jpht

Research Article

Journal of Postharvest Technology
02 (03): 177-187, July' 2014
www.jpht.info

Physico-Chemical and Textural Changes in Elephant Foot Yam (*Amorphophallus paeoniifolius*) Tubers Infested by the Mealy Bug, *Rhizoecus Amorphophalli* Betrem during Storage

Sreerag R.S, Jayaprakas C.A, Sajeev M.S

Central Tuber Crops Research Institute, Sreekariyam
Thiruvananthapuram 695 017, Kerala, India

Received : 20 April 2014
Revised : 24 May 2014
Accepted : 01 June 2014

Keywords

Rhizoecus amorphophalli, Elephant foot yam, Tubers, Storage, Physico-chemical properties, Texture

Abstract

Elephant foot yam, *Amorphophallus paeoniifolius* is an edible aroid cultivated in the tropical countries. Corm or tuber is the storage organ and is used as seed material or as a vegetable after cooking. Owing to the indisputable palatability, cooking quality, medical utility and therapeutic values of its tubers, this has been dubbed as "King of tubers". Infestation by the mealy bug, *Rhizoecus amorphophalli* is a serious problem during its long-term storage. This study aims at analysing the physicochemical and textural changes in the mealy bug infested tubers of elephant foot yam. For the study, infested and uninfested tubers were stored for 4 months at ambient conditions and data on the physico-chemical and textural changes were evaluated at monthly interval. The moisture content showed a regular decreasing trend in both uninfested and infested tubers registering higher loss for infested set throughout the storage period. Starch and sugar content decreased with storage period whereas fibre and ash content increased. Functional properties of flours from the uninfested tubers were low compared to the infested tubers and these parameters slightly increased with storage period. Texture profile analysis showed that the firmness of the infested tubers were more than that of the uninfested tubers in their native form.

INTRODUCTION

Elephant foot yam, *Amorphophallus paeoniifolius* (Dennst.) Nicolson is one of the most widely cultivated edible aroids of humid tropics and its cultivation is very much prevalent in Philippines, India, Malaysia, Indonesia, China, Sri Lanka and many other Southeast Asian countries (Ravi et al. 2009; Sankaran et al. 2011). India is a major producer of this crop, with productivity potential of 30-100 t/ha (Ravi et al. 2011). The tubers of elephant foot yam are commonly used as a vegetable after cooking and in preparation of indigenous ayurvedic medicines (Mishra et al. 2002). The tubers are cheap source of starch, vitamins and minerals (Bradbury and Holloway 1988), and play a vital role in food security and are the important staple or subsidiary food for a large population (Ramanandam et al. 2008; Quaye et al. 2009).

During storage, mealy bugs and scale insects are the major pests attacking the tubers of elephant foot yam. Palaniswami and Pillai (1979) recorded two species of mealy bugs *viz*. *Pseudococcus longispinus* Targioni-Tozzetti and *Rhizoecus* sp., whereas during the last few decades the

* *Email: sreerag6989rs@gmail.com*

ISSN 2348-4330

mealy bug, *R. amorphophalli* has emerged as a noxious pest infesting on stored tubers of elephant foot yam (Rajamma et al. 2002, 2006). The mealy bug produces a white, waxy substance and due to prolonged infestation the tuber gets disfigured by this substance. The gregarious nature of this pest speeds up the disfiguration which affects the acceptability and marketability of the tubers. Relentless infestation results in vast economic loss for the farmers and large quantities of stored tubers are rendered unfit for human consumption as a result of the pest attack. Different storage damages and quality changes of stored tubers of cassava, yams and aroids have been discussed earlier (Raja et al. 1978; Ravi and Aked 1996; Ravi et al. 1996). Texture is the most important factor in determining the overall quality and consumer acceptability of fresh fruits and vegetables (Sajeev et al. 2008). Knowledge of the textural properties of tuber crops as measured by objective instrumental methods is essential for understanding their behavior under mechanical forces, which in turn helps to check the quality deterioration if any due to insect attack.

Reports on the quality changes for the tubers of elephant foot yam having a rich amount of starch and a good source for minerals and vitamins due to infestation of the mealy bug is scanty. Hence, this study was aimed at analyzing the physico chemical and textural changes of elephant foot yam due to the infestation of mealy bug during storage.

MATERIALS AND METHODS

Materials

Fully matured, fresh, insect free tubers of elephant foot yam, 24 numbers and each one weighing between 500-1250 g, obtained from the farm of Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala were segregated into two sets (12 tubers each) and stored separately in storage racks for four months with an average temperature regime of 30.80-35.93°C and relative humidity 64.48±8.72% (see Fig. 1).

