Original Research Article

Physicochemical and biochemical changes in fresh onion (*Allium cepa* L., *Alliaceae*) bulbs produced from four dry-seasonal varieties in Korhogo, northern Côte d'Ivoire

ABSTRACT

Aims: Onions are fresh vegetables whose post-harvest storage life is closely related to the variety and season of production. The study aims to investigate the effect of storage upon the nutrients in fresh onion bulbs for better management of the local onion production.
Study design: Fresh onion bulbs of four dry season varieties, namely Dayo, Safari, Red Star and Red Jewel, were produced and stored to study variations in physicochemical and biochemical properties during storage.
Place and duration of study: The study was carried out in the experimental site and laboratory of the University Peleforo GON COULIBALY for four (4) months from June to September 2022.
Methodology: Bulbs of all four varieties were bagged after production and stored in a warehouse at ambient conditions. During the storage, the physicochemical and biochemical descriptors in onion samples were assessed at 30 days intervals.
Results: The results revealed significant changes of the parameters assessed from the investigation, according to both the storage duration and onion variety ($P<0.001$). The lipid and protein contents increased from overall onion bulbs during the storage. Dayo and Safari onion bulbs recorded more significant dry matter (11.59 and 13.19g/100g FM) than the *Red* varieties (9.70 to 11.31 g/100g FM). The total polyphenols content also increased in Red Star onion bulbs from 43.86 to 53.62 mg/100g FM at day 120 but decreased from the other onion varieties. According to the Principal Components Analysis, *Red Star* and *Red Jewel* onions on days 60, 90 and 120 displayed the highest levels of phenolic compounds.
Conclusion: *Dayo* and *Safari* bulbs with greater dry matter rates during storage appear as suitable for storage. Nevertheless, the polyphenols profiles increased from the *Red Star* and *Red Jewel* onions and are also appreciable.

Keywords: onion varieties, storage, fresh bulbs, variation in compounds.

1. INTRODUCTION

Onion (*Allium cepa*) is a vegetable crop belonging to the *Alliaceae* plant family, onion is native from Central Asia [1]. The fresh onion bulbs contain about 89% water, 9% carbohydrates including 4% sugars and 2% dietary fiber, 1% protein and a slight amount of lipids [2]. It is also a significant source of vitamins C and B and phenolic compounds which ensure bioactive properties in foods [3].
Playing a major role in world agriculture, onion is produced and used all over the world for its bulbs, as the one of the most cultivated vegetables, with tomatoes and potatoes. World onion production reached 110,616,269.81 tons for upon 5,967,491 ha of grown acreages in 2022, leading to a yield of 18.54 t/ha [4]. In African, onion is mainly produced from countries with tropical climates [5]. In Côte d'Ivoire, this crop sector is under-sustained with an annual production estimated at 8,226.98 tons in 2022 [4].

Furthermore, onion bulbs are subject to post- harvest losses during storage. The losses observed can be of a quantitative nature which affects marketability and reduces bulbs quantitative yields or qualities regarding nutritional approach [6].

According to Petropoulos *et al*. [7], the quality of onion bulbs during storage is highly affected by water losses, sprouting and rooting incidents and changes in chemical composition. Also, these authors showed the influence of temperature, storage duration and genotypes on the physical, chemical and bioactive traits of onion bulbs.
In Côte d'Ivoire, few studies have been operated focusing the nutritional profile of bulbs during storage. Such data are of strategic basis for selecting and popularizing onion varieties in agriculture. This work investigates the potential postharvest variation in the physicochemical and biochemical properties of four varieties of seasonal onion produced in Korhogo.

2. MATERIAL ET METHODS

2.1 Crops material

The plant material was constituted of fresh bulbs of four onion varieties produced on the experimental site of Peleforo GON COULIBALY University, Korhogo, Côte d'Ivoire. The onion varieties assessed were *Dayo*, *Safari*, *Red Star* and *Red Jewel*.

2.2 Experimental methods

2.2.1 Packaging and storage of onion bulbs

After harvest, a batch of 10 kg bulbs per onion variety was gathered, packaged in commercial net bags and stored upon a wooden rack in an airy open room under ambient temperature and humidity. The onion bulbs were stored for a four (04) months (120 days) period from June to September 2022.

2.2.2 Sampling and onion bulb processing

An earlier sample of 800 g onion bulbs per variety was drawn before storage (D0). Then, 800 g of onion bulbs were also sampled by 30 days stages for 4 months. Thus, five (05) samples (D0, D30, D60, D90 and D120) were collected per onion variety for a total of 16 kg (800 g × 5 samples × 4 varieties) onion bulbs. The onions were dried and processed into powder following similar operations from samples. Onion bulbs were peeled using stainless steel knife, washed, drained, sliced, spread on stainless steel trays and placed into a food dehydrator (MEMMERT) at 45°C for 36 hours. Thereafter, the dried onions were grinded using a home grinder and the onion powders packaged into zip lock plastic bags before physicochemical and biochemical analyzes.

