



Assessment of Nutritional Properties from Six Varieties of Onion (*Allium cepa* L., *Alliaceae*) Produced in Northern Côte d'Ivoire

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Authors' contributions

This work was carried out from collaboration between all authors. Author KNY designed the study, performed the statistical analysis, and fitted the first draft of the manuscript. Author SK performed the laboratory analyses, managed the literature searches and wrote the protocol supervised by author CM. Authors KEBZ and YSDM expertised the study design and assisted the results interpretations. Author DN supported the results recovery from Lab analyses and supervised the full study with author BGHM. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2021/v43i1130769

Editor(s):

(1) Dr. Rusu Teodor, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.

Reviewers:

(1) Djilani Ghemam Amara, University El Oued, Algeria.

(2) Maha Ali Abdul-Ameer, Al-Qadisiyah university, Iraq.

Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here:

<https://www.sdiarticle5.com/review-history/78217>

Original Research Article

Received 06 October 2021

Accepted 13 December 2021

Published 14 December 2021

ABSTRACT

Aims: Onion is a common vegetable engaging significant nutritional interests and widely consumed over the world. In Côte d'Ivoire, 95% of the onion consumption is filled by imports despite the availability of suitable areas for its local production. The current study aimed to investigate nutritional features of onion varieties for fitting the agronomical trends in order to strengthen the onion cultivation in northern Côte d'Ivoire.

Study Design: Six onion varieties produced for bulbs, namely ARES, BATI, CARA, DAMANI, KARIBOU, and SAFARI. Onion bulbs sampled, oven-dried, and then processed to powders for

analysis. The main study consisted in analyzing the biochemical properties of the resulted onions powders.

Place and Duration of Study: Experimental farming from the plants experimenting location, and onion samples analyzed from Laboratory of Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire, between March 2020 and April 2021.

Methodology: Batches of 2 kg fresh bulbs collected per onion variety after harvest. Once at Lab, onion bulbs peeled, washed, cut into small dice-shaped pieces and dried into an oven at 80 °C for 24 h using stainless trays. Dried samples ground and kept for analyses regarding physicochemical traits (moisture, acidity, ash) and nutritive parameters (glucides, lipids, proteins, antioxidants).

Results: The works showed higher contents in moisture (16.91%), ash (4.46%), and lipids (1.99%) from CARA variety with more significant acidity; while greatest amounts of total soluble carbohydrates (14.5%), tannins (1.02%), and proteins (13.6%) were recorded from BATI and more vitamin C in DAMANI (0.133%). However, SAFARI variety samples were more provided in reducing carbohydrates (1.04%) and total polyphenols (1.46%) as secondary metabolites; and the ARES variety revealed highest flavonoids contents (0.057%). In addition, ARES, CARA, and KARIBOU varieties displayed great dietary fibers amounts compared to BATI, KARIBOU, and SAFARI.

Conclusion: The particular nutritional traits of the studied onion varieties could be confronted with their agronomical yield and consumption trends for supporting sustainable production of onion in Côte d'Ivoire.

Keywords: Onion variety; local production; nutritional features; Northern Côte d'Ivoire.

1. INTRODUCTION

Onion (*Allium cepa* L., Alliaceae) is a vegetable crop produced for human consumption over the world and which main uses are about the bulbs as most value-added part. Originating from Central Asia, the most cultivated onions plants species are of the genus *Allium* [1]. The onion bulb is used as an ingredient for flavor and aroma in various food recipes. Onions are among the most consumed vegetables worldwide, especially the fourth most consumed vegetable behind tomatoes, cabbage, and watermelon [2].

Onion is cultivated in various agro-climate areas over the world with a global yield around 100 million tons in 2019, accounting over 66 million tons produced from Asia. In Western Africa, the major onion producing countries are Niger and Nigeria (over 1.3 million tons) and Senegal (445 000 tons) according to FAOSTAT [3].

Onions account significant food, nutritional and therapeutic interests for consumers [4], since they are important source of numerous phytonutrients. From most cultivars, fresh onion bulbs contain about 89% water, 9% carbohydrates with 4% soluble sugars and 2% dietary fibers, 1% proteins, and are fatless [5]. Onion is a significant source of vitamins, namely vitamins B and C, and is provided in polyphenols and bioactive compounds such as flavonoids, and other organosulfur compounds ensuring

potential health benefits [6]. In addition, onion are known to exhibiting antimicrobial and pharmacological properties [7] deriving from the polyphenol compounds, vitamins and minerals nutrients [8].

