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Full Length Research Paper

Monitoring the changes in chemical properties of red and white onions (*Allium cepa)* during storage

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Effects of postharvest storage conditions and varietal differences on the chemical properties of onion bulbs were demonstrated. Fresh red and white onion varieties were stored for two months under three different storage conditions: ambient temperature (28-30ºC), refrigeration (5-7ºC) and control cupboard temperature storage (45-50ºC). Main and interaction effects of the two factors (storage and variety) on proximate compositions, flavonoids, vitamin C and mineral contents of the onions were determined weekly using Two-way ANOVA. Storage techniques were found significant (P<0.05) with respect to all the chemical characteristics of both onion cultivars. The rate of moisture uptake in onion stored under refrigerated temperature increased slightly in the first three weeks and remained relatively constant the rest of storage period, whereas ambient and warm temperature caused about 22.5 and 27% moisture loss, respectively at the end storage period. The reverse was true in the case of carbohydrate. Generally, red onion cultivar had higher protein, lipid, flavonoid and ascorbic acid contents irrespective of the storage conditions. Flavonoid content declined as storage time progressed under refrigeration, and highest loss of ascorbic acid; 73 and 69% were experienced in red and white bulbs respectively, during cold storage. There were slight variations in the mineral contents of onions during storage. Generally, ambient and warm temperature conditions retained some of the postharvest quality properties of onions better than refrigeration.

Key words: Fresh onions, storage, cultivars, chemical properties.

INTRODUCTION

Onion is one of the most important commercial condiments grown and consumed widely all around the world. Its consumption is due to the presence of bioactive chemical components of different nutritional and health benefits. Polyphenols, fructopolysaccharides, and many other health promoting compounds determine to a large extent the majority of research on onion (Kumar et al., 2015). Nigeria occupies 6th position in the World's onion producing countries; producing over 618,000 tonnes in year 2007 (Sulumbe et al., 2015). Its utilization is mainly as flavorant and taste-enhancer with very attractive sensorial appeal when used as spice and condiments in

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foods (Bhattacharjee, 2013). Onion is rich in sulfur-containing polyphenolic compounds responsible for the strong astringenic flavor (Corzo-Martinez et al., 2007). The overall nutritional compositions, morphological make up coupled with low cost of production, make onion an integral part of many African and Asian cuisines. Onion is also a vital source of minerals and micronutrients such as: calcium and potassium as well as non-essential heavy metal such as selenium, depending on the area of cultivation. In addition to the array of nutrients compositions, onion is well endowed with some important bioactive functional constituents conferring its anti-oxidative, antiplatelet, antithrombic, antiasthmatic and antibiotic capacities (Nile and Park, 2013). Flavonoids, specifically quercetin represents the most prevalent phytochemical in onion with its attendant health-promoting effects (Caridi et al., 2007). Apart from its free-radical scavenging capacity and prevention of lipid peroxidation, flavonoids have been demonstrated to have anti-cancer properties (Linsalata et al., 2010; He et al., 2014). Onion is second most abundant source of dietary flavonoids below berries and above garlic (Manach et al., 2004). All the three notable derivatives of flavonoids such as: kaempferol, myricetin and quercetin are present in onion with quercetin as the most abundant (Sellappan and Akoh, 2002).