2.2.3 Determination of dry matter content and acidity

The dry matter content, pH and acid values of the onion samples were investigated using standard methods of AOAC [8]. The dry matter was analyzed from the gravimetric method using 5 g onion sample dried into an oven at 105 °C for constant weight. The dry matter content was recorded from the following formula:

$$\mathbf{DMC\ (g/100g\ FM)} = \frac{(\boldsymbol{m_2} - \boldsymbol{m_0}) \times \mathbf{100} \times \boldsymbol{r}}{\boldsymbol{m_s}}$$

With: DMC = dry matter content, m_2 = mass of the full pod with the dried onion sample, m_0 = mass of empty pod, m_s = mass of the sample and r = dry to fresh onion ratio.

Regarding acidity traits, aqueous onion powder solutions were prepared at 10% using distillated water, and then filtered for analysis. The pH value was read out with a standard pH meter. The titratable acidity was measured by titration of 10 mL onion filtrate added with 3 drops of phenolphthalein and using 0.1 N sodium hydroxide solution (NaOH) until persistent pink coloration. The acidity was calculated according to the following expression:

$$\mathbf{TAC\ (mg/100g\ FM)} = \frac{\boldsymbol{N} \times \boldsymbol{V_e} \times \mathbf{10^5} \times \boldsymbol{r}}{\boldsymbol{m} \times \boldsymbol{V}}$$

With: TAC = titratable acid content, N = normality of NaOH solution, Ve = volume (mL) of NaOH used at equivalence, r = dry to fresh onion ratio, m = mass (g) of sample, V= volume (mL) of sample.

2.2.4 Determination of onions biochemical properties

Total soluble carbohydrates and reducing carbohydrates contents

The total soluble carbohydrates were extracted referring to Martinez-Herrera *et al.* [9]. A sample of 1 g onion powder was mixed with 10 mL ethanol (80%) then the mixture was centrifuged at 3,000 rpm for 30 min. The resulting supernatant was collected, and the tube cap was treated with 2 mL zinc acetate (5%, w/v), and the total volume centrifuged at 2,000 rpm for 2 min. The final supernatant was also collected, added with 2 mL oxalic acid (10%, w/v), and centrifuged as above. Overall supernatants were then gathered and submitted to 5 min heating for ethanol evaporation. The final ethanosoluble carbohydrates solution was adjusted to 25 mL with distilled water.

The total carbohydrates content was determined using phenol and sulfuric acid reagents [10]. Into a test tube, 0.1 mL soluble carbohydrates extract was taken and successively added with 0.9 mL distilled water, 1 mL phenol (5%, w/v), and 5 mL concentrated sulfuric acid (96%). After heating for 5 min and cooling, the absorbance was read at 490 nm from a spectrophotometer (PG Instruments, England).

The dinitrosallycylic acid (DNS) reagent was used for the assessment of reducing carbohydrates [11]. To 1 mL ethanosoluble extract into a test tube, 0.5 mL distilled water and 0.5 mL DNS solution were added. The mixture was heated in a boiling bath for 5 min, cooled, and 2 mL distilled water were added and the absorbance was measured at 540 nm using the spectrophotometer.

Absorbances of the solutions were read against control tubes operated from the same conditions without the soluble extract. The onions' total and reducing carbohydrates contents were recovered from calibration using standard solutions of glucose and sucrose.

Fats content

The fats fraction was extracted from 15 g onion powder sample with hexane as solvent reagent using a Soxhlet device [12]. The extraction was runed at 70 °C for 7 hours. The extracted mixture was treated with rotavapor and oven devices for the oil recovering. The final oil content was measured according to the following formula:

$$\mathbf{LIC\ (g/100g\ FM)} = \frac{(\mathbf{m_1} - \mathbf{m_0}) \times \mathbf{100} \times \mathbf{r}}{\mathbf{m_s}}$$

With: LIC = lipid content, m_0 = mass of the empty extraction flask (g), m_1 = mass (g) of the flask+ extracted oil, r = = ratio of dry to fresh onion, m_s = mass (g) of onion powder sample

Crude proteins content

The full nitrogen method was implemented for the evaluation of onions protein content using Kjeldahl device [8]. A sample of 350 mg onion powder was added with 1 g catalyst and 3 mL concentrated sulfuric acid (96%) and digested and mineralized at 400 °C for 1h 30 min. The resulted mineralisate was added with 30 mL NaOH (10 N) in submitted to full distillation. The distillate was collected into a beaker with 5 mL boric acid added with a dye indicator and titrated with a sulfuric acid solution (0.01 N). The following formula was used to estimate the crude proteins content of samples:

$$\mathbf{TPC\ (g/100g\ FM)} = \frac{(\mathbf{V_1} - \mathbf{V_0}) \times \mathbf{14} \times \mathbf{6.25} \times \mathbf{N} \times \mathbf{r}}{\mathbf{m_s}}$$

