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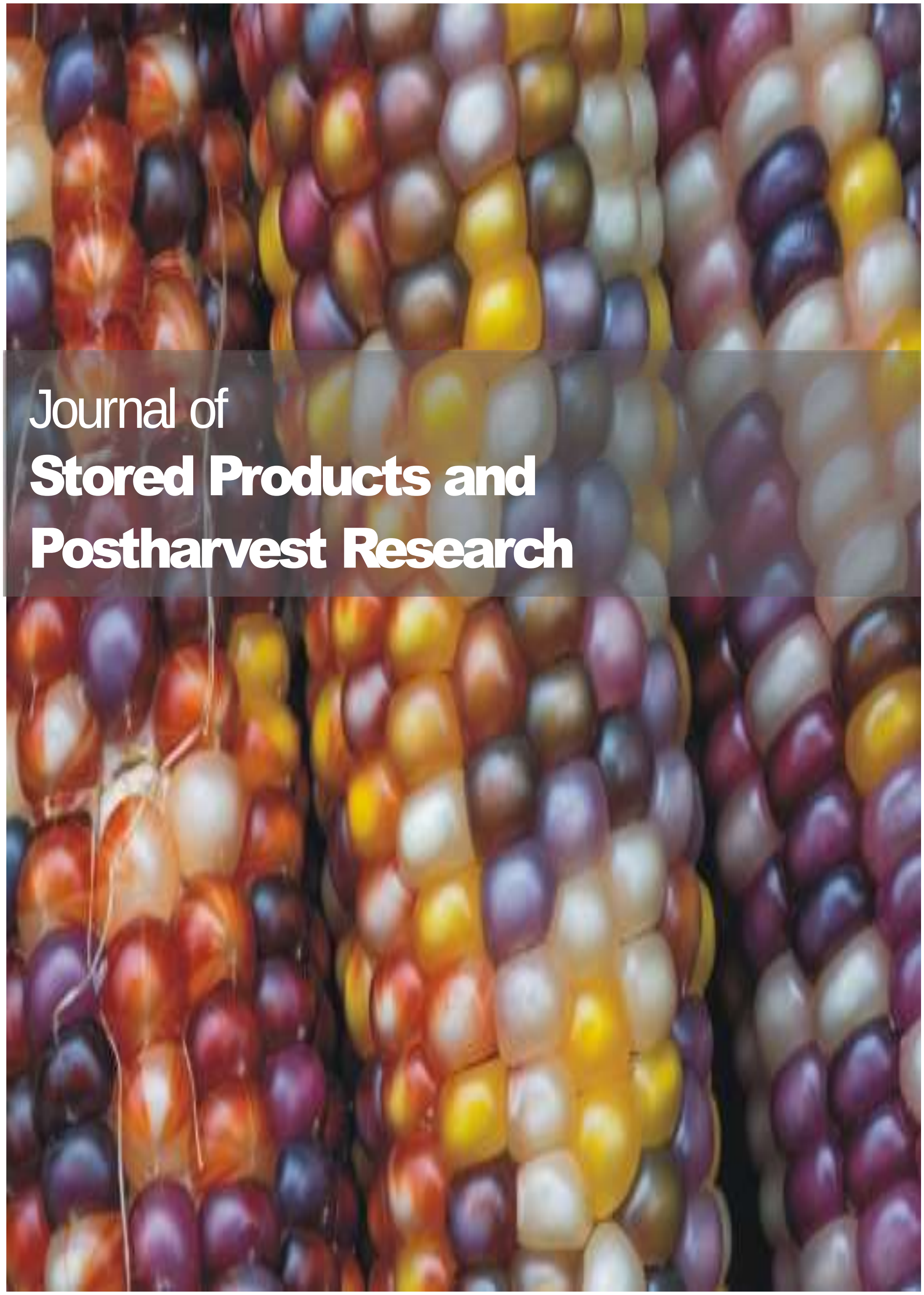

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Table of Contents: Volume 9 Number 7 September 2018

ARTICLES

Laboratory evaluation of six new cassava genotypes to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) infestation 68
Zakka U., Lale N. E. S., Onoriode A. H. and Ehisianya C. N.

A study on the causes of apple (*Malus Domestica*) fruit loss at Chencha Woreda of Gamo Gofa Zone, Southern Ethiopia 72
Behailu A. and Kebede J.

Monitoring the changes in chemical properties of red and white onions (*Allium cepa*) during storage 78
Olusola Samuel Jolayemi, Sanusi Shamsudeen Nassarawa, Oluranti Mopelola Lawal, Mopelola Ajoke Sodipo and Isaac Babatunde Oluwalana

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Journal of Stored Products and Postharvest Research

Full Length Research Paper

Laboratory evaluation of six new cassava genotypes to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) infestation

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Two products, chips and flour, processed locally from six new cassava genotypes; 98/0505, 01/1368, 05/1636, 05/0473, 01/1371 and 01/1412 obtained from National Root Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria were evaluated for losses (qualitative and quantitative) caused by rust red flour beetle *Tribolium castaneum* under storage conditions (25 to 30°C and 70 to 90% RH) in the General Laboratory, Faculty of Agriculture, University of Port-Harcourt. The response of each cassava genotype was evaluated by infesting 20 g lots of either chips or flour with 8 pairs of adult *T. castaneum* in 300 ml plastic containers with air tight lids. The trial was arranged in a completely randomized design in which treatments were replicated four times. With a few exceptions, cassava flour supported significantly more adults and immature *T. castaneum* progeny than chips; chips suffered significantly lower quantitative losses than flour. Cassava genotype 98/0505 was infested the most and consequently sustained the most damaged flour derived from it.