Onion is of important interests for global agriculture and is mainly cultivated in tropical Africa [9]. So, the onion economy is one of the most sustainable agricultural values chain in African countries, especially in Western Africa where agriculture contributes at 35% gross domestic product (GDP) and is concerned by 60% active population [10]. Nevertheless, in Côte d'Ivoire, the onion cultivation is practiced in lower areas, and the country yearly records no more about 4,500 tons of onion bulbs, against a global demand over 115,000 tons [11]. For fitting such onion demand, large onion volumes are usually imported by Côte d'Ivoire, so that the country has become the top onion importing country in Western Africa for years. Thus, 95% of Ivorian onion consumption is provided by external supply [12]. Consequently, about 75 million dollars were committed for onion imports between 2015 and 2016 [13].

The onion cultivation is still fairly worked in Côte d'Ivoire although the country possesses wide areas with favorable climate for this crop, especially in northern country. For improving the local sustainable production of onion, the main varieties spread over the world need to be assessed about their environmental and

agronomic adaptation and dietary potentials. The current study is an investigation of the nutritional profile of six onion varieties in order to fit quite valorization and strengthen the local onion production in Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Crops

Biological material consisted of onion bulbs grown from experimental farming designed in the plants experimenting location of Peleforo GON COULIBALY University, Korhogo, northern Côte d'Ivoire.

Analyses were performed from six (6) onion varieties, namely BATI, CARA, DAMANI, KARIBOU, and SAFARI varieties produced during dry season, and ARES variety produced in rainy season. Batches of 2 kg fresh bulbs were collected per onion variety after harvest and then sent to the laboratory for analysis. The analyses were carried out using the onion powder processed from the fresh bulbs collected.

2.2 Methods

2.2.1 Onion powders production

Using a stainless knife, onion bulbs were peeled in order to remove any residues and non-consumable parts. The peeled onion bulbs were thus washed in running water and then wrung out. The layers of bulbs were separated and cut into small dice-shaped pieces before being placed in stainless trays and placed into an oven (Memmert, Germany) for drying at 80 °C for 24 h. The dried onions samples were then ground using an electric grinder (Blender). Finally, the resulted samples of onion powders were recovered into plastic hermetic box and kept in dried place till analysis.

2.2.2 Determination of the biochemical properties of onion powders

2.2.2.1 Assessment of moisture, acid value, and ash contents

Standard AOAC methods were used for the assessment of moisture, pH, titratable acidity, and ash contents of the onions studied [14].

The moisture content of onion powder was determined using gravimetric tries from 5 g (w1) powder dried at 105 °C in an oven (Memmert) for

constant weight (W2) checked upon a two-digit scale. Moisture content (MoiC) was deduced by the following relation:

$$\text{MoiC (\%)} = (W1 - W2) * 100 / W1$$

The pH value and titratable acidity from were recovered from 10 % (w/v) aqueous onion powder solution. Thus, 10 g onion powder were homogenized in 100 mL of distilled water using a magnetic agitator (Heidolph) for 20 min. The resulting mixture was filtered and the filtrate analyzed for acidity parameters. The pH value was read out using a standard pH-meter (Hanna Instruments, HI 8010). The titratable acidity was measured by titration of 10 mL onion filtrate added with 3 drops of phenolphthalein, using 0.1 N sodium hydroxide solution (NaOH) until persistent pink coloration. The acidity was calculated according to the following expression:

$$\text{TTA (mEq H}^+ / 100\text{g)} = (0.1 * V_{\text{eq}} * 10^5) / 10 W$$

With TTA: total titratable acidity; 0.1: normality of NaOH solution; V_{eq} : volume of NaOH used for onion filtrate coloration (mL), 10^5 : conversion factor; 10: volume of the onion filtrate sample (mL); w: weight of the onion filtrate sample (g).

For ash content determination, 2 g onion powder were submitted to 12 h incineration into a muffle furnace (Heraeus) at 550 °C. The incinerated residue was therefore removed from the furnace, cooled in a desiccator, weighed upon a 3 digit-scale, and the ash content calculate using the relation below:

$$\text{AshC (\%)} = (W_A * 100) / W_p$$

With AC: ash content (%); W_A : weight of ash (g); W_p : weight of onion powder incinerated (2 g)