Consumer acceptability of onion depends on many factors which can be categorized as agronomic and technological. For example, onion cultivars, harvest time and other pre-harvest climatic conditions are very important in determining the most suitable storage conditions for onions (Liguori et al., 2017). One of the major factors influencing the storage stability of onion is proper selection of cultivar (Petropoulos et al., 2016). Onion of low dry matter and short-day cultivars are usually less prone to long-term storage defects when compared to long day cultivar (Gubb and MacTavish, 2002). Like most horticultural produce, onion is susceptible to post harvest losses among which water losses, sprouting and rooting rank above others. Therefore, despite the relative high production and its wide utilization, onion has a very short postharvest life (Priya et al., 2014). Although onion is regarded as a semi-perishable crop, post-harvest losses can be quite enormous especially in the regions of high production. It is estimated that loss of total onion crop in developing countries is high and can reach 16-35% (Steppe, 1976). Exact data on the nature and extent of these losses at each step in the postharvest chain is not readily available in literature. However losses of over 9% have been reported for Spring onion between wholesale and retail (Linus, 2003). Postharvest losses have been linked to serious economic impacts, such as direct financial losses on the part of the growers and also for the marketers. It also indicates a waste of productive agricultural resources such as land, water, labour, managerial skills and other inputs that have been proposed as a mean of extending the shelf life of onion with additional benefits of ease of transportation, packaging and weight reduction (Kashif et al., 2016).

The success of onions in adapting to most common storage techniques apart from drying, are relatively poor, with storage losses reaching as high as 66% in some cases (Biswas et al., 2010). However, the sensorial and nutritional integrity of this essential commodity depend on its freshness and wholesome state, rather than in dehydrated form. Alteration of chemical composition and other unfavorable changes in the sensory properties discourages dehydration as a preservative technique. In developing countries where onion plays major role as food condiment, flavourant and functional ingredient, developing appropriate storage technology that will preserve onion in its fresh state is a necessity. A careful selection of appropriate temperature, relative humidity and light intensity is required to control metabolic activities of onion during storage (Sharma and Lee, 2016). Yadav and Yadav, (2012) minimized decay and sprout losses in onion using locally made bamboo structure. Similarly, losses in onion stored in aerated basket at room temperature were lower compared to those of less ventilated structures (Imoukhuede and Ale, 2015). However, some other relatively less expensive storage method has been adopted in literature with satisfactory results (Ranpise et al., 2001; Jamali et al., 2012). Therefore, the objective of this study is to suggest and test the viability of some simple but practicable storage techniques to extend the shelf life of two onion cultivars. Effect of refrigeration, ambient and controlled cupboard temperatures were monitored on the post-harvest chemical characteristics of red and white onion cultivars grown in the northern part of Nigeria. These adaptable and cheaper storage technologies are capable of alleviating seasonal gluts and subsequent postharvest losses in onion production.

MATERIALS AND METHODS

Onion samples

The fresh samples of red and white onions varieties were obtained in the Modibbo Isa Farm, in Kano North in Bichi Local Government areas located at the longitude of 12º 16” 53” North and latitude of 8 º 23” 38” East, Kano State Nigeria. Onions were harvested from this local farm at optimum maturity (50 - 60% fallen tops) within 3 days. Preliminary sorting and grading were done for firm and compact bulb, strong skin, and uniform quality, size and disease-free. Samples were cured (air-dried) for two weeks to ready-for-marketing before storage. After collection, samples from each variety were randomly divided into three batches. Each batch contained 45 pieces of wholesome and cured red and white onion bulbs. All chemical analysis were done using analytical grade reagents.

Storage techniques and conditions

The ambient storage compartment was designed; made up of

Table 1. ANOVA p-values showing the effect of factors and their interactions.

Response	Storage	Variety	Storage + Variety
Proximate composition (%)			
Moisture	0.01	0.36	0.24
Carbohydrate	0.02	0.42	0.33
Fats and oils	0.01	0.03	0.03
Protein	0.03	0.01	0.02
Ash	0.04	0.28	0.08
Fibre	0.02	0.04	0.04
Phytochemicals (mg/kg)			
Flavonoids	0.01	0.04	0.04
Vitamin C	0.04	0.11	0.03
Minerals (mg/kg)			
Sodium	0.05	0.12	0.18
Calcium	0.01	0.06	0.04
Potassium	0.03	0.22	0.10

p-value < 0.05 is significantly different.