Key words: *Tribolium castaneum*, cassava, genotype, infestation, chip, flour.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a primary staple food crop for more than 800 million people in the world (Lebot, 2009). In most of the tropics, its production and yield are highly prolific and usually consumed in place of yam and cocoyam as the number one carbohydrate source and it is said to provide up to 40% of all the calories consumed in Africa (Hahn et al., 1987; FAO, 2008). The produce is the net result of all the prior efforts of crop husbandry; it is frequently stored for some period of time before consumption for a variety of reasons (Adesuyi, 1997). During storage, food commodities are usually liable to depredation by pests such as micro-organisms, mites, insects, rodents and birds (Lale and Ofuya, 2001). A processed cassava when available or purchased by households in large quantities is not immediately consumed and is often kept in storage where it is infested by stored product pests (Haines, 1991).

The red rust flour beetle, *Tribolium castaneum,* has

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Table 1. Mean weight loss (g) of two forms (chips and flour) of dried cassava genotypes infested by *Tribolium castaneum* and mean number of adult and immature *T. castaneum* after 30 days.

Cassava genotype	Mean weight loss (g)		Mean number of adult		Mean number of immature	
	Chips	Flour	Chips	Flour	Chips	Flour
98/0505	0.7750[a]	1.3500[ab]	4.00[a]	3.75[cd]	12.75[c]	71.50[a]
01/1412	0.3250[b]	1.3750[ab]	0.50[b]	2.25[d]	16.25[bc]	48.75[ab]
01/1371	0.3000[b]	1.6500[ab]	1.25[ab]	36.25[a]	17.25[a-c]	21.75[cd]
01/1368	0.2500[b]	0.6500[b]	2.50[ab]	16.00[bc]	27.75[a]	42.75[bc]
05/0473	0.2500[b]	2.4750[a]	2.25[ab]	1.50[d]	24.50[ab]	16.75[d]
05/1636	0.1500[b]	0.6750[b]	2.50[ab]	20.75[b]	24.25[ab]	31.50[b-d]

For each parameter and for each product, means followed by the same letters in the same column are not significantly different (P>0.05).

been reported to be a major pest of processed or damaged grain in storage (Haines, 1991). It is a polyphagous and cosmopolitan insect that has beenreported to have a long association with human stored food, but milled grain products such as flour appears to be preferred food (Campbell and Runnion, 2003). *T. casteneum* is a pest both as adults and larvae (Lale and Yusuf, 2001). It is an important secondary pest of most cereal grains especially maize, sorghum, wheat, millet and their products. It is also a serious pest in flour mills and wherever cereal products and other dried products are stored and/or processed. The pest has been reported to be prolific and has the ability to produce millions of progeny within a life span (Haines, 1991).

There is need to have accurate and current information on storage of cassava and its products, losses due to storage pests and the direct effect of infestation by this pest (*T. castaneum)* on stored cassava products. Six new cassava genotypes were subjected to *T. castaneum* infestation to assess their susceptibility as well as to determine quantitative and qualitative losses attributable to *T. castaneum* attack in storage.

MATERIALS AND METHODS

Insect rearing and culture

Adults of *T. castaneum* used to establish the culture were obtained from infested flour in a local market in Rumuokoro, Rivers State, Nigeria. The insects were left to breed in a series of 1-L Kilner jars under laboratory conditions (25 to 30°C and 70 to 90% RH) in the Faculty of Agriculture, University of Port-Harcourt. The age of the insects was standardized by sieving out the parental *T. castaneum* adults and used F_1 generation of known age as a sub culture.

Experimental materials

Chips and flour of six cassava varieties (01/1371 orange, 01/1412 orange, 05/1636 orange, 01/1368 orange, 05/0473 orange and 98/0505 white) were obtained from NRCRI, Umudike, Abia State, Nigeria, and used to evaluate their response to *T. castaneum* infestation in the humid Niger Delta region.

Experimental procedure

Approximately twenty grams of chips or flour of each variety were weighed using an electronic balance (model J2003) and put into jars and infested with eight pairs of *T. castaneum* adults. On day 7, these insects were sieved out and the eggs laid were allowed to develop.

Proximate analysis

Proximate composition of chips and flour derived from the six cassava genotypes was carried out prior to the commencement of the study at the biochemistry laboratory of NRCRI Umudike. The method of AOAC (1990) was used in the proximate analysis and alkaline picrate method (modified after Onwuka (2005) was used in cyanide determination.

T. castaneum progeny development

The adult progenies that developed in each jar after 30 days were counted and removed at the sight of first emergence. The pupae and larvae (immature) were sieved out and counted separately at the end of the experiment. Moisture content (wet basis) (Lale, 2002) was measured as the weight of water expressed as a percentage of the weight of the original material before the insects were introduced.

$$Mc = \frac{X-Y}{X} \times 100$$

Where; X= Original weight of material, Y= Final weight of material, X-Y= Weight of water, Mc=Moisture content.

The final weight of the chips and flour in each jar was taken and the difference between the initial weight and the final weight of the product introduced was regarded as the quantitative loss (g) of material due to *T. castaneum* infestation.

RESULTS

Table 1 shows the mean weight loss (g) of the two forms (chips and flour) of six cassava genotypes infested by *T.*

Table 2. Chemical composition of chips and flour derived from six cassava genotypes.