2.2.2.2 Determination of crude fiber and protein contents

Crude fiber and protein contents were also measured using standard methods form AOAC [14]. The crude fiber content was assessed from 2 g onion powder treated with 50 mL sulfuric acid (H_2SO_4 0.25N) and 50 mL sodium hydroxide (NaOH 0.31N) with intermittent boiling for 30 min under refrigerant. The full extract was filtered upon Whatman paper and the resulted residue was washed with hot water till complete removal of the alkalis. Then, the final residue was dried in an oven at 105 °C for 8 h, cooled in a desiccator and then weighed. The crude fiber content was obtained according to the following expression:

$$\text{FibC (\%)} = (W1 * 100) / W$$

With FibC: crude fiber content (%); W1: weight of dry residue; W: weight of onion powder sample. Protein rate in onion powders was assessed using Kjeldhal technique, following stages of mineralization, distillation and titration. Mineralization was performed by boiling a mixture of 350 mg onion powder, 1 mg of catalyst (consisted of K₂SO₄, CuSO₄ and Se), and 3 mL concentrated sulfuric acid for 1 h 30 min at 400 °C. Afterward, 30 mL NaOH (10 N) were added and the mixture was distilled. The resulted distillate was then collected in a beaker with 5 mL boric acid and color indicator consisted of methyl red-bromocresol green reagents. The final mixture was measured using sulfuric acid solution (0.01 N) till orange coloration against a blank test, and the total protein content calculated.

$$\text{ProC (\%)} = (V1-V0) * 14 * 6.25 * N / W$$

With Pro: protein content (%); V0: volume (mL) of sulfuric acid used for the blank test; V1: volume (mL) of sulfuric acid used for sample test; N: normality of sulfuric acid (0.1N); m: weight (g) of sample powder; 14: atomic mass of nitrogen; 6.25: conversion coefficient of nitrogen to proteins.

2.2.2.3 Determination of lipid content

Lipids were extracted from 30 g onion powder using Soxhlet device and hexane as extraction solvent [15]. The extraction was processed by boiling the solvent for 7h at 70 °C, and the final extracted oil-hexane mixture was separated using a rotavapor device (Heidolph). As such, the hexane solution was recovered and the oil was cleared from hexane residue by oven drying at 100 °C for 20 min. The final oil was weighed for the lipid content:

$$\text{LipC (\%)} = (W1-W0) * 100 / W$$

With LIP: lipid content (%); W0: weight of the empty flask (g); W1: weight of the flask + lipids; W: weight of the onion sample (g)

2.2.2.4 Total soluble carbohydrates and reducing carbohydrates

The main soluble glucides were extracted by diluting one 1 g onion powder into a composite solution of 10 mL ethanol at 80% (v/v), 1 mL zinc acetate at 10% (m/v), and 1 mL oxalic acid at

10% (m/v) according to the method described by Martinez-Herrera et al. [16]. The mixture was homogenized and centrifuged for 30 min at 3000 rpm using a LACTER model centrifuge. The resulting supernatant was collected and the residue treated as above. All supernatants were gathered and used for the determination of total soluble and reducing carbohydrates contents. Total soluble glucides were measured out with phenol and sulfuric acid reagents [17]. A volume of 0.1 mL of ethanosoluble extract was put into a test tube and added with 0.9 mL of distilled water, 1 mL of 5% phenol solution (w/v), and 5 mL of 96% sulfuric acid solution. Then the absorbance was measured at 490 nm with a spectrophotometer (PG instruments, England). For the reducing sugars, 1 mL of ethanosoluble extract was processed with 0.5 mL distilled water and 0.5 mL of 3, 5- dinitrosalicylic acid [18]. This solution was then boiled in a hot bath for 5 min and the absorbance finally measured at 540 nm using PG instruments spectrophotometer. Both total soluble and reducing carbohydrates were measured against control test tubes without any ethanosoluble extract. Calibrations were performed with standard solutions of glucose and sucrose.

2.2.2.5 Assessment of antioxidant nutrients

Phenolic compounds were extracted according to the method of Singleton et al. [19] from 1 g onion powder sample homogenized in 10 mL methanol (70%, v/v). The solution was centrifuged at 1000 rpm for 30 min using LACTER centrifuge. The supernatant was collected and the residue treated with 10 mL methanol (70%) for other centrifugation. All supernatants were gathered and adjusted to 50 mL added with distilled water.

The total polyphenols content was measured using folin- ciocalteu reagent [19]. From 1 mL phenolic extracts taken into test tubes, respective solutions of 1 mL folin- ciocalteu reagent, 1 mL sodium carbonate at 20% (w/v) and 7 mL distilled water were added. These assays were kept at darkness for 30 min and the absorbance was measured at 725 nm from PG- instruments spectrophotometer against a control solution without phenolic extract. Total polyphenols content was recovered using calibration processed from gallic acid.