plywood with both sides covered with wire gauze. The temperature of the cupboards ranged between 28 – 30°C and this was maintained throughout the storage period. The dimension of the cupboard was 2 m length, 1.5 m height and 1 m breath. Red and white onion samples were stored in two separate compartments with each containing 45 pieces of either variety. Similarly, in the refrigerated storage 45 pieces of red and white onions were stored in refrigerator at 5 - 7°C. In the case of controlled temperature storage, cupboards were constructed using plywood materials of the same dimensions with ambient storage. Both sides of the cupboard were sealed with plywood and few holes were bored to simulate controlled atmosphere condition. Artificial light was created within the compartment by fitting electric bulb. This raised the temperature of the cupboard to 45 - 50°C (warm storage). The temperature and relative humidity were monitored with the aid of a thermometer and hygrometer, respectively throughout the storage period. The onions samples were stored for a period of eight weeks and samples were taken for analysis weekly. A total of 6 samples, 2 from each variety (Red and white onions) stored under 3 different conditions (ambient, refrigeration and controlled atmosphere) were analysed each week for their chemical characteristics.

Proximate compositions determination

Changes in proximate composition of onions stored under ambient, refrigerated and controlled temperature conditions were evaluated according to the standard methods of AOAC (2010). The protein content was obtained as nitrogen equivalent by multiplying the nitrogen content by 6.25 (conversion factor) and the carbohydrate content was determined by difference. Moisture, fats, crude fibre and ash were all determined and reported in percentage.

Vitamin C, flavonoid, and mineral contents determination

Vitamin C content of the samples, using 2, 6–dichlorophenol indophenols dye, flavonoid content and some minerals such as: sodium, potassium and calcium contents of the onion samples were determined according to the standard method (AOAC, 2010).

Statistical data analysis

All analyzes were carried out in triplicate. Data were analyzed by a Two-Way ANOVA using Minitab 16.0 (Minitab Inc., State College, USA) statistical package. The significance of storage techniques and onion variety as well as their interaction were determined at 95% confidence level ($P < 0.05$) and the results were presented as p-value. One-Way ANOVA was also conducted to compare each treatment combination (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white onion in warm storage) as storage weeks progressed.

RESULTS AND DISCUSSION

Influence of variety and storage time on the proximate compositions

The main factors and interaction effects were found significant with respect to some proximate compositions (Table 1). There was no significant difference between the onion varieties with respect to moisture content. However, refrigerated onion (RR and WR) showed a slight moisture uptake between 0 and 3rd weeks. This increment remained relatively constant throughout the rest of the storage period (Figure 1a). The high relative humidity at low temperature in refrigerated conditions may be responsible for the slight adsorption of water within the first few weeks. As the storage time advanced, equilibrium moisture content between onions and refrigerator must have prevented further water adsorption.