Cassava genotypes	M.C (%)	Crude fibre (%)	Fat (%)	Ash (%)	DM (%)	Reducing sugar (g/100g)	Cyanide (µg/g)	Total Carotenoid (µg/g)
98/0505 C	12.95	2.13	0.67	2.43	87.05	0.31	27	0.89
98/0505 F	11.60	1.43	1.23	1.40	88.40	-	21	-
05/1636 C	8.40	2.33	1.20	1.07	91.60	2.62	27	5.50
05/1636 F	8.40	1.67	0.40	1.80	91.60	-	30	-
01/1412 C	9.10	1.60	2.53	1.70	90.90	1.47	45	5.25
01/1412 F	9.05	2.07	2.97	1.26	90.95	-	56	-
01/1371 C	9.80	2.00	0.83	2.60	90.20	0.52	30	3.71
01/1371 F	9.90	2.03	1.93	2.10	90.10	-	40	-
01/1368 C	10.50	2.60	0.73	2.27	89.50	1.05	40	6.56
01/1368 F	8.70	2.03	1.23	2.03	91.30	-	28	-
05/0473 C	8.35	1.73	1.17	1.87	91.65	0.84	50	4.19
05/0473 F	8.90	1.57	1.13	1.20	91.10	-	30	-

Key: C= chips; F=flour.

castaneum and the number of teneral adults that developed in all products. There was a significantly higher (P≤0.05) weight loss on cassava genotype 98/0505 chips and variety 05/0473 flour while chips of cassava variety 05/1636 and flour of cassava genotypes 01/1368 and 05/1636 varieties had the least weight loss. Higher numbers of teneral F_1 adults was recorded in cassava genotype 01/1371 flour and chips of variety 01/1412 had the least adult progeny. However, variety 98/0505 flour had a significantly higher (P≤0.05) immature progeny than chips from the other varieties. With a few exceptions, however, cassava flour supported significantly more adults and immature *T. castaneum* progeny than chips; chips suffered significantly lower quantitative losses than flour.

Table 2 shows the chemical composition of the six cassava genotypes. Chips of variety 98/0505 had the highest moisture content while those of variety 05/0473 had the least moisture content. Cassava genotype 01/1368 chips contained more crude fibre than the other varieties. Higher percentage of fat was recorded in cassava genotype 01/1412 flour and the least in genotype 05/1636 flour. Variety 01/1371 chips had high value of ash while cassava genotype 05/0473 chips had higher dry matter content. Reducing sugar content was highest in cassava chips genotype 01/1636 and lowest in 98/0505 variety. Cyanide content was more in cassava variety 01/1412 flour and more carotenoid content in chips of cassava genotype 01/1368.

DISCUSSION

The study has shown that both products (chips and flour) of the cassava genotypes are susceptible to infestation by *T. castaneum* though to varying degrees. Cassava genotype 98/0505 which had high number of immature stages but relatively few adults in flour suffered more damage. This could be attributed partially to the high moisture content of this variety which may have favoured *T. castaneum* activities as earlier reported by Loko et al. (2013) that moisture content is a major constraint in yam chips storage especially in the traditional storage structures.

The result shows that weight loss was lower in chips than in flour in all the cassava genotypes. This could be attributed to the usual trend exhibited by secondary pests which are known to perform better and develop faster in flour than in chips or solid substrates (Lale and Ajayi, 2000). It suggests that storing these cassava genotypes in flour form is likely to aggravate the problem of infestation by secondary storage pests. Haines (1991) reported that *T. castaneum* being a secondary pest develops poorly or slowly on chips in storage. Trematerra et al. (1999) however, reported that damaged grain or flour releases some volatile compounds and these facilitate the attraction of secondary pests. The variation in degree of susceptibility observed across the different cassava genotypes showed that genotype 01/1412 was more resistant than the other genotypes to *T. castaneum* infestation.

Loss in quality ascribable to *T. castaneum* infestation includes reduction in loose and packed bulk densities of stored infested cassava varieties as a result of the activities of insects and micro-organisms (fungi and bacteria) (Zakka et al., 2010) though not evaluated in this research. Others include persistent objectionable odour imparted to the infested commodity due to secretion of benzoquinones from a pair of abdominal defense glands (Haines, 1991), the growth of moulds and caking of flours (Ehisianya et al., 2010; Zakka et al., 2010). However, the level of weight losses recorded in one generation across the genotypes confirms the report that *T. castaneum* is probably the most important secondary pest of a wide range of crop products in tropical storage environment and that its infestation results in colossal weight and quality losses (Haines, 1991).

The study has also shown that the number of adults as well as immature progeny were higher in flour than in chips; this concurs with the observation of Odeyemi (2001) and Turaki et al. (2007) that *T. castaneum* prefers flour for development; the implication of this observation is that cassava processed into flour is likely to enhance the development and survival of *T. castaneum* and that the cassava genotypes investigated in this study probably may not contain significant amounts of secondary compounds that could be anti-biotic against developing stages of *T. castaneum.* Earlier Zakka et al. (2010) reported that milling sweetpotato chips into flour could mean increasing the chances of the pest to pick up harmful amounts of these secondary compounds that will impede their chances of development and survival. This phenomenon does not seem to be of general application to all tropical roots and tubers. In the case of sweet potato more progeny developed in the chips than in the flour.

Conclusion

T. castaneum performed differently on the different forms and genotypes of cassava. It was observed that the insect is capable of posing a threat to processed cassava in store, if left uncontrolled. Control measures to mitigate the activities of the pest should be implemented in order to safeguard cassava products from infestation.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

A study on the causes of apple *(Malus Domestica)* fruit loss at Chencha Woreda of Gamo Gofa Zone, Southern Ethiopia

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Apple (*Malus domestica*) is a temperate climate fruit tree grown in the highland climates. Specifically, it is widely and largely cultivated in the Gamo Gofa administrative zone at Chencha woreda in Ethiopia. Although there is inadequate information regarding the cause of fruit loss, some other details reveal the production status of the fruit in the area. This study was aimed at assessing the causes of apple fruit loss at harvest, transport and storage conditions in the study area. Survey was done in selected twenty kebeles known for high apple fruit production. A total of 60 respondents (males and females) were purposely pre-selected with the help of woreda agricultural extension experts based on their experience in producing the fruit. Group discussion, interviews and field observation were held. Farmers were interviewed using easy and relaxed questionnaires. Data was analyzed using SPSS software version 20. From total respondents interviewed, 46.7, 53.3 and 43.3% of them reported fruit bruise and wound while harvesting, lack of appropriate box/bag during transport, absence of storage facility respectively accounted for the maximum loss of the fruit in the study area. Only 8.3, 10 and 11.7% of total respondents reported loading and unloading during transport, knowledge gap on how to pick the fruit at harvest along with apple varieties under cultivation and during storage aas factors for the loss of fruit. Therefore, provision of training on fruit postharvest management and handling, harvesting containers, bag/boxes and developing of storage technologies (local/improved) are vital.