Flavonoid phenols were quantified according to Meda et al. [20]. To 0.5 mL phenolic extract, were respectively added 0.5 mL distilled water, 0.5 mL aluminum chloride solution (10%, w/v),

0.5 mL sodium acetate and 2 mL distilled water. Then, the absorbance was measured from PG-Instruments spectrophotometer at 415 nm against a control test tube without phenolic extract. Quercetin solution calibrated as standard flavonoid led to the recovery of the flavonoids contents from the onion samples.

The tannins content was determined with the method proposed by Bainbridge et al. [21]. Onion phenolic extract (1 mL) was added with 5 mL sulfuric- vanillin solution (vanillin in 70% sulfuric acid) into test tubes. The mixtures were kept at darkness for 20 min and the absorbance was measured at 500 nm from PG- Instruments spectrophotometer against a control tube without phenolic extract. Standard tannic acid solution was calibrated for the determination of tannins contents from onion samples.

Vitamin C was also assessed as antioxidant vitamin according to the method described by Pongracz et al. [22]. Two grams (2 g) of onion powder were dissolved in 50 mL of 20% metaphosphoric acid-acetic acid mixture. After filtration, 10 mL of the filtrate were titrated with a solution of 2, 6- dichlorophenol- indophenol (2.6 DCPIP) at 0.5 g/L for persistent pink coloration, and the final content of vitamin C was calculated.

$$\text{Vit C (mg/100g)} = (C_{\text{DCPIP}} * V_{\text{eq}} * 5 * 100) / W$$

With Vit C: Vitamin C content (mg/100 g); C_{DCPIP} : concentration of DCPIP solution (0.5 g/L); V_{eq} : volume (mL) of 2.6 DCPIP used for titration; W : weight (g) of onion powder sample

2.3 Statistical Analysis

With all assays achieved in triplicate, the collected data were statistically analyzed using Statistical Package for Social Sciences (SPSS 22.0, USA) and STATISTICA (7.1, France) softwares at 5% significance. The statistical treatment consisted first in descriptive calculation of means and standard deviations per biochemical trait and onion variety. Then, a one-way analysis of variance (ANOVA-1) was performed considering onion variety as the sole source of variation, followed by means comparison using Student Newman Keuls (SNK) post-hoc test. Finally, multivariate analysis (Principal Component Analysis and Ascending Hierarchical Clustering) was achieved to check the correlation between biochemical parameters and the overall onion varieties studied.

3. RESULTS AND DISCUSSION

Statistical analysis shows a significant difference ($P < 0.05$) between onion varieties for overall characteristics determined.

3.1 Moisture, Ash Content and Acidity of Onion Powders

Table 1 displays physicochemical parameters of onion powders. The results show more moisture from CARA onion (16.91%), while SAFARI onion powder records least moisture content (11.58%). The highest ash content is also recovered from CARA onion (4.46%) followed by DAMANI (3.95%) and ARES (3.85%). Overall onion varieties present acid pH close to 4. But the highest titratable acidity value is obtained from CARA (358.34 mEq $H^+/5$ g Onion Powder) and the weakest value is recorded from ARES (250.01 mEq $H^+/5$ g OP). BATI, DAMANI, KARIBOU and SAFARI varieties exhibit statistically similar titratable acidity between 308 and 325 mEq $H^+/5$ g OP.

3.2 Macronutrients in Onion Powders

The main macronutrients in onion powders are recorded in Table 2. From crude fiber content, top values derive from ARES, CARA, and KARIBOU (over 10.4%), when BATI, DAMANI and SAFARI provide only around 8% fiber.

CARA variety displays a preponderant lipid content (1.99%) compared to the other varieties. On the other hand, the onion powders of BATI, KARIBOU and SAFARI varieties record lower lipid contents below 1%.

Regarding glucides, the total soluble carbohydrates contents are highly concentrated from BATI variety (14.5%) while SAFARI is more provided in reducing carbohydrates (1.04%), followed by ARES (0.99%). KARIBOU and DAMANI display lower values for respective total soluble and reducing carbohydrates. As such, the reducing sugars represent 3.90% to 9.29% total carbohydrates in onion powders.

Table 2 also shows significant protein contents from the studied onion varieties (10.6% to 13.6%), except from ARES variety which contains only 6.7% protein.