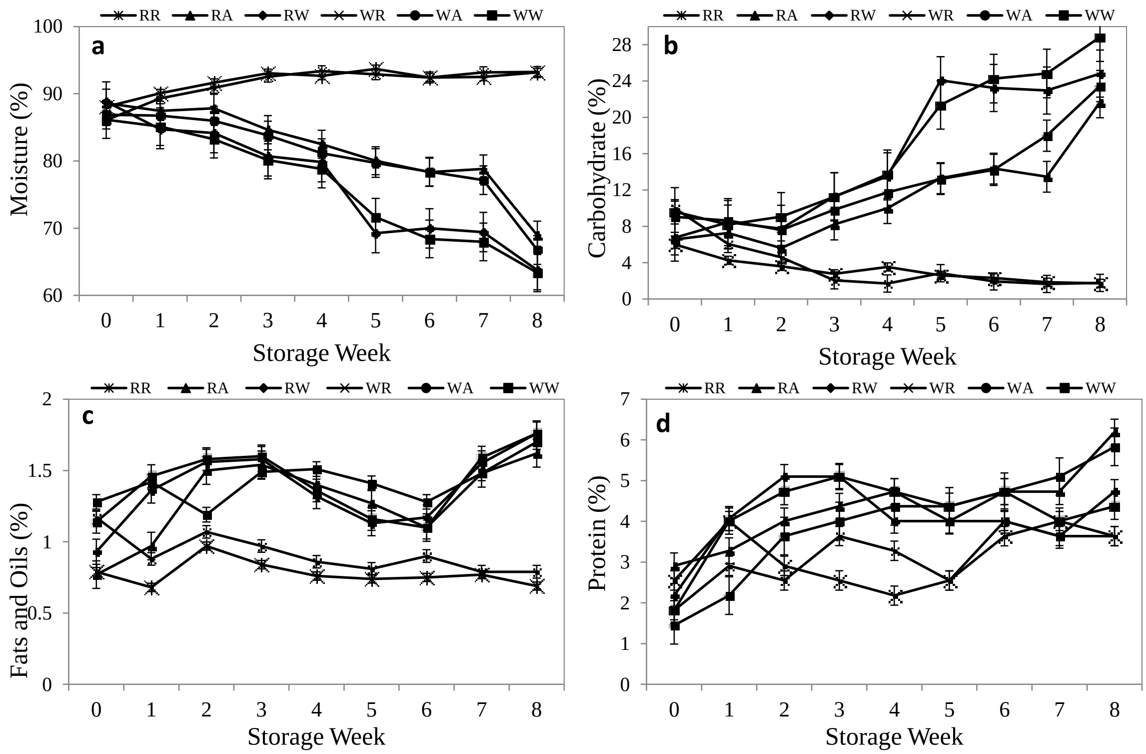

Figure 1. Changes in (a) moisture content (b) carbohydrate (c) fats and oils and (d) protein content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white onion in warm storage.

However, there appeared a sign of fungal growth on the bulb by the end of 8th weeks of refrigerated storage. Conversely, onions stored under ambient temperature experienced gradual decline in moisture content between 0 and 7th week and a sharp drop at 8th week of storage. The temperature gradient between the sample and storage environment may be responsible for moisture loss during ambient condition. The moisture loss could be due to desiccation, respiration and sprouting which are dependent on the storage temperature (Sharma and Lee, 2016). These changes became more pronounced in controlled warm temperature stored onions (RW and WW). An average of 28% moisture loss was observed in onions stored under this warm temperature between 0 – 8th weeks. Direct quantitative losses leading to decrease in saleable weight is one of the obvious consequences of raising the storage temperature of onion above 30°C (Sharma et al., 2014). It has been shown that metabolic rate leading to the consumption of soluble solid in fruit and vegetable increases at elevated temperature (Pablo et al., 2013). It is noteworthy to state that the moisture content of onions stored at controlled warm temperature after 8th week (63.37%) came very close to the expected value (60.50 ± 0.5%) for acceptability and export preference (Ministry of Economic and Foreign Trade, 1992). This may be responsible for the corresponding increase in carbohydrate content of onions stored at ambient and warm temperatures (Figure 1b). Effects of onion variety, storage method and their interaction were significant with respect to lipid and protein content of onions (Table 1). The patterns of change in these parameters appeared visually similar amongst the samples (Figure 1c to 1d). Onions stored at ambient temperature (RA and WA) were slightly high in fats and oils and protein content at initial stage prior to storage. Red onions stored under a warm condition (RW) experienced a significant increase in fats and oils and protein contents especially at early storage period (0 -2nd week). White onion exhibited the same pattern up until 3rd week before declining. A regular progressive increase was observed in fats and oils and protein contents of onions under ambient storage (RA and WA); with the final values of these parameters at the end of 8th weeks more than twice the initial values (from 2.91 to 6.19% and 1.45 to 5.83%, for red and white onions, respectively). These results implied that ambient and warm storage conditions are capable of preserving the protein and lipid content of onion. The first week of refrigerated storage resulted in small increase in fats and protein contents of onions. Red onions experienced a remarkable decline in these parameters when compared with white cultivar between 1st and 4th weeks of cold storage. However, the rates