Key words: Fruit loss, harvesting, transport, storage.

INTRODUCTION

Apple (*Malus domestica*) is a temperate climate fruit tree native to many parts of Europe and Asia. The leading apple growing country is China, producing about 41% of the world's apples, followed by the United States (Ferenc, 2008). Apple fruit tree was first brought to Chencha area in the Gamo hills by missionaries (Kale-Hiwot Church) about 60 years ago. Even though Ethiopia is not found in the temperate zone, temperate fruits like apple, pear and plum are currently widely adapted, grown and produced in Ethiopian highlands of the different regions by virtue of

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high altitude. The Chencha area, a district (Woreda) in the Gamo Gofa administrative zone of the southern region of Ethiopia, has nearly 50 years of experience in growing highland fruits including apple, pears and plums (Timoteos, 2008). Specifically, in Ethiopia apple is a widely and largely cultivated temperate fruit grown in the Gamo Gofa administrative zone at Chencha woreda. Following the expansion of its production in Chencha and other areas, there is a growing demand for apple in central and local markets in Ethiopia (Seifu et al., 2014).

Chencha district is conducive to producing more than 100 varieties of apples and also serves as a resource base for the rest of the country (Timoteos, 2008). According to Seifu et al. (2014), appropriate standards for tree management and agronomic practices have not been determined for successful apple fruit production in Chencha area. However, yields varied depending on varieties, age, tree management (pruning and training) and agronomic practices (watering, cultivation, manure application, disease and insect pest management) applied. However, the area is with such long years of experience in apple fruit tree production and management the fruit loss is very high during harvesting, transporting and storage time. Even though many factors accounted for the loss of apple fruit in the study area, these are the critical postharvest factors responsible for the loss of the fruit and the cause should be studied.

The production of apple fruit in the area have been impacting the livelihood and serves as a source of income for growers and small holders. The quality and condition of produce sent to market and its subsequent selling price are directly affected by the care taken during harvesting and field handling. However, there are many biotic and abiotic factors that could cause fruit loss and affects the fruit quality in Chencha district. According to Timoteos (2008), lack of capacity, knowledge and skills in fruit tree management, harvesting, transportation and storage systems were the identified problems that constrain the quality of apple production and marketing in the area, and needs intervention strategies to improve the system. Behailu and Sabura (2017) reported complete harvest and sale due to lack of storage facility as the common practice. These, at a time, creates a higher supply and lower demand in the market which results in lower fruit price and lower income to producers. Fruits are sold at farm gate price by producers and through different actors in the market chain reaches consumers at local and distance markets. Harvesting of the fruit in the study area have been done using hand picking by mere selection of the ripe fruit from the tree not considering maturity index factors. In the study area, while harvesting and transporting fruit bruise, breakage and wound are the commonly faced problems, these subsequently affects the fruit size, shape, color, quality and resulted in poor price (Woreda Agriculture and Rural Department Office - WARDO, 2014). In order to maintain quality and keep loss of fruit harvesting, transporting and storage should follow the basic principles and operations.

Growers should be skillful and have knowledge of how to harvest, transport and store the fruit to get quality apple fruit at the end. In Chencha district, there were no improved postharvest handling methods that have been developed and the loss was becoming very high due to inappropriate handling, harvesting, transportation and storage of the fruit. Thus, in this survey, specific factors that cause fruit loss during harvesting, transportation and storage of the fruit were studied at Chencha woreda of Gamo Gofa zone.

MATERIALS AND METHODS

Description of the study area

The survey was conducted in Gamo Gofa administrative zone of Chencha woreda, Southern Nations, Nationalities and Peoples Region (SNNPR). Chencha woreda is located in the Gamo Gofa administrative zone of the SNNPR of Ethiopia with an altitude ranging between 1600-3200 masl. Apple has become a very valuable crop in the area and is highly cultivated over large hectares. It has two agro-ecological zones: ‘dega’ (2300 – 3200 masl, 82%) and ‘woina dega’ (1500-2300 masl, 18%); with total area of 37,650 ha. The population of the woreda is 125,628 (Female: 66,363 and Male 59,263) and 21,655 households, of which 2461 households are female headed. It is one of the most populous districts in the zone. The major means of livelihood is subsistence agriculture followed by traditional weaving and causal labor employment (WVE, 2012). The woreda encompasses 50 (45 rural and 5 urban) administrative kebeles. The mean annual temperature and rainfall of the study areas are 22.5°C and 810 – 1600 mm/annum respectively.

Data collection, sampling and survey methods

Survey was done to assess factors that were contributed for loss of the fruit in the study area. The questionnaires were prepared to collect information about the causes of fruit loss during harvesting, transporting and storage of the fruit. Twenty potential apple fruit growing kebeles and three model farmer respondents from each kebeles’ were purposely preselected in the study area with help of woredas’ agricultural office extension experts. A total of 60 farmer respondents were listed in a separate sheet and used for the interviewee.

The survey data were collected with the help of validated and pre-tested interview scheduled through personal interviews by the researcher team and with the help of the woreda agricultural extension experts. The interviews and discussions were conducted in the local language (Gamugena). The causes of fruit losses at harvest, transport and storage condition were asked and recorded and discussions were made with respondents.

Methods of data analysis

The descriptive statistics was used and data were presented in percentages and tabulation form. The data were coded and entered in SPSS software version 20.