With: PRC = protein content, V_0 = volume (mL) of sulfuric acid solution used for the blank test, V_1 = volume (mL) of sulfuric acid solution poured for the test, N = normality of sulfuric acid solution, m_s = mass (g) of onion sample, 14 = atomic mass of nitrogen, 6.25 = conversion coefficient from nitrogen to protein, r = ratio of dry to fresh onion

Total polyphenols and flavonoids contents

Phenolic compounds were extracted following the method of Singleton *et al*. [13]. Thus, 1 g onion powder was homogenized in 10 mL of ethanol (70%) then centrifuged at 1000 rpm for 30 min. The supernatant was kept, and the pellet added with 10 mL ethanol followed by another centrifugation. Both supernatants were gathered, and then completed at 25 mL with distilled water, and this final phenolic extract was used for determining polyphenols and flavonoids content. For polyphenols, 1.5 mL of diluted Folin- ciocalteu reagent (1/10) was added to 300 µL of phenolic extract in a test tube. The mixture was rested for 3 min and added with 1.2 mL sodium carbonate solution (20%, w/v). The tubes were respectively placed in a bain-marie at 50 °C for 5 min, out of the light rays for 30 min, and the absorbance of the mixtures was finally measured at 760 nm against a control tube free from phenolic extract. The total polyphenols content was assessed using standard gallic acid solution at 1 mg/mL.

Flavonoids were investigated from phenolic extracts according to Meda *et al*. [14]. One (1) mL aluminium chloride (10% w/v) and 1 mL sodium acetate (1 M) were respectively added to 1 mL phenolic extract into a test tube. The tubes were rested at room conditions for 30 min and the absorbance was read at 415 nm against a control tube free from phenolic extract. The final flavonoid contents of onion samples were recovered using standard quercetin solution at 1 mg/mL.

2.3 Data statistical processing

All parameters were determined in triplicate. Then, Statistical Program for Social Sciences (version 26, USA) and STATISTICA (version 7.1, France) software were used for the statistical processing of the collected data. Results were filled using means and standard deviation by parameter from analyzed stage and statistical differences were checked from analysis of variance (ANOVA) performed at 5% significance according to the onion variety and storage duration. Means were thus compared and ranged using Student Newman Keuls (SNK) post-hoc test. Then, Pearson r index was investigated to sound the significant correlation trends between onion characteristics during the bulbs' preservation. Principal Components Analysis (PCA) was also achieved as multivariate assessment of the overall variability of the onion samples traits.

3. RESULTS AND DISCUSSION

3.1 Results

The statistical analysis resulted in significant changes of the data according to the onion varieties, storage duration, and interaction between variety and duration, as shown in table 1.

Table 1. Statistical data for parameters studied according to the varieties during storage

Sources of variation	ddl		Parameters studied								
			pH	TAC	DMC	TSC	RSC	LIC	PRC	TPC	FLC
		SQ	0.37	79228.37	43.99	3.75	2.69	0.15	0.27	3485.50	130.45
Varieties	3	F- value	2653.24	179.60	1488.53	348.11	351.36	187.45	2.85	766.77	242.73
		p- value			< 0.001				= 0.05	< 0.001	
		SQ	0.07	51200.75	5.20	3.34	3.32	0.26	2.85	196.65	2.08
Duration	4	F- value	394.05	87.05	131.96	232.39	324.86	242.30	22.82	32.44	2.91
		p- value				< 0.001					0.033
		SQ	0.09	33498.39	4.60	5.97	1.62	0.11	0.28	1317.65	49.64
Varieties × Duration	12	F- value	163.39	18.98	38.89	138.46	52.74	33.62	0.74	72.47	23.09
		p- value			< 0.001				0.708	< 0.001	

DMC = dry matter content, TAC = titratable acid content, LIC = lipid content, PRC = protein content, TSC= total sugar content, RSC= reducing sugar content, TPC= total polyphenols content, FLC= flavonoids content, SQ= sum of squares.

<u>3.1.1 Changes of dry matter content</u>

Figure 1 shows the variation of dry matter content of onion bulbs during storage, between 9.70 ± 0.19 and 13.19 ± 0.13 g/100g fresh onion. Onion varieties *Dayo* and *Safari* produce bulbs with significantly higher dry matter contents during storage than *Red Star* and *Red Jewel*. Overall, there is a slight decrease in dry matter content during storage for bulbs of the *Dayo*, *Red Star* and *Red Je*wel varieties.

On the other hand, the dry matter content of *Safari* increased from 11.85 ± 0.13 g/100 g FM at the beginning of storage to 12.10 ± 0.08 g/100 g FM after storage.