3.3 Antioxidant Compounds of Onion Powders

Table 3 shows the contents of antioxidant compounds, namely vitamin C and phenolic compounds of onion powders. KARIBOU, CARA, DAMANI and SAFARI record more significant vitamin C contents (116.67 to 133.33 mg/100 g) compared to BATI (104.17 mg/100 g) and ARES (87.5 mg/100 g). About phenolic derivatives, values of total polyphenols are more consistent

from SAFARI (1456.59 mg/100 g) followed by ARES (1227.96 mg/100 g), whereas CARA displays lower content of 604.3 mg/100 g. Tannins are the most represented polyphenols molecular group, with a rate over 60% of the polyphenols. BATI, DAMANI and KARIBOU onions show more tannins contents (about 1000 mg/100 g). Oppositely, flavonoids constitute 2.6% of the polyphenols and ARES and CARA reveal greater flavonoids contents (57.44 and 45.33 mg/100 g).

Table 1. Physicochemical characteristics of onion powders

Varieties	MoiC (%)	AshC (%)	pH	TTA (mEq H ⁺ / 5 g OP)
ARES	13.61 ± 0.03 ^c	3.85 ± 0.05 ^b	4.29 ± 0.01 ^b	250.01 ± 0.00 ^c
BATI	15.58 ± 0.40 ^b	3.56 ± 0.05 ^{bc}	4.31 ± 0.01 ^b	325.01 ± 25.00 ^b
CARA	16.91 ± 0.00 ^a	4.46 ± 0.09 ^a	4.09 ± 0.00 ^d	358.34 ± 14.43 ^a
DAMANI	12.26 ± 0.04 ^d	3.95 ± 0.46 ^b	4.31 ± 0.01 ^b	308.34 ± 14.43 ^b
KARIBOU	13.97 ± 0.03 ^c	3.24 ± 0.24 ^c	4.18 ± 0.01 ^c	316.67 ± 28.86 ^b
SAFARI	11.58 ± 0.31 ^e	3.47 ± 0.17 ^{bc}	4.44 ± 0.00 ^a	308.34 ± 14.43 ^b
F-value	272.23	10.42	277.84	10.72
P-value	< 0.001	< 0.001	< 0.001	< 0.001

MoiC= moisture content; AshC= ash content; pH= potential hydrogen; TTA= total titrable acidity; OP= onion powder; F-value= value of statistical Fisher test; P-value= value of statistical probability. For each variable, the means ± standard deviations with different lower scripts are statistically different at 5% significance

Table 2. Biochemical characteristics of onion powders

Varieties	FibC (%)	LipC (%)	TCarbC (%)	RCarbC (%)	ProC (%)
ARES	10.43 ± 0.11 ^a	1.29 ± 0.12 ^b	13.6 ± 0.01 ^c	0.99 ± 0.00 ^b	6.7 ± 0.67 ^c
BATI	8.47 ± 0.05 ^b	0.89 ± 0.08 ^c	14.5 ± 0.10 ^a	0.76 ± 0.00 ^c	13.6 ± 1.36 ^a
CARA	10.73 ± 0.75 ^a	1.99 ± 0.2 ^a	14.21 ± 0.06 ^b	0.59 ± 0.01 ^e	11.7 ± 1.17 ^{ab}
DAMANI	8.25 ± 0.25 ^b	1.33 ± 0.13 ^b	12.55 ± 0.05 ^d	0.49 ± 0.00 ^f	10.9 ± 1.09 ^b
KARIBOU	10.5 ± 0.5 ^a	0.96 ± 0.09 ^c	9.98 ± 0.09 ^f	0.68 ± 0.00 ^d	10.6 ± 1.06 ^b
SAFARI	8.48 ± 0.02 ^b	0.94 ± 0.09 ^c	11.2 ± 0.16 ^e	1.04 ± 0.00 ^a	11 ± 1.1 ^b
F-value	28.42	31.12	1044.91	15608.87	12.79
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

FibC= fiber content; LipC= lipid content; TCarbC= total sugar content; RCarbC= reducing sugar content; ProC= protein content; F-value= value of statistical Fisher test; P-value= value of statistical probability. For each variable, the means ± standard deviations with different letters are statistically different at 5% significance

Table 3. Content of antioxidant compounds (Vitamin C and polyphenols) in onion powders

Varieties	VitC (mg/100g)	TPC (mg/100g)	TNC (mg/100g)	FLC (mg/100g)
ARES	87.5 ± 0.00 ^d	1227.96 ± 2.14 ^b	920.53 ± 9.58 ^c	57.44 ± 0.81 ^a
BATI	104.17 ± 7.21 ^c	1190.4 ± 0.68 ^d	1022.86 ± 0.82 ^a	24.67 ± 0.92 ^e
CARA	129.17 ± 7.21 ^{ab}	604.3 ± 0.73 ^f	481.32 ± 0.90 ^e	45.33 ± 0.88 ^b
DAMANI	133.33 ± 7.21 ^a	1199.02 ± 1.18 ^c	990.53 ± 0.95 ^b	32.79 ± 1.25 ^d
KARIBOU	120.83 ± 7.21 ^{ab}	1070.14 ± 1.16 ^e	997.01 ± 0.91 ^b	41.63 ± 0.95 ^c
SAFARI	116.67 ± 7.21 ^b	1456.59 ± 1.61 ^a	890.08 ± 1.62 ^d	23.99 ± 0.73 ^e
F-value	20.00	132589.63	7625.89	570.29
P-value	< 0.001	< 0.001	< 0.001	< 0.001