Table 1. Respondents' gender and household status.

Gender and household status	Frequency	%
Male led household	44	73.3
Female led household	16	26.7

Source: Own survey result (2016).

Table 2. Respondents' educational status.

Educational status	Frequency	%
Primary	15	25.0
Junior	12	20.0
High School	14	23.3
Diploma	11	18.3
Illiterate	8	18.3

Source: Own survey result (2016).

RESULTS AND DISCUSSION

Respondents' gender, household and educational status

From the total purposely pre-selected twenty potential apple fruit growing kebeles, 60 model farmers' respondents were interviewed and among this, 26.7% were females and 73.3% were males (Table 1)' this implied that most of the households in the area were headed by male than female. As indicated in Table 2, from the total, 25, 23.3, 20 and 18.3% of respondents were found to have attained primary, high school, junior education and diploma holders respectively. Only 13.3% of the respondents were illiterate. The finding showed that a large portion of the households attained primary and high school education. In line with this, Seifu et al. (2011) reported that most of the sampled respondents (39.8%) attained primary school education and 26.6% were above secondary school. Contrary to this study, they reported that a significant portion of the respondents (33.7%) had never been to school.

Fruit loss while harvesting

Apple fruit deterioration as well as quantity/physical losses starts from harvesting. The result showed in Table 3 revealed that from the total interviewed, 46.7, 25, 18.3 and 10% of the respondents reflected bruise and wound, lack of fruit picking bags, knowledge and awareness gap among fruit growers on how to pick the fruit are factors for the deterioration of apple. The respondents revealed that the causes vary in degree of fruit loss. In this finding, the respondents (46.7%) interviewed revealed that fruit bruise and wound due to either dropping or throwing fruit against other fruit or other surfaces, along with finger bruise contributed a lot to loss of the fruit. They claimed that this is probably due to improper hand harvesting, climbing on fruit tree and pulling down the fruit bearing branches. Harvesting of the fruit has been achieved in the area by hand picking and pulling down the fruit bearing branches According to Kupferman (2006), bruise has been a problem since apples were first harvested and harvesting activities play a major role in bruise development. In agreement to Wills et al. (2007), apple fruit is vulnerable to physical injury and hand harvesting is mostly used for fresh market. Lack of fruit picking bags (25%) is also another factor that leads to the loss of the fruit during collecting and harvesting since dropping of fruits thus results in mechanical damage to the fruit. According to Mitcham and Mitchell (2002), dropping of the produce is a common cause of impact damages. During the discussion, the respondents (18.3%) informed that breakages of fruit bearing branches when farmers' climbs on tall fruit trees or bend the branches mainly due to the lack of ladder while harvesting is responsible for loss of the fruit. This method disturbs the tree, usually causing other fruits to fall down to the ground and possibly leads to significant bruising. In line with this, Thompson (2003) has stated it is difficult to harvest the apple fruits which are bearing on trees and conventionally the picker would carry a ladder and use that to reach the fruit. Only 10% of the respondents confirmed that knowledge and awareness gap among fruit growers of how to pick the fruit is another factor for the loss of produce by creating unnecessary mark or damage on the surface of the fruit while detaching the fruit from the tree. According to Timoteos (2008), lack of capacity, knowledge and skills in fruit management and harvesting is one of the constraints that lead to fruit loss in the study area.

Fruit loss during transport

Handling and transport, represents a serious hazard to quality and has the potential to significantly reduce the value of the product (Van Zeebroeck et al., 2007). In this finding, as presented in Table 4, and from the total interviewed, 43.3, 33.3, 15 and 8.3% of the respondents reported that lack of appropriate bag/boxes, fruit bruise and wound, poor transportation system along with loading and unloading, respectively accounted for the loss while transporting the fruit. In this study, the respondents (43.3%) explained that apple fruit produced in the study area has been marketed by different actors in the market chain until it reaches the consumer; however, no designed boxes or bags are available to bring the fruit to distant and nearby places. Therefore, after harvesting, the apple fruit still faced different challenges that would result to loss and damage of the fruit. The respondents confirmed that sacks and locally prepared material from bamboo "kirechat" are mostly used as a box or container.

Table 3. Respondents' response about the causes of fruit loss while harvesting.

Cause of fruit loss	Frequency	%
Bruises and wounds	28	46.7
Lack of fruit picking bags	15	25.0
Breakages of fruit bearing branches during harvesting	11	18.3
Knowledge and awareness gap of how to pick the fruit	6	10.0

Source: Own survey result (2016).

Table 4. Respondents' response about the causes of fruit loss during transportation.

Cause of fruit loss	Frequency	%
Lack of appropriate box or materials	26	43.3
Bruises and wounds	20	33.3
Poor transportation system	9	15.0
Loading and unloading	5	8.3

Source: Own survey result (2016).

Table 5. Respondents' response about the causes of the fruit loss during storage.

Cause of fruit loss	Frequency	%
No storage system adopted or introduced	32	53.3
Lack of appropriate storage box	13	21.7
Shrinkage and weight loss	8	13.3
Varieties cultivated	7	11.7

Source: Own survey result (2016).

They reported that even tough disposable "carton'', which is left from other use, was used as a bag/boxes to bring the fruit to distant places since the maximum weight load per small carton size results in the fruit bruised, suffocated and heated due to maximum temperature inside carton. However, there are cooperatives engaged in fruit marketing and have been using plastic containers for collection of the fruit from their members, though this is insufficient and small in number. In line with the study, Mohammad (2011) reported that improper bags used by farmers possibly results in damages to the fruits.