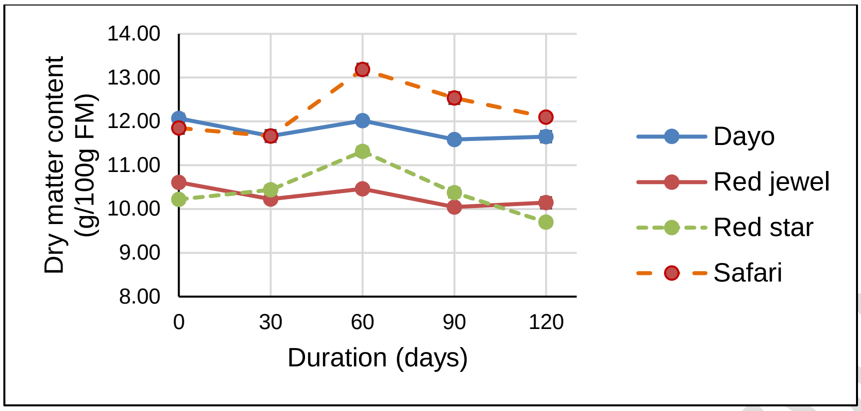

Fig. 1. Variation in dry matter of onion bulbs during storage

3.1.2 Changes of acidity parameters

The variation of onion pH and titratable acidity during storage is shown in Figure 2. A significant difference ($p < 0.001$) in pH values was observed between varieties. Onion pH was acidic with values ranging from 4.85 ± 0.01 to 5.23 ± 0.00. *Safari* onions have the highest pH values during storage, with values ranging from 5.14 ± 0.01 (day 0) to 5.2 ± 0.00 at day 120. The two *Red* varieties (*Red Star* and *Red Jewel*) showed the lowest pH values, ranging from 4.97 ± 0.01 to 4.99 ± 0.01 and from 4.85 ± 0.01 to 5.03 ± 0.01, respectively. In general, all varieties showed a slight increase in pH during storage, with the exception of *Dayo*, whose pH became more acidic.
On the other hand, a decrease in acidity was observed in onion bulbs at the end of storage. Acidity levels ranged from 148.02 ± 12.51 mg/100g FM for *Red Star* on day 120 to 306.73 ± 10.60 mg/100g FM for *Dayo* on day 60. At the beginning, the acidity levels are statistically identical for all onion varieties. *Red Star* has the lowest acidity during storage, ranging from 249.13 ± 11.32 mg/100g (day 0) to 148.02 ± 12.51 mg/100g FM (day 120).

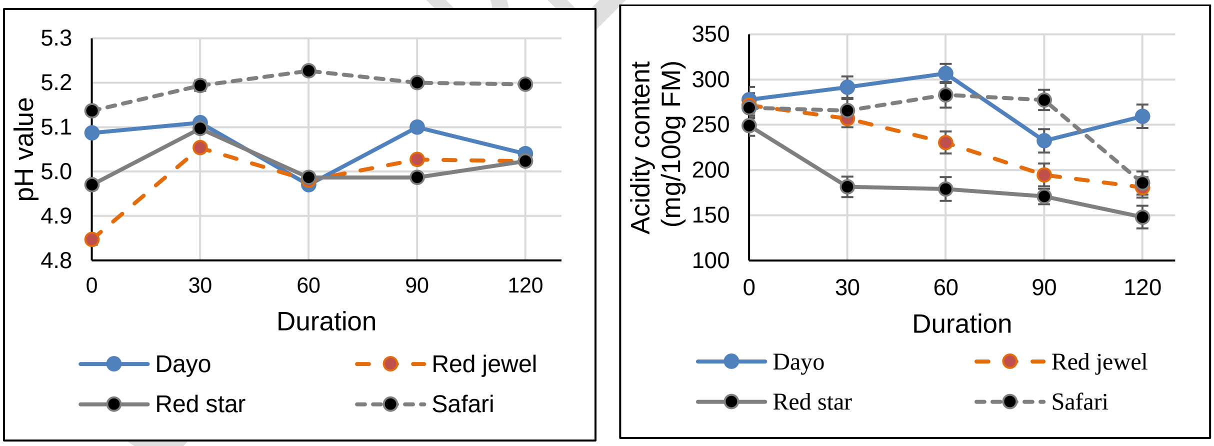

Fig. 2. Variation in pH and acidity content of onion during storage

3.1.3 Changes of carbohydrates contents

Figure 3 shows the changes in total and reducing carbohydrates content of onion bulbs during storage. At time 0, the *Dayo* and *Red Star* varieties had identical total sugar contents ($p<0.001$) and were higher than the other varieties, with values of 2.71 ± 0.04 and 2.84 ± 0.06 g/100 g FM, respectively. However, a decrease in these contents was observed during storage, with a more pronounced decrease in *Red Star*, where the value fell to 0.93 ± 0.02 g/100 g FM. In addition, the total carbohydrates content of *Red Jewel* onion increased from 1.61 ± 0.02 to 2.11 ± 0.07 g/1000 g FM at the end of storage. For *Safari*, a

stable total sugar content was observed with statistically similar values during storage ranging from 1.57 ± 0.08 to 1.58 ± 0.08 at the end of 4 months storage.
Reducing sugar values recorded in this study ranged from 0.62 ± 0.02 (*Dayo* D30) to 1.87 ± 0.05 (*Red Jewel* D120). The results show an increase in reducing sugars in *Red Jewel*, *Dayo* and *Safari* onion bulbs. These contents increased from 0.84 ± 0.05 to 1.87 ± 0.05 g/100 g FM for *Red Jewel*, from 0.70 ± 0.03 to 1.11 ± 0.03 g/100 g FM for *Dayo* and from 0.82 ± 0.15 to 1.24 ± 0.03 g/100 g FM for *Safari*. For *Red Star*, the reducing sugar content was statistically equal ($p < 0.001$) at the beginning and end of the storage.