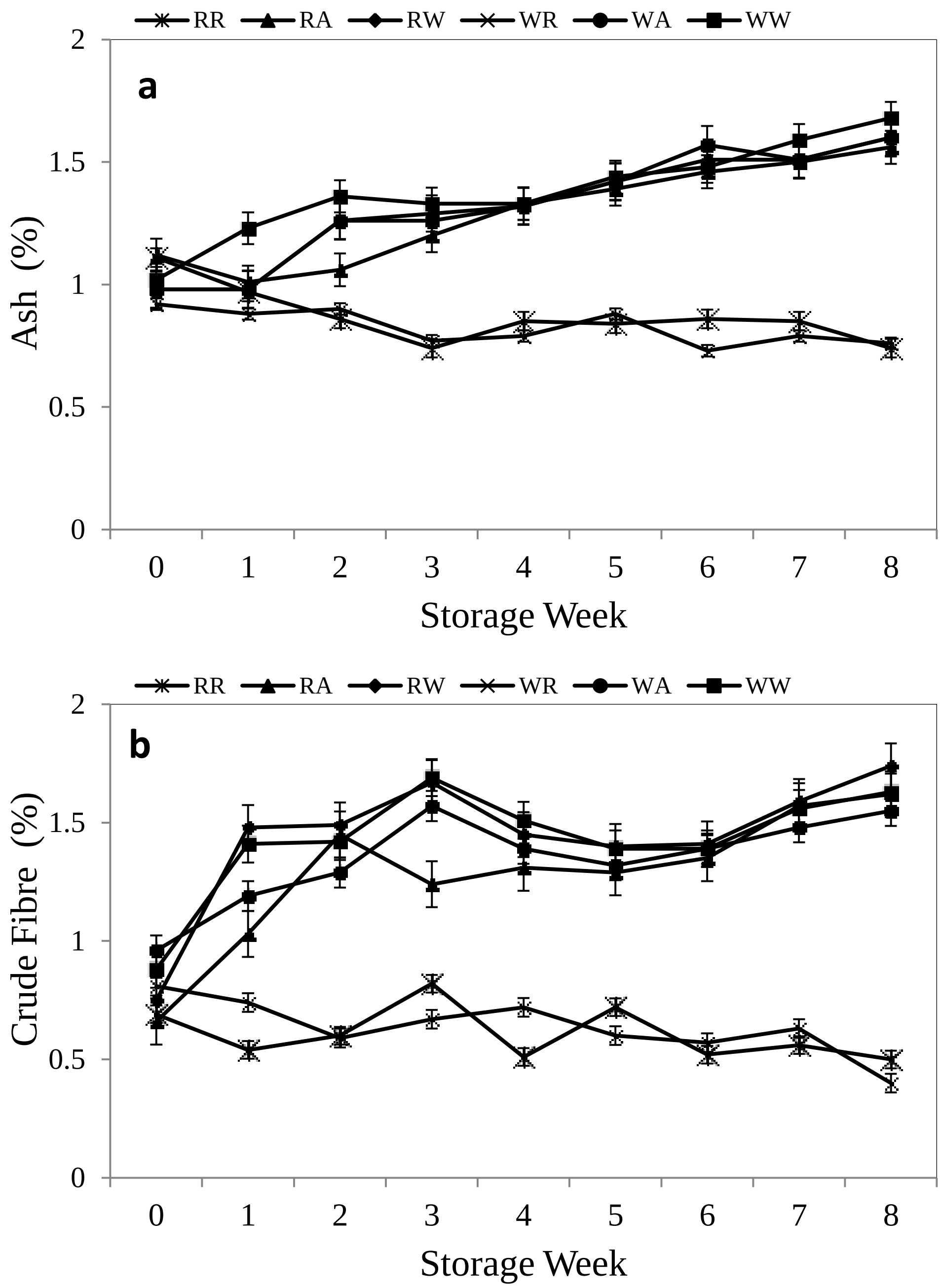

Figure 2. Changes in (a) ash content and (b) fibre content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white onion in warm storage).