According to respondents (33.3%), bruise and wound was probably due to fruits constantly hitting the side of the container, fruits hitting each other, along with excess loading are factors for the deterioration of the fruit during transportation. Similarly, Knee and Miller (2002) reported that during fruit transportation, bruising is the major postharvest mechanical damage problem. Dynamic forces during fruit transport and handling cause is by far the most bruise damage (Van Zeebroeck et al., 2007). They reported also that poor transportation system (15%) due to speeding vehicle on rough road, sudden starting or stopping of vehicle, vibration of the vehicle causing load movement also accounted for the loss of the fruit. In general, they confirmed that public transport or "Isuzu Track" have been used to bring the fruit to distant places; and sometimes, animals or in animal-drawn carts and manpower (mostly females' for long distances) were used for local market, which would damage and enhance the deterioration until the fruit reaches the consumer. 8.3% of respondents also revealed that loading and unloading during transportation is another factor for deterioration of the fruit. They confirmed that fruit loading mostly done from the outside, exposure to unnecessary heat shock, little or no care during loading and unloading, overloading and throwing or dropping are factors for the loss of fruit. Public transport vehicles or Isuzu Track was the main means of transport used. According to Van Zeebroeck et al. (2007), every time there is an unloading of the container a danger exists for impact with other fruit, containers and equipment used to sort and pack the fruit.

Fruit loss during storage

The results shown in Table 5 from the total interviewed revealed that 53.3, 21.7, 8 and 7% of respondents reported lack of storage system, lack of appropriate box, weight loss and shrinkage and varieties under cultivation, respectively as factors responsible for deterioration of the fruit. From the total respondents interviewed, 53.3% of the respondents confirmed that since there is no storage system adopted or introduced in the study, harvesting is mainly dependent on the availability of market and subsequent harvesting would occur in different period of time depending on the fruit maturity and the available market. Similarly, Girmay et al. (2014) in their research finding described that absence of cold storage in study area limited the availability of the fruit throughout the year. In line with this, Behailu and Sabura (2017) reported that since there are no storage facilities in the area, to balance the demand and supply, fruits are sold at farm gate price by producers and through different actors in the market chain. The complete harvest and sale at a time creates a higher supply and lower demand in the market which results in lower income to producers. On the contrary, 21.7% of the respondents reflected that if appropriate box is available, the fruit can be stored at their homes for 3 – 4 weeks and retailed for consumers. According to Mohammad (2011), retailers store their apples in their shops for 1.5 months as an average, and have no proper storage room to control the relative humidity and temperature.

From the total, 8% of the respondents reported that fruit weight loss and shrinkage, along with retailers storing of their apples at their homes are factors for the loss of the fruit. They confirmed that this is due to the improper stage of maturity at picking and handling of the fruit before storage. According to Kader (2006), picking and handling will help reduce crop losses. Weight loss and decay during storage can greatly affect marketability. Weight loss during storage depends on fruit maturity at harvest time (Ghafir et al., 2009; Schrader et al., 2009). Only 7% respondents notify that the fruit from some varieties (Crispin) are easily more prone to deteriorate and lost than others after harvested. In line with this Seifu and Berhanu (2014) reported appropriate varieties need to be selected in terms of shelf life and resistant to diseases and insect pests. Variety selection remains the most important hindering factor for successful apple production in Chencha area.

CONCLUSION AND RECOMMENDATION

Quality loss and deterioration as well as quantity/physical losses start from harvesting of apples. The study confirmed that fruit bruise and wound, lack of appropriate bag/boxes, and lack of storage facility are the main factors responsible for loss of fruit during harvesting, transport and storage respectively. Lack of postharvest storage facilities in the study area are one of the limiting factors for fruit loss. Improper handling of the fruit during harvesting, transportation and storage were serious problems to the producers. Growers should be skillful and have knowledge about how to harvest, transport and store their fruit to get quality apple fruit and high price at the end. The study showed that provision of training on the fruit postharvest management and handling, harvesting containers, bag/boxes and developing of storage technologies (local/improved) are vital and a call for higher institutions, NGOs and governments. There should be intervention polices and integrated approach to reduce the loss of the fruit in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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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.