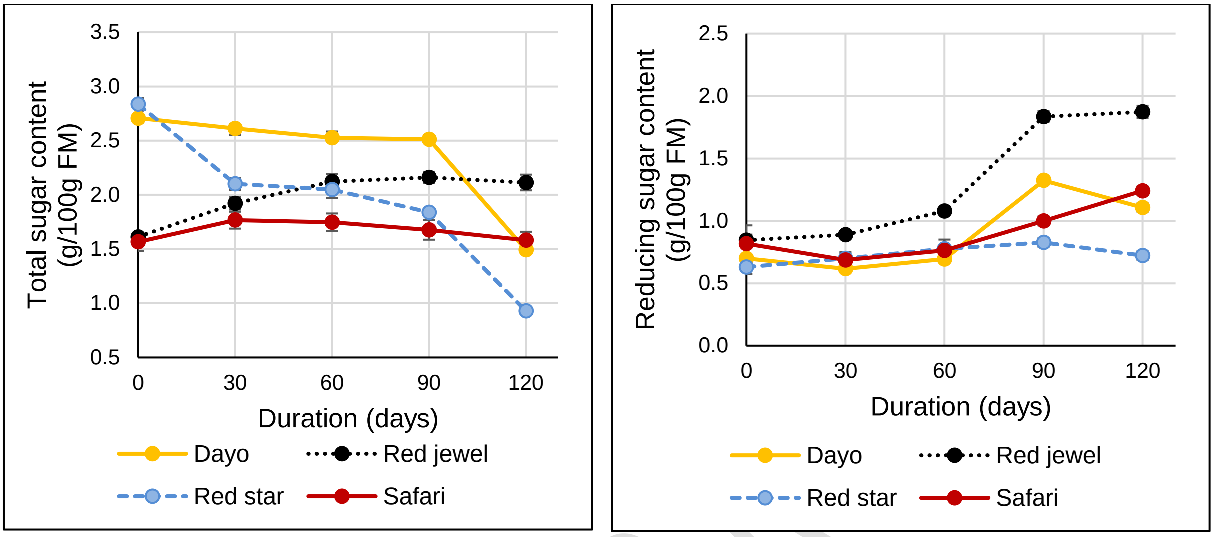

Fig. 3. Variation in total and reducing carbohydrates content of onions

3.1.4 Changes of protein content

Protein contents ranged from 1.90 ± 0.19 g/100 g FM obtained from *Safari* on day 30 to 2.70 ± 0.09 g/100 g FM obtained from *Red Jewel* on day 120. The results show a slight increase in protein content in the onion samples during storage (Figure 4) compared to the initial values, which are statistically similar.

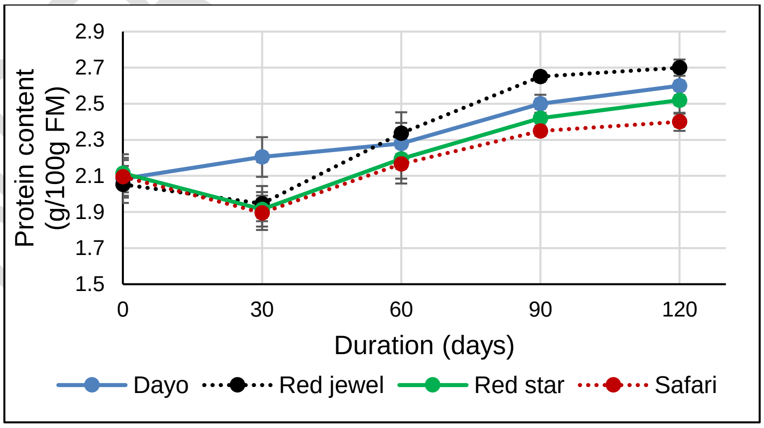

Fig. 4. Variation in protein content of onion during storage

3.1.5 Changes of lipids content

The lipid content does not exceed 0.50 g/100 g FM and increases during storage (Figure 5). In fact, the lipid content of *Red Star*, which had the highest lipid content at time 0 (0.26 ± 0.00 g/100 g FM), increased to reach a value of 0.32 ± 0.02 g/100 g FM at day 120. The lipid content of *Red Jewel* and *Safari* onions, identical at time 0, increased to reach values of 0.42 ± 0.01 and 0.43 ± 0.03 g/100 g FM, respectively, after 120 days of storage. The lowest lipid contents were recorded in onions of *Dayo* variety, which increased from 0.12 ± 0.00 g/100 g FM at the beginning to 0.25 ± 0.00 g/100 g FM at the end of storage.

