c]	13.402 ± 0.003[d]	5.195 ± 0.001[e]	6.034 ± 0.001[f]	8.365 ± 0.001[g]	8.585 ± 0.007[h]	8.565 ± 0.002[i]
Proteins (g/100 g)	15.634 ± 0.001[a]	4.455 ± 0.001[b]	9.986 ± 0.001[c]	11.253 ± 0.004[d]	4.084 ± 0.002[e]	2.815 ± 0.000[f]	5.335 ± 0.001[g]	3.781 ± 0.001[h]	5.649 ± 0.002[i]
Ener. Value *(kcal/100 g)*	112.98 ± 0.003[a]	36.673 ± 0.006[b]	70.266 ± 0.001[c]	98.686 ± 0.002[d]	37.2 ± 0.012[e]	35.451 ± 0.001[f]	54.884 ± 0.001[g]	50.72 ± 0.014[h]	56.953 ± 0.001[i]

strongly influenced by the environment [22]. In addition, other factors such as harvest date, handling, techniques and storage conditions can also alter the sugar profile of plants [23]. Indeed, carbohydrates are also required in many biochemical reactions and can serve as substrates for the production of aromatic amino acid and phenolic compounds through the shikimic acid pathway, which may confer them high antioxidant potentials [24]. Lipids are nutritionally important biological constituents from the caloric point of view and the supply of essential fatty acids as well as fat-soluble vitamins. Lipids are present in trace amounts in all varieties of onion. Indeed, the content varies from 0.006 ± 0.001 (Gandiol) to 0.050 ± 0.057 g·100 g^{-1} (Dayo). The Gandiol and White Grano varieties have a lipid content (0.006 ± 0.057 g·100 g^{-1}) lower than that of the imported variety (0.011 ± 0.010 g·100 g^{-1}). These results are lower than those reported by Chukwu *et al.* (0.95 g·100 g^{-1}) [25] and by Nwinuka *et al.* (2.33 g·100 g^{-1}) [26] in *Allium cepa*, which means that the local varieties are low in fat. This could be explained by edaphic conditions which are unfavorable to a good production of lipids during the cultivation of the varieties. The high water content is a factor influencing the lipid content besides the nature of the solvent and the extraction method, which could also explain the low lipid content of onions [27]. The energy value of the different onion varieties studied has an average value of approximately 62.10 kcal·100 g^{-1} of dry matter, with a minimum of 35.45 kcal·100 g^{-1} (White Grano) and a maximum of 112.98 kcal·100 g^{-1} (Gandiol). Furthermore, the comparative analysis showed that some local varieties such as Gandiol (112.98 kcal·100 g^{-1}), Dayo (70.27 kcal·100 g^{-1}) and Orient F1 (98.69 kcal·100 g^{-1}) would provide more metabolizable energy than the imported variety (56.95 kcal·100 g^{-1}). The local onion could therefore constitute a significant energy supply and participate in the diversification of the diet, nutritional balance and food security.

3.3. Total Phenolic Content

Total phenolics constituted one of the major groups of compounds acting as primary antioxidants, it was reasonable to determine their total amount in bulbs of different varieties of onion [28]. The content of phenolic compounds (mg GAE/g DM) in all extracts of onion, determined from regression equation of ca-

libration curve (y = 3.120x + 0.069, R^2 = 0.98) and expressed in gallic acid equivalents (GAE). The results showed that the total phenolic contents vary significantly between the bulbs of different variety of onion (**Figure 2**). It showed that the imported variety has a higher polyphenol content (9.973 mg GAE / g DM) than local ones with a higher content with the Bellani variety (4.535 mg GAE / g DM). The polyphenol contents in the varieties Gandiol (3.425 ± 0.006 mg EAG/g) and Violet-Galmi (2.323 ± 0.001 mg EAG/g) are higher than those obtained by Beye with contents of 1.620 ± 0.002 and 1.110 ± 0.004 mg EAG/g respectively [29]. This disparity of polyphenols in organs of the same plant was a phenomenon reported by several authors, on several Saharan medicinal plants [30].

3.4. Minerals

The results of the mineral content of the nine varieties of onion are represented in **Table 3**.

The values are significantly different from one variety to another. They are established in macroelement orders such as calcium, magnesium and microelements such as iron and copper. The results show that onions have a high mineral content, especially potassium regardless of variety. The potassium content of local varieties is between 502.16 ± 0.06 mg·100 g^{-1} and 582.77 ± 0.04 mg·100 g^{-1} while the imported variety has a content of 536.62 ± 1.30 mg·100 g^{-1}. They note that the local varieties have a better calcium content (249.75 ± 0.07 to 434.20 ± 0.57 mg·100 g^{-1}) and magnesium (142.15 ± 0.07 to 162.60 ± 0.42 mg·100 g^{-1}) than the imported variety (229.58 ± 0.04 mg·100 g^{-1}) except for the varieties White Grano (228.29 ± 0.01 mg·100 g^{-1}) and Rouge Amposta (117.00 ± 0.42 mg·100 g^{-1}) respectively. Calcium is an intracellular second messenger in the insulin hormonal response and its electrophysiological potentialities make it an ion of great importance [31]. As for magnesium, it is an enzyme activator; it participates in major metabolisms in the body. It elevates insulin secretion, and facilitates glucose utilization [32]. Moreover, the sodium content of the imported variety (82.59 ± 0.02 mg·100 g^{-1}) is lower than that obtained in the local varieties. Indeed, the latter have contents varying from 85.13 ± 0.04 g·100 g^{-1} (Violet Galmi) to 195.68 ± 0.04 mg·100 g^{-1} (Sakanal). However, it has the best iron content (4.09 ± 0.01 mg·100 g^{-1}) than the local varieties which have low values ranging from 1.14 ± 0.06 to 3.48 ± 0.04 mg·100 g^{-1}. The zinc content obtained is mostly higher with the local varieties (5.09 ± 0.13 mg·100 g^{-1}, Sakanal) than for the imported variety (3.22 ± 0.02 mg·100 g^{-1}). Some traces of copper were observed on the different varieties of onion. Minerals such as calcium, magnesium and copper potentiate the action of secondary metabolites. They are essential elements involved in molecular structures and many metabolic reactions. Calcium and magnesium have a structural role in the body [33]. However, deficiencies in zinc and copper lead to a functional disturbance which can be corrected by food or drug supplementation.