of increase in fats and protein contents of the two onion varieties between 5th and 7th weeks were relatively the same. Only storage technique significantly influenced ash and crude fiber contents of the samples (Table 1). The pattern of change in ash content showed that onion stored in warm temperature (RW and WW) had a significant increase within the first three and the last two weeks of storage period (Figure 2a). The same trend, with little variations was observed in samples stored under ambient condition (RA and WA). These observations were true for crude fibre content as well (Figure 2b). However, refrigerated samples did not indicate a significant change in ash and fibre contents throughout the storage period. These results indicated that ash and fibre contents of onion are less susceptible to cold temperature storage. The irregular pattern of

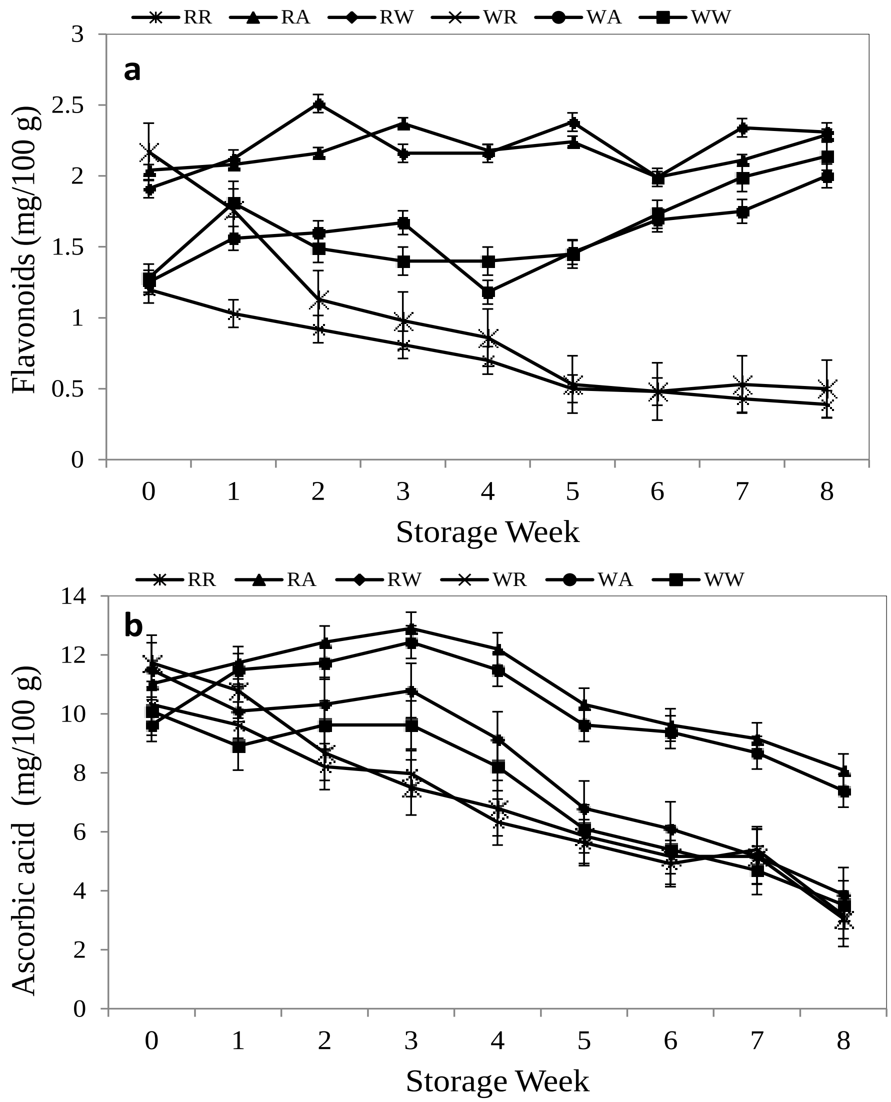

Figure 3. Changes in (a) total flavonoid content and (b) ascorbic acid content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white onion in warm storage).

change in these parameters at ambient and warm temperature may be due to physiological activities, agronomical and other pre-harvest parameters leading to fluctuations of some chemical components in onion (Lee and Lee, 2014).