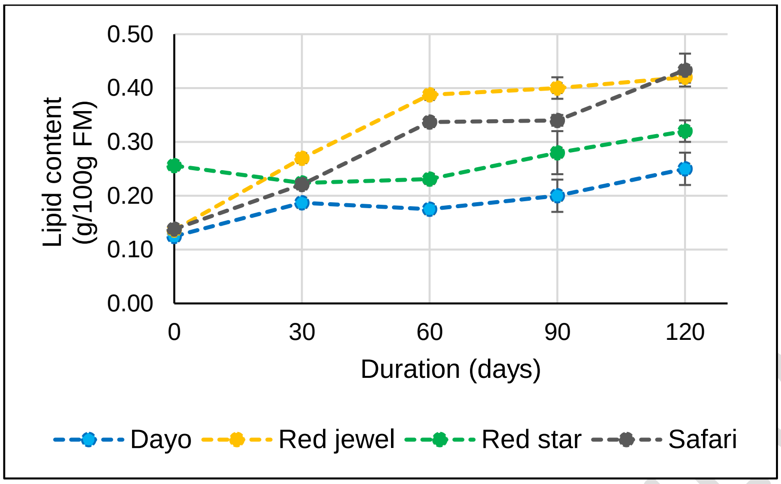

Fig. 5. Variation in lipids content of onion bulbs during storage

3.1.6 Changes of total polyphenols and flavonoids contents

The polyphenol and flavonoid contents of onions obtained during storage are presented in Table 2. These contents varied significantly ($p<0.001$) according to variety and storage time. A decrease in polyphenol content during storage was observed in onions of *Dayo*, *Red Jewel* and *Safari* varieties, while an increase was observed in *Red Star* variety. Thus, the levels of 62.24 mg/100g FM, 57.73 mg/100g FM and 41.48 mg/100g FM observed on day 0 in *Red Jewel*, *Dayo* and *Safari*, respectively, decreased to 59.65 mg/100g FM, 39.05 mg/100g and 33.42 mg/100g FM after storage. For *Red Star*, the total polyphenols content increase from 43.86 mg/100g FM (day 0) to 53.62 mg/100g FM (day 120), with a peak value of 71.58 mg/100g FM on day 60.
The flavonoid content of the onion samples ranged from 9.05 mg/100g fresh matter (*Safari* Day 0) to 15.19 mg/100g FM observed at *Dayo* on day 0. The analysis shows that onion variety and storage time are sources of significant variation in flavonoid content. The flavonoid contents, which were statistically identical and higher in onions of *Dayo* and *Red Jewel* varieties at day 0, decreased from 15.19 ± 0.45 and 14.76 ± 0.46 mg/100g FM to 12.53 ± 0.39 and 13.55 ± 0.23 mg/100g FM, respectively. In addition, an increase in flavonoid content was observed in *Safari* and *Red Star* onions, ranging from 10.83 ± 0.41 mg/100g FM on day 0 to 12.95 ± 0.5 mg/100g FM at the end of storage for *Red Star*. *Safari* had the lowest flavonoid content, ranging from 9.05 ± 0.35 to 10.21 ± 0.15 mg/100g fresh onion during storage.

3.1.7 Correlation between physicochemical and biochemical parameters evaluated during storage

According to the results, parameters analyzed are significantly divided into five (05) factors or main Table 3 shows the Pearson's r correlation indices between the physicochemical and biochemical parameters studied. Several significant correlations are observed at the 5% level of significance. A positive correlation was observed between dry matter content and pH ($r= 0.65$). Similarly, acidity increased with dry matter content ($r= 0.59$). In addition, depending on the matrix, an increase in protein would lead to an increase in the reducing sugar content of the onions. Negative correlations were observed between total polyphenol content and pH ($r= -0.62$) and between polyphenol content and dry matter ($r= -0.70$). A strong positive correlation was also observed between polyphenol content and flavonoid content ($r= 0.76$).