Table 3. Mineral content of different varieties of *Allium cepa* L.

Mineral (mg/100 g)	*Ga*	*Sa*	*Da*	*Or*	*Be*	*Wg*	*Ra*	*Vg*	*Iv*
K	532.65 ± 0.35^{a}	522.00 ± 0.28^{b}	543.60 ± 0.14^{c}	540.16 ± 0.35^{d}	502.16 ± 0.06^{e}	582.77 ± 0.04^{f}	505.21 ± 0.01^{g}	521.38 ± 0.04^{h}	536.62 ± 1.30^{i}
Mg	142.15 ± 0.07^{a}	149.60 ± 0.71^{b}	168.15 ± 1.34^{c}	162.60 ± 0.42^{d}	156.29 ± 0.02^{e}	159.39 ± 0.01^{f}	117.00 ± 0.42^{g}	163.58 ± 0.04^{h}	117.41 ± 1.00^{i}
Zn	3.39 ± 0.01^{a}	5.09 ± 0.13^{b}	2.89 ± 0.01^{c}	3.31 ± 0.01^{d}	2.12 ± 0.03^{e}	3.20 ± 0.01^{f}	3.22 ± 0.02^{g}	2.58 ± 0.03^{h}	3.22 ± 0.02^{g}
Na	171.76 ± 0.36^{a}	195.68 ± 0.04^{b}	101.77 ± 0.04^{c}	127.03 ± 0.25^{d}	106.35 ± 0.50^{e}	190.80 ± 0.14^{f}	100.48 ± 1.03^{g}	85.13 ± 0.04^{h}	82.59 ± 0.02^{i}
Ca	263.10 ± 0.28^{a}	249.75 ± 0.07^{b}	257.85 ± 0.07^{c}	294.65 ± 1.06^{d}	295.50 ± 0.71^{e}	228.29 ± 0.01^{f}	307.91 ± 0.01^{g}	434.20 ± 0.57^{h}	229.58 ± 0.04^{i}
Fe	3.76 ± 0.04^{a}	3.61 ± 0.06^{b}	1.14 ± 0.06^{c}	1.39 ± 0.01^{d}	4.84 ± 0.05^{e}	1.98 ± 0.03^{f}	1.19 ± 0.02^{g}	3.48 ± 0.04^{h}	4.09 ± 0.01^{i}
Cu	-	-	2.277 ± 0.02^{a}	-	-	-	-	1.24 ± 0.01^{b}	-

On the same line, the means bearing the same letter are not significantly different at the 5% level.

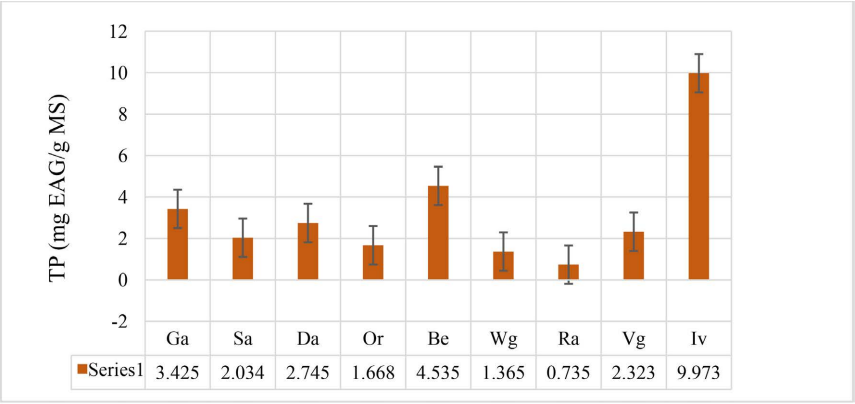

Figure 2. Total phenolic (PT) content in bulbs of different variety of onion.

4. Conclusion

The characterization of the different varieties of onion (*Allium cepa* L.) has provided scientific knowledge on the physicochemical and biochemical parameters of onion variety bulbs consumed in Senegal. The analytical result of *Allium cepa* L. varieties studied has significant quantities of macromolecules (proteins, sugars, lipids). Mineral characterization showed the presence of K, Mg, Na, Ca, Fe, Zn and Cu with a very high content of potassium (K), calcium (Ca) and magnesium (Mg). These results can be exploited and complemented in scientific research in the field of phytochemistry and biochemistry. It seems necessary to us to continue the investigations in the direction of the transformation of this product for a better conservation in order to boost the onion sector in Senegal.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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