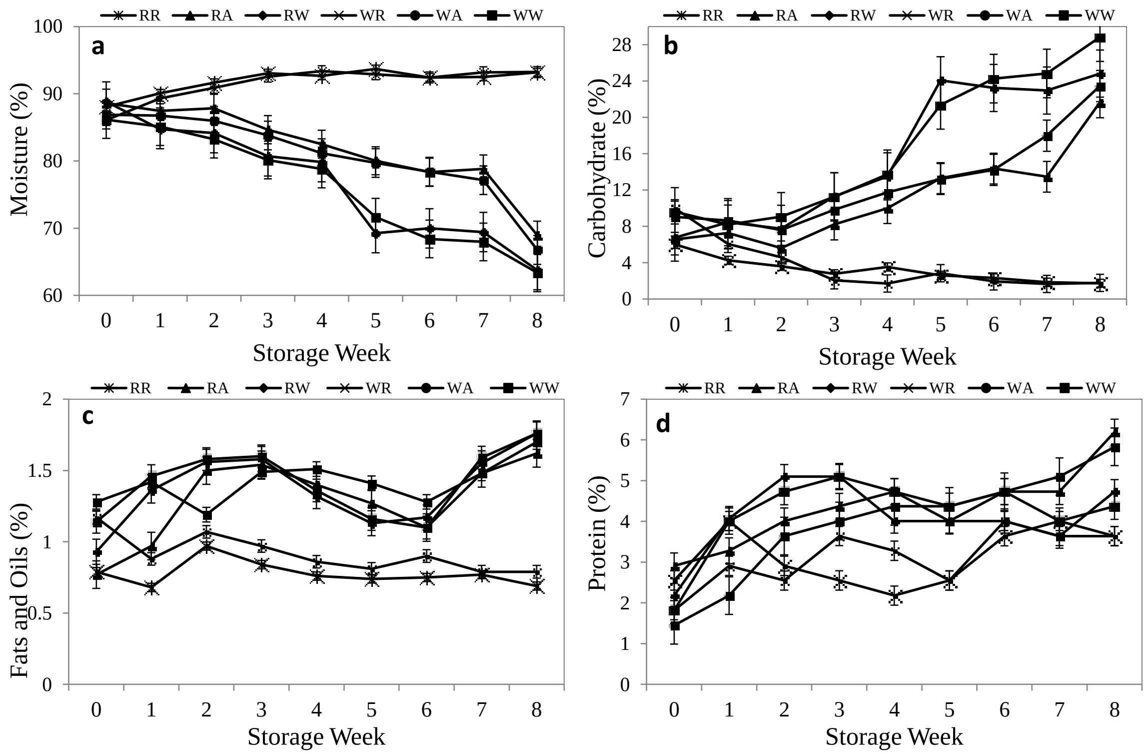

Figure 1. Changes in (a) moisture content (b) carbohydrate (c) fats and oils and (d) protein content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition,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

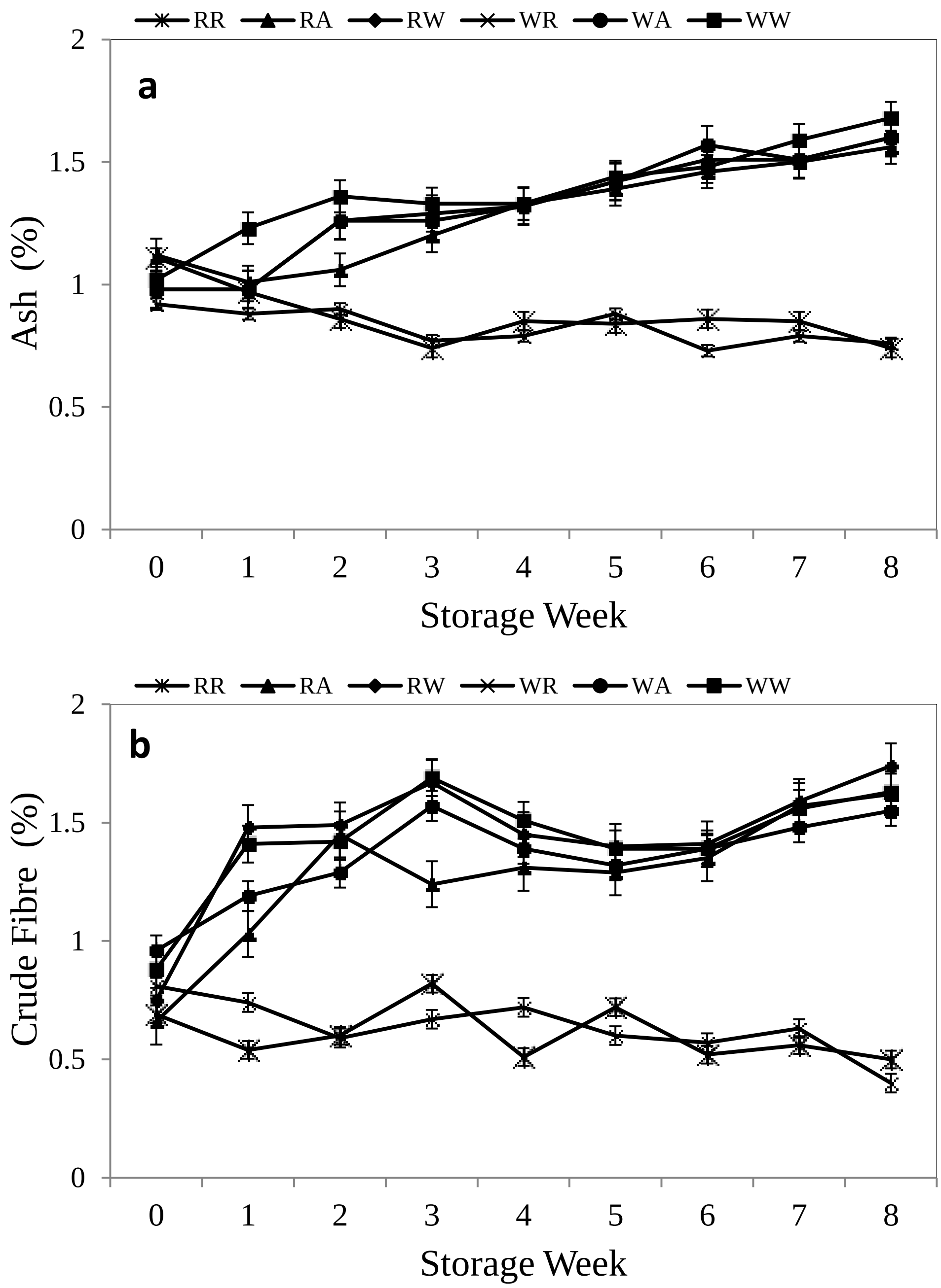

Figure 2. Changes in (a) ash content and (b) fibre content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm storage, WW: white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