VitC= vitamin C content; TPC= total polyphenols content; TNC= tannins content; FLC= flavonoids content; F-value= value of statistical Fisher test; P-value= value of statistical probability. For each variable, the means ± standard deviations (SD) with different letters are statistically different at 5% significance

3.4 Multivariate Characteristics of Onion Powders

The overall parameters assessed are significantly shared around four (4) factors (F1 to F4), from the Principal Components Analysis (PCA), engaging eigenvalues superior to 1 and supporting 89.35% total variance and therefore used to describe the PCA. Among these factors, both F1 and F2 factors assuming 69% total variance are used for the PCA draw.

Fig. 1 shows correlations between F1-F2 factorial design and the variables and onion samples. It appears that the onion samples from SAFARI variety are located in the negative part of the F1 factor and are more correlated to pH value and contents of total polyphenols, tannins and reducing sugars for which they present greatest values. Onions samples of BATI and DAMANI varieties are located from the negative part of F2 factor and have the highest levels of protein, vitamin C and titratable acidity. The onion samples of CARA variety are negatively correlated with F1 factor and the moisture, ash and lipid contents. As for ARES variety, higher levels of crude fibers and flavonoids are rated, with strong positive correlation to the F2 factor.

As from PCA, the ascending hierarchical clustering (AHC) assembles the onion samples into five (05) groups at the aggregation distance of 60 (Fig. 2). Group 1 consists of ARES variety, while group 2 gathers BATI and DAMANI varieties. Groups 3, 4 and 5 include respective KARIBOU, SAFARI, and CARA onion varieties. Thus, the PCA and AHC display similar variability trend: pH, polyphenols, tannins and reducing carbohydrates are in higher amount from SAFARI onion variety; vitamin C, protein and titratable acidity record more significant content in BATI and DAMANI onion varieties; greater moisture, ash and fat are found in CARA onion; while higher crude fiber and flavonoid contents are provided from ARES variety.

4. DISCUSSION

The results of the biochemical analysis show higher nutrients concentrations from the onion powders compared to fresh onion bulbs, since the drying processing facilitates dehydration from the raw product [23].

The significant difference of the residual moisture from onion varieties was recorded, suggesting an unequal water absorption capacity depending on

the variety [24]. Moisture is a quite trait of significant involvement on crops preservation. Thus, the lower moisture content in foods, the better preservation is succeeded for long. Indeed, high moisture above 15% promotes microbial development in crops stocks using nutrients compounds [25]. Based on our results, the SAFARI onion powder displaying 11.58% moisture could therefore be kept for nutrients than that of CARA onion (16.91%).

Determination of ash content is part of the proximate analysis for nutritional assessment because ash is the representative residue of the total minerals in foods [26] after destruction of the organic compounds. As such, the variation in mineral presence could reflect a variation in the hydro-mineral absorption from the onion varieties studied since they are grown on the same soil. The ash contents obtained (from 3.24 to 4.46%) are comparable to those reported by Yahaya et al. [27]. The significant presence of mineral nutrient supports the nutritional value of onion for human diet.

The crude fiber contents recorded are lower compared to the results (close to 14%) reported by Yahaya et al. [27]. Nevertheless, the onion samples deriving from ARES and at a lesser extent CARA and KARIBOU varieties provide significant fiber amounts. These onions could be valued in the diet for protection against digestive concerns. In fact, adequate intake of dietary fiber ensures protection against colon cancer and also supports maintenance of lipidemia in normal range reducing physiological hazards of obesity, hypertension, and cardiovascular diseases [28].

The results reveal general divergence between varieties of onions for nutrients. According to Shewfelt [29], the main sources of variation in plant products are genes, pre-harvest conditions, stage of maturity for harvest, harvesting methods, postharvest handling, and storage conditions.

From lipids content, a greater rate was measured from CARA variety (1.99%). However, the values resulting from the current work are lower than those reported by Konaté et al. [30]. Plants food lipids provides energy benefit and functional role through their liposoluble vitamins [31].