Influence of variety and storage time on flavonoids and ascorbic acids content

The total flavonoid contents of onions were found to be dependent on onion varieties and storage conditions. White onions are known to contain less anthocyanin content than colored onions (Shi-lin et al., 2016). This observation was evident in red onion samples irrespective of the storage conditions (Figure 3a). However, red onions stored at ambient and warm controlled temperature had the highest flavonoid contents and remained relatively the same throughout the storage time. Phenolic compounds are structurally unstable and can easily undergo degradation at high temperatures. This is due to its relatively high redox potential and tendency for complex formation. Rodrigues et al. (2010) found a positive linear correlation between flavonoid content and storage time. Onions stored under refrigerated temperature showed a huge decline in flavonoid content. Authors are divided about their opinions on the effect of cold temperature on bioactive

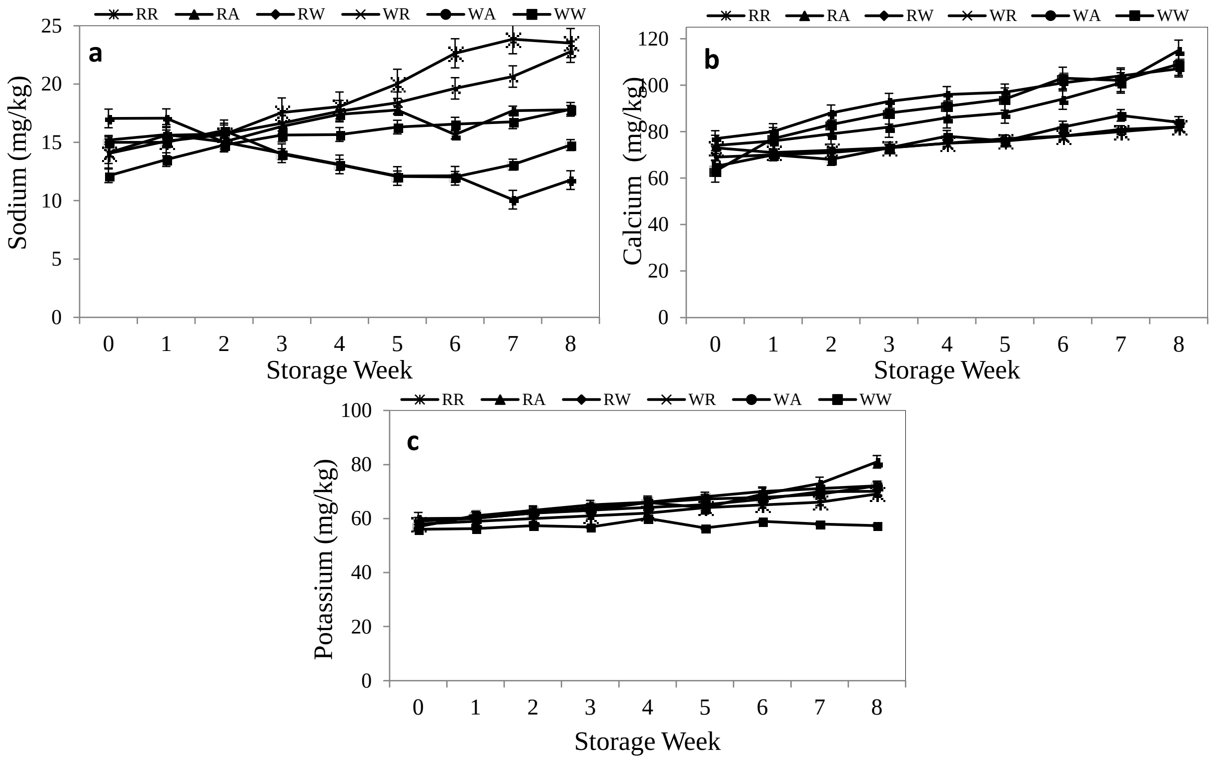

Figure 4. Changes in the mineral: sodium (a) calcium (b) and potassium (c) contents of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white onion in warm storage).