Table 2. Variation of total polyphenols and flavonoids content of onion during storage

Parameters	Duration	Dayo	Red jewel	Red star	Safari	F- value	p- value
	0	57.73 ± 1.73^{aB}	62.24 ± 1.81^{aA}	43.86 ± 0.55^{eC}	41.48 ± 1.31^{bC}	150.91	
	30	41.40 ± 1.76^{bC}	63.74 ± 1.26^{aA}	46.28 ± 0.27^{dB}	47.10 ± 1.22^{aB}	181.63	
	60	41.99 ± 1.68^{bC}	55.14 ± 1.45^{cA}	51.58 ± 1.42^{cB}	38.55 ± 0.17^{cD}	105.29	< 0.001
TPC (mg/100g FM)	90	41.90 ± 1.05^{bB}	58.63 ± 0.84^{bA}	57.80 ± 1.61^{aA}	36.76 ± 1.24^{cC}	249.70	
	120	39.05 ± 1.33^{bC}	59.65 ± 0.72^{bA}	53.62 ± 0.47^{bB}	33.42 ± 0.58^{dD}	631.83	
	F- value	72.24	20.35	90.71	78.80		
	p- value			< 0.001			
	0	15.19 ± 0.45^{aA}	14.76 ± 0.46^{aA}	10.83 ± 0.41^{cB}	9.05 ± 0.35^{cC}	152.31	
	30	12.58 ± 0.23^{bB}	14.77 ± 0.59^{aA}	11.79 ± 0.22^{bC}	9.43 ± 0.30b^{cD}	106.62	
FLC (mg/100g FM)	60	12.35 ± 0.57^{bB}	13.54 ± 0.52^{bA}	13.91 ± 0.48^{aA}	10.98 ± 0.71^{aC}	15.83	< 0.001
	90	12.99 ± 0.20^{bA}	13.00 ± 0.19^{bA}	13.72 ± 0.51^{aA}	10.30 ± 0.43^{abB}	52.73	
	120	12.53 ± 0.39^{bB}	13.55 ± 0.23^{bA}	12.95 ± 0.50^{aAB}	10.21 ± 0.15^{abC}	53.67	
	F- value	26.77	10.24	26.80	9.41		
	p- value			< 0.001			

TPC = Total polyphenol content, FLC = Flavonoid content; values with different capital letters in rows are statistically different at $p < 0.001$; values with different lowercase letters in columns are statistically different at $p < 0.001$.

Table 3. Matrix of Person correlation between parameters studied during storage

	pH	TAC	DMC	TSC	RSC	TPC	FLC	LIC	PRC
pH	1	0.26	**0.65**	-0.15	-0.03	**-0.62**	**-0.66**	0.19	-0.13
TAC		1	**0.59**	0.25	-0.39	-0.28	-0.29	-0.5	-0.5
DMC			1	0.04	-0.25	**-0.70**	-0.44	-0.21	-0.18
TSC				1	-0.03	0.03	0.22	-0.27	-0.15
RSC					1	0.20	0.14	**0.63**	**0.74**
TPC						1	**0.76**	-0.01	-0.02
FLC							1	-0.11	0.15
LIC								1	**0.58**
PRC									1

With : TAC = titrable acidity content, DMC= dry matter content, TSC: total sugar content, RSC= reducing sugar content, TPC= total polyphenol content, FLC= flavonoid content, LIC= lipid content, PRC= protein content.

3.1.8 Study of variability between individuals and parameters assessed by Principal Component Analysis

According to the results of the PCA, the data are divided into 9 components or factors. The first three factors (F1, F2, F3) with eigenvalues greater than 1 better express the variability (Kaiser's rule). Figure 6 shows the correlation circle for the analyzed individuals and parameters in the plane formed by the F1 and F2 factors. These two factors express 62.55% of the global variability. pH, acidity and dry matter content are positively correlated with factor F1, while polyphenol and flavonoid content are negatively correlated with this factor. In addition, reducing sugar content, protein content and lipid content are negatively correlated with F2 factor. According to the projection, the individuals are divided into four different groups according to their correlation with the F1 and F2 factors. The first group includes *Red Jewel* individuals from day 60 to day 120 and *Red Star* individuals from day 90 to day 120. This group is characterized by individuals with high levels of antioxidant compounds (polyphenols and flavonoids). The second group, characterized by individuals with higher levels of reducing sugars, proteins and lipids, includes *Dayo* individuals from day 120, *Safari* individuals from day 90 to day 120. The third group, comprising *Safari* individuals from day 0 to day 60 and *Dayo* individuals from day 30 to day 60, is characterized by the highest dry matter, acidity and pH values. The fourth group is not characterized by a set of parameters. It includes *Dayo* day 0, *Red Star* day 0 to day 60 and *Red Jewel* day 0 to day 30.