Along with ethanosoluble glucides, the results showed general contents over 10%. However, as any other vegetable, onions are not considered

Table 4. Eigen- values and variability expressed supported by the first six components of the principal component analysis (PCA) achieved for the onions varieties parameters studied

PCA Factors	F1	F2	F3	F4	F5	F6
Eigen-values	5.92	3.05	1.52	1.12	0.74	0.39
Variability (%)	45.54	23.45	11.72	8.63	5.67	2.99
Cumulative variability (%)	45.54	69.00	80.71	89.35	95.01	98.00

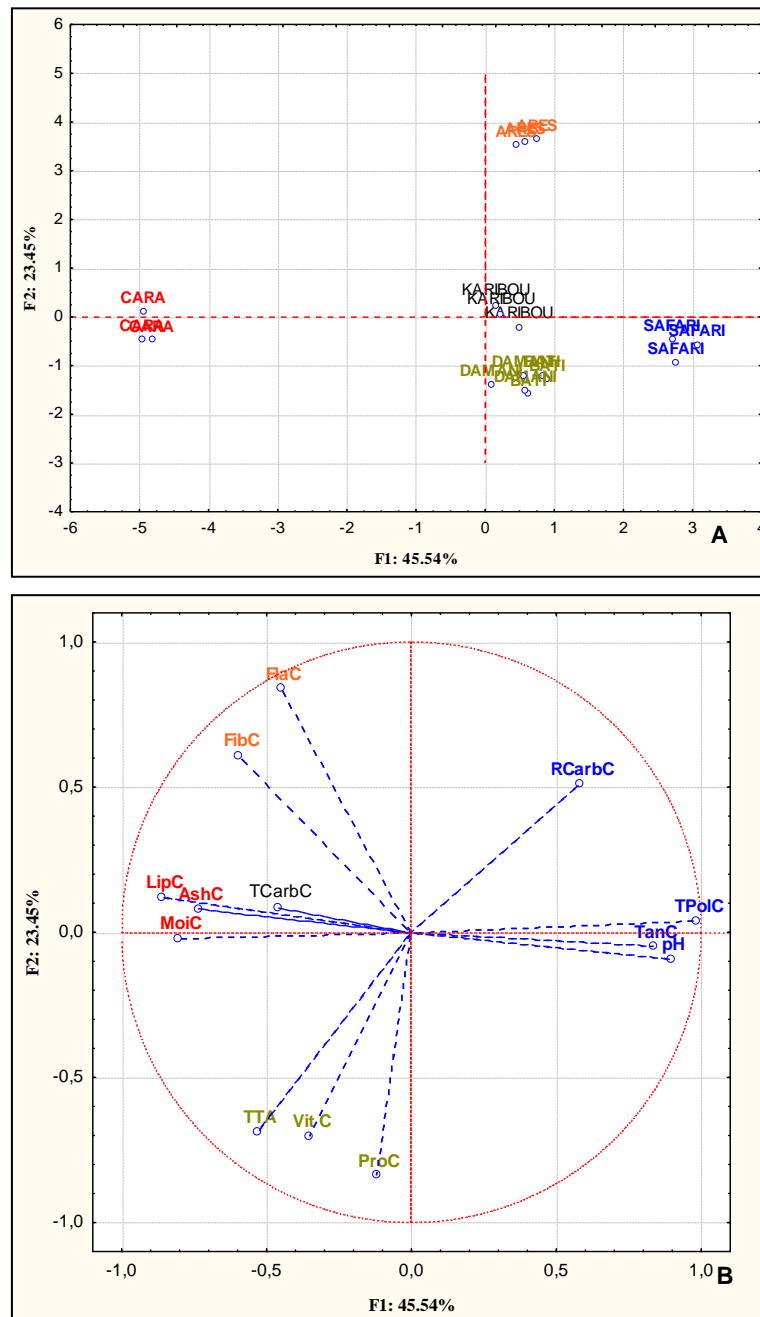


Fig. 1. Correlation between the F1-F2 factorial design and the studied onion samples (A) and their characteristics (B) drawn from the principal component analysis

MoiC= moisture content; AshC= ash content; FibC= crude fiber content; pH= potential of hydrogen; TTA= total titrable acidity; LipC= lipid content; TCarbC= total soluble carbohydrates content; RCarbC= reducing carbohydrates content; ProC= protein content; VitC= vitamin C content; TPoIC= total polyphenols content; TanC= tannins content; FlaC= flavonoids content