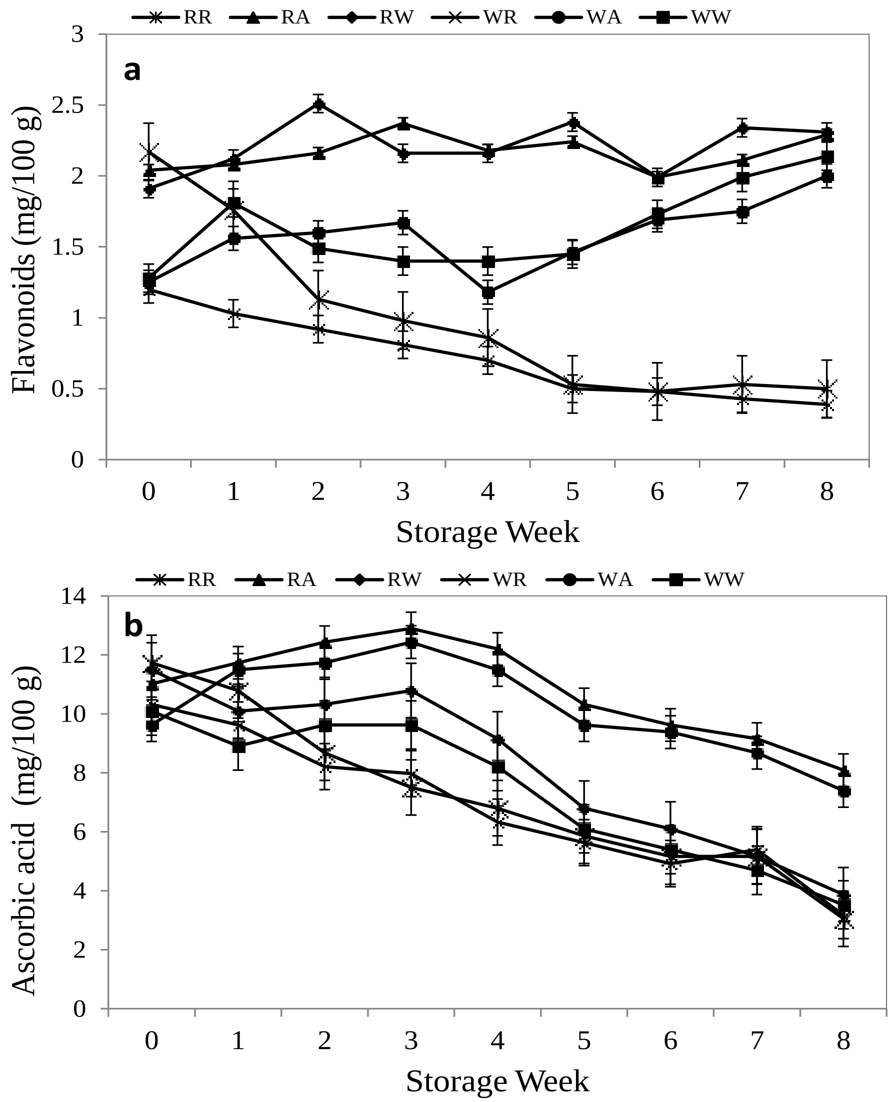

Figure 3. Changes in (a) total flavonoid content and (b) ascorbic acid content of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in warm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

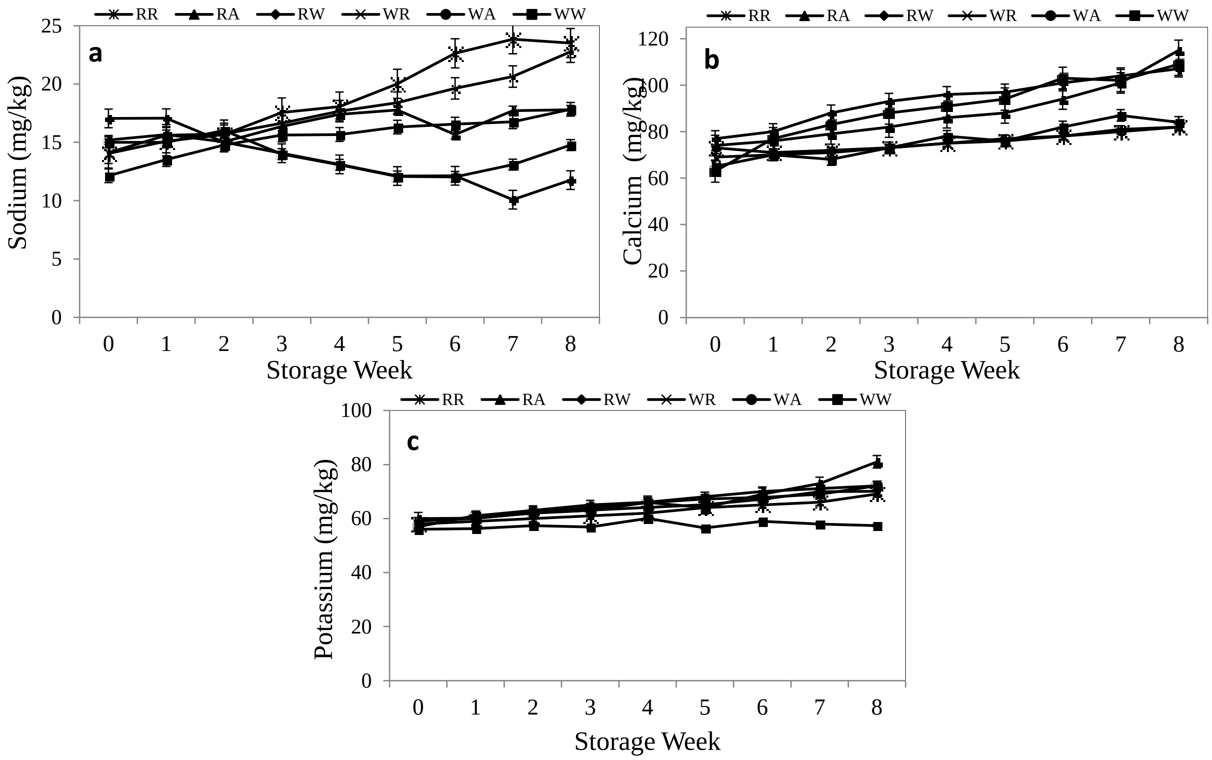

Figure 4. Changes in the mineral: sodium (a) calcium (b) and potassium (c) contents of onions stored under different postharvest conditions (RR: red onion under refrigeration WR: white onion under refrigeration, RA: red onion in ambient condition, WA: white onion in ambient condition, RW: red onion in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