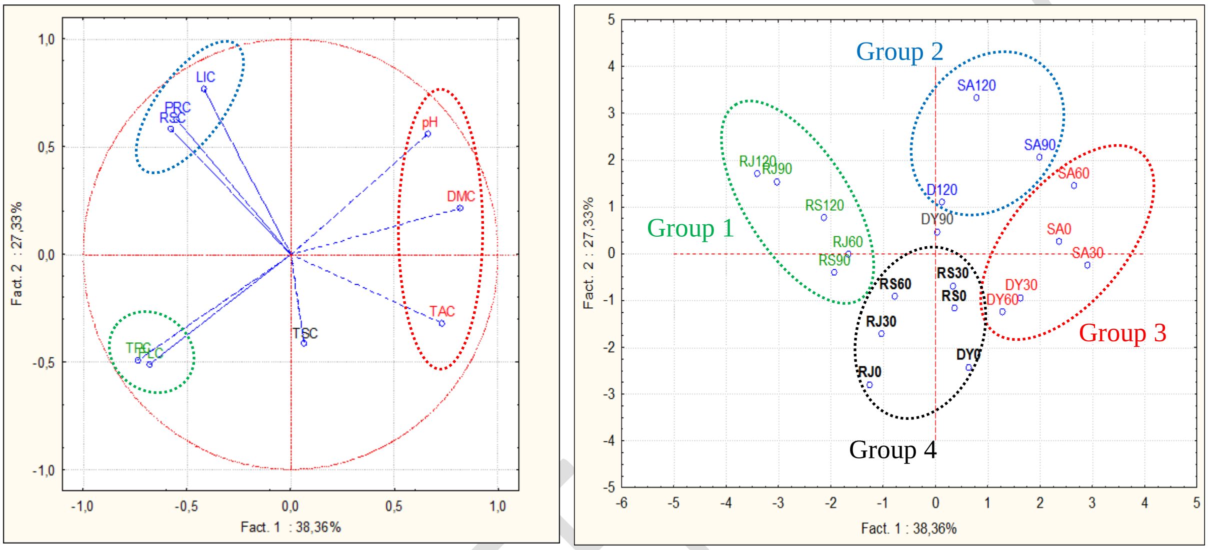

Fig. 6. Correlation between the F1-F2 factorial of Principal Components Analysis (PCA) deriving from the stored onion bulbs

With : TAC = titrable acidity content, DMC= dry matter content, TSC: total sugar content, RSC= reducing sugar content, TPC= total polyphenol content, FLC= flavonoid content, LIC= lipid content, PRC= protein content, DY= Dayo, RS= Red star, RJ= Red jewel, SA= Safari, 0 à 120 = stockage duration from 0 to 120 days.

3.2 Discussion

The study shows that the physicochemical and biochemical parameters of onion bulbs change during storage. These parameters vary from one variety to another. These variations shows that cultivar specificity is at the origin of the variation of parameters during storage. The dry matter contents obtained in this experiment are lower than those reported by Ayalew [15], where the contents ranged from 12.5 to 15.3%. The decrease in dry matter obtained with *Red Star*, *Red Jewel* and *Dayo* varieties during storage could be due to the mobilization of nutrients, especially sugars, during germination and microbial growth phenomena. Petropoulos *et al*. [7] also found a decrease in dry matter content of onion bulbs during storage.

The profiles of carbohydrate content changes vary from variety to variety. A decrease in sugar content is observed in *Dayo* and *Red Star* onion bulbs. These changes can be attributed to aging and high respiration rates in the bulb tissue. In addition, pathogen infection and the incidence of sprouting may play an important role in changes in chemical composition [16].

According to Hansen [17], this decrease led to an increase in the nitrogen and protein content of the dry matter. This may partly explain the increase in protein content in onion bulbs. An increase in sugar content was also observed in *Red Jewel* onions. This increase in sugar content was also observed by Sharma *et al*. in 2015 in bulbs stored under ambient conditions (20-25°C and 60-80% relative humidity). This variability is related to genotype (variety), but also to storage temperature according to Petropoulos *et al*. [7].

Variations in polyphenol and flavonoid content were observed during storage, as reported by Sharma *et al*. [18]. The *Dayo*, *Red Jewel*, and *Safari* cultivars showed a decrease in total polyphenol content, while the *Red Star* cultivar showed an increase. The same trends in polyphenol content were obtained by Petropoulos *et al*. [7]. In addition, several authors, such as Rodrigues *et al*. [19] and Yoo *et al.* [20], observed an increase in the content of flavonoids. In fact, it has been reported that phenolic parameters, flavonoids and antioxidant activity increase during ripening and storage of various fruits and vegetables [21]. The increase in flavonoids is thought to be caused by tissue aging and is also associated with respiration in onion scales. The profile of changes in phenolic compounds in the *Red Star* variety, with high levels at the end of storage, is significant because onions are rich in these compounds.

4. CONCLUSION

The study evaluated the changes of physicochemical and biochemical properties of onion during storage. Variety and storage time influence the physicochemical and biochemical properties of onion bulbs. Dry matter content is higher in *Dayo* and *Safari* bulbs than in the two *Red* varieties. Protein and lipid contents increase during storage in all varieties. Ther is no difference in protein content between bulbs of all varieties at any given time. For other parameters studied, changes in content depend on the variety. *Red Star* and *Red Jewel* bulbs are characterized by the highest contents of total polyphenols and flavonoids at days 60, 90 and 120 days. The phenolic compounds evolution profile of *Red Star* and *Red Jewel* varieties seem to be a selection criterion for these two varieties.
Comparing these data with those of post-harvest losses and sensory profiles, as well as the production potential of these varieties, could guide varietal selection.

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