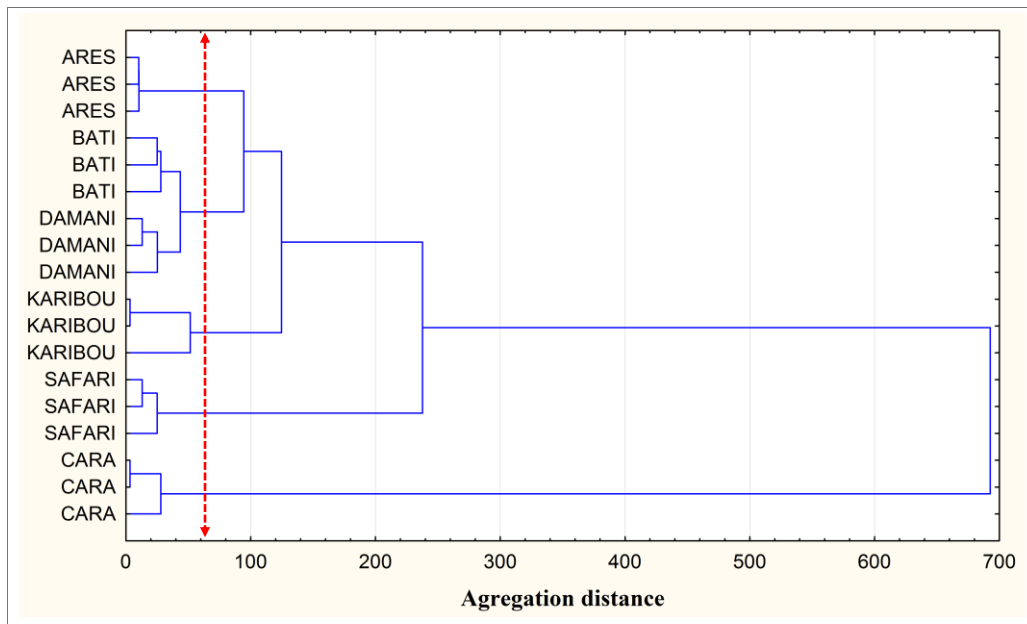


Fig. 2. Diagram of ascending hierarchical clustering drawn from the unweighted pair group methods with arithmetic means (UPGMA) deriving from powders samples of onion varieties according to their studied characteristics

as carbohydrates foods thought they could contribute for caloric intake when combined with common starchy products as potato and other tubers [32].

The variation in the protein content recorded from the work could be related to the intrinsic physiology of each onion variety involving protein metabolism. In fact, plants are known to be different in their ability to use the same amount of soil nutrients (e.g. nitrogen) even cultivated under similar agro-conditions [33]. Onion varieties with great protein contents could meet successful biological functions such as growth and maintenance for consumers [34].

Antioxidant compounds also differed significantly from the onion samples. The plant variety and the main cultivation stress sources as soil nutritive richness, season of production and other bio-agents faced are scientifically known to induce production of secondary metabolites as polyphenols in plants [35]. Regarding vitamin C, the amounts could significantly depend on the species or variety within the same plant genus [36]. The consumption of foods containing vitamin C may prove to be beneficial because vitamin C is an antioxidant which role is crucial against stress [37]. For total polyphenols content, the values resulted from the onions powders studied are highly appreciable for nutritional interest. Indeed, several studies have reported a

good correlation between the total phenols content and antioxidant activity [38]. The polyphenols support the body prevention against metabolic disorders. According to the results, tannins are the major polyphenols compounds in the onion powder. However, in the literature, flavonoids are identified as the main polyphenolic compounds in onions. The resulting low flavonoid contents of the onion powder is explained by the degradation reactions of bioactive compounds that could have been occurred during drying process [39].

5. CONCLUSION

The physicochemical and nutritive analyses of the onion powder performed using six onion varieties showed particular group of nutrients highly expressed from each variety; that can stand as basis for their optimal promotion. ARES variety has a good fiber and flavonoid content. BATI and DAMANI varieties are richer in Vitamin C and proteins. As for the CARA variety, more lipids, moisture, and ash contents are found, while SAFARI onion is rated by total polyphenols and tannins. These onion varieties could meet successful contribution in the proper functioning of the organism. Thanks to their various nutritional profile, the sustainable production of the onion varieties should also be implemented accounting other trends as agronomical values,

preservation qualities, organoleptic profile and preferences from consumers.

ACKNOWLEDGEMENTS

The authors hereby thankfully address due acknowledgments to funders of the project number KAH20200103 entitled "Enhancement of tomato and onion production in Africa for maximum sustainable yield" for ensuring sufficient grants regarding any analysis implemented throughout the document.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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