contents of horticultural produce. Some have reported that low temperature positively affect the biosynthesis of phenolics compounds and induce flavonoid accumulation (Bakhshi and Arakawa, 2006). White onion stored at ambient and warm temperature showed slightly similar pattern of change in flavonoids with storage time. Therefore, the changes in flavonoid contents were more significant with storage conditions than onion varieties (Table 1). A different but more regular trend was observed in the case of ascorbic acid content of the samples (Figure 3b). The ascorbic acid at the beginning of storage was about 9.62 – 11.73 mg/kg, with red onion having higher value. A slight increase in ascorbic acid was observed between 0 – 3 weeks among the samples stored under ambient and warm temperature storage. Right from the 3rd week, ascorbic acid declined slightly in onions stored under ambient conditions. The rate of decline was more pronounced among refrigerated samples and followed by warm temperature onion samples. This is partially in agreement with the study of Alam and Islam (2015) who found a negative correlation between drying time at constant temperature (45 - 50°C) and vitamin C content of onion. Storage time and temperature has been found to be highly significant in influencing ascorbic content of fruits and vegetables during storage (Polinati et al., 2010). Ascorbic acid is highly susceptible to oxidation during long time storage. Being an antioxidant, factors such as presence of endogenous enzymes (ascorbic oxidase), oxygen, metal ions, alkaline pH and high temperature influence the variation of vitamin C contents of fruits and vegetables (Philips et al., 2010). Nutritionally, the relatively small daily consumptions of red onion could be beneficial to human health, since 100 g of raw red onion contains 9.62 - 11.73 mg ascorbic acid, and 1.91 – 2.17 mg flavonoids contents.

The results of the mineral compositions of the onion samples were presented with respect to sodium, calcium and potassium. Onions of different varieties did not show significant difference between sodium at the initial stage prior to storage. Sodium contents of red and white onions under refrigerated temperature experienced over 60% increase by the end of 8th weeks. This rate of increase was the most significant among the storage conditions followed by ambient storage. However, an equivalent decline was observed in sodium contents of onions stored under slightly higher temperature. A different trend was observed in the case of calcium and potassium. Calcium increased slightly and warm temperature stored sample had the highest calcium content at the end of storage time (Figure 4b). Similarly, potassium slightly increased with storage time with red onions somewhat higher than white onions at the same storage conditions (Figure 4c). As far as we know, there is little or no information on the effect of storage conditions and time on the mineral composition of onions bulbs. Comparatively, the mineral contents of onions in our study were lower than that suggested by USDA (2016) for raw onions. However, the value of sodium, potassium and calcium at the end of 8th weeks storage, especially under ambient and control warm temperature, were reasonably high.

Conclusion

Storage conditions and onion variety were important factors influencing postharvest quality characteristics of onion bulbs. Red onion cultivar had higher initial contents of some important parameters such as: protein, lipids, flavonoids and vitamin C. The rate of postharvest loss in any of these variables was independent of the varietal differences but dependent on the storage techniques. Ambient and warm controlled temperature storage methods were found better in retaining the initial quality characteristics of the onion bulbs. Protein, lipid, flavonoid, vitamin C and mineral compositions of onions either increased or remained comparatively unchanged over the storage period, when held at ambient and warm temperature. The abilities of these storage temperatures (28 - 30°C) and (45 – 50°C) to sustain the quality characteristics of onion for two months are affordable means of preventing undue postharvest deterioration and its attendant economic losses in onion for farmers. The factors considered in this study are not by any means exhaustive. Therefore, other probable agronomical and technological variables influencing the quality characteristics of onions such as: geographical differences, soil characteristics, seedling, rainfall and so on, should be considered in future study.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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