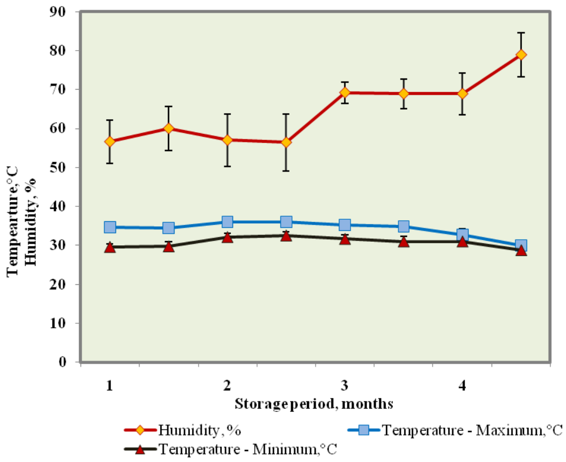

Fig 1. Temperature and relative humidity in the storehouse of elephant foot yam

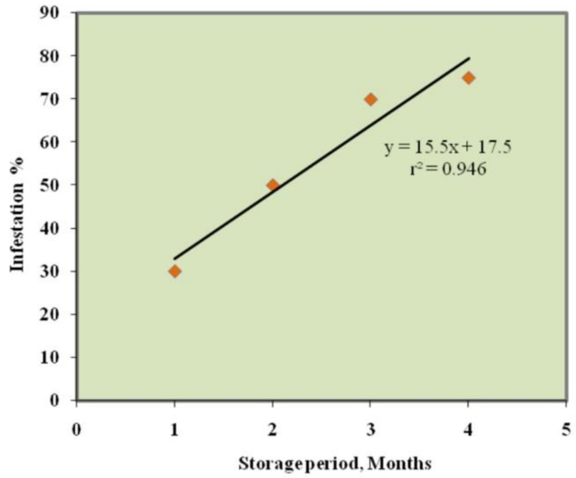

Fig 2. Infestation of R*hizoecus amorphophalli* on the tubers of elephant foot yam during storage

One set was maintained insect free and categorized as uninfested (UI), and the other set was kept for natural infestation (I). Monthly, three tubers were selected from each categories and physicochemical analysis were done. The uninfested set was monitored every week and the tubers were cleaned to ensure them free from mealy bug infestation. Under the infested category, the tubers taken for the analysis at each month were observed individually. Based on the intensity of infestation, the tubers were scored from I to V with the infestation level 20, 40, 60, 80 and 100% respectively.

Moisture content

The moisture content of the sample was measured on fresh weight basis by drying about 10 g of the tubers in a hot air oven at 105 ^{o}C till constant weight was obtained. Moisture content was calculated as the ratio of the weight of moisture evaporated to the initial weight of the sample and expressed as % (fb).

Preparation of Flour

The flour was prepared by drying the peeled and sliced tubers in a hay drier at 50oC. The dried tubers were powdered using laboratory grinder (Cyclotech 1093 sample mill), and the flour was used for all the biochemical analysis.

Biochemical analysis

All biochemical tests including starch, sugar, fibre and ash content of the dried flour were determined by AOAC (1975) methods.

Starch and sugar

One gm of flour sample was mixed with 20 ml of 80% ethanol and kept overnight. It was filtered and to the filtrate 1 ml of concentrated HCl was added and kept for hydrolyses on a hot plate. The solution was made up to 25 ml and then titrated against a mixture of 5 ml potassium ferricyanide (1%) and 5 ml NaOH (2.5 N) to obtain the value of sugar. The residue was transferred into a conical flask and 20 ml of 2 N HCl was added and hydrolyzed. It was made up to 100 ml and titrated against a mixture of 10 ml of potassium ferricyanide (1%) and 5 ml of NaOH (2.5 N) and the titer value (T) was observed. Starch and sugar were estimated as given below.

Starch content of flour samples = 90/T
Sugar content of flour samples = 12.5/T

Fibre

Flour, (5 g) was taken in a beaker into which 200 ml of 1.25% H2SO4 was added. After boiling for 30 minutes, it was cooled and filtered using muslin cloth. The residue collected was added with 200 ml of 1.25% NaOH and boiled for 30 minutes. After filtering, the residue was taken in a pre weighed Petri dish and oven-dried at 105°C till the weight remained constant.

Ash

Flour samples were taken in a pre weighed crucible and the total weight was recorded. It was then placed in the muffle furnace at 500°C for 5 hours and on cooling at room temperature (32°C) its weight was further taken. Amount of ash was represented as ratio of differences in final weight with respect to the weight of sample taken initially (5 g).

Functional properties

Swelling volume and solubility of flour was determined by the method of Schoch (1964) using 400 mg flour in 40 ml distilled water. Flour (400 mg) was taken in a 100 ml conical flask and into which 40 ml of distilled water was added. It was kept in water bath and swirled vigorously till the flour completely gelatinized. The flask was again kept in the water bath for 15 minutes after complete gelatinization with occasional swirling. Subsequently it was taken out and cooled to room temperature (32°C). The contents were centrifuged at 2200 rpm for 15 minutes.

The volume of gelatinous precipitate (V) was noted and the swelling volume was calculated as follows:

Swelling volume of sample = Volume of gelatinous precipitate (V) × 2.5 ml/g

Ten ml of the supernatant of the centrifuged material after the swelling volume test was transferred into pre weighed Petri dish. It was kept at 100ºC for 3-6 h and the weight of the soluble material was calculated as shown below

Solubility, % = weight of soluble starch × 400/weight of sample on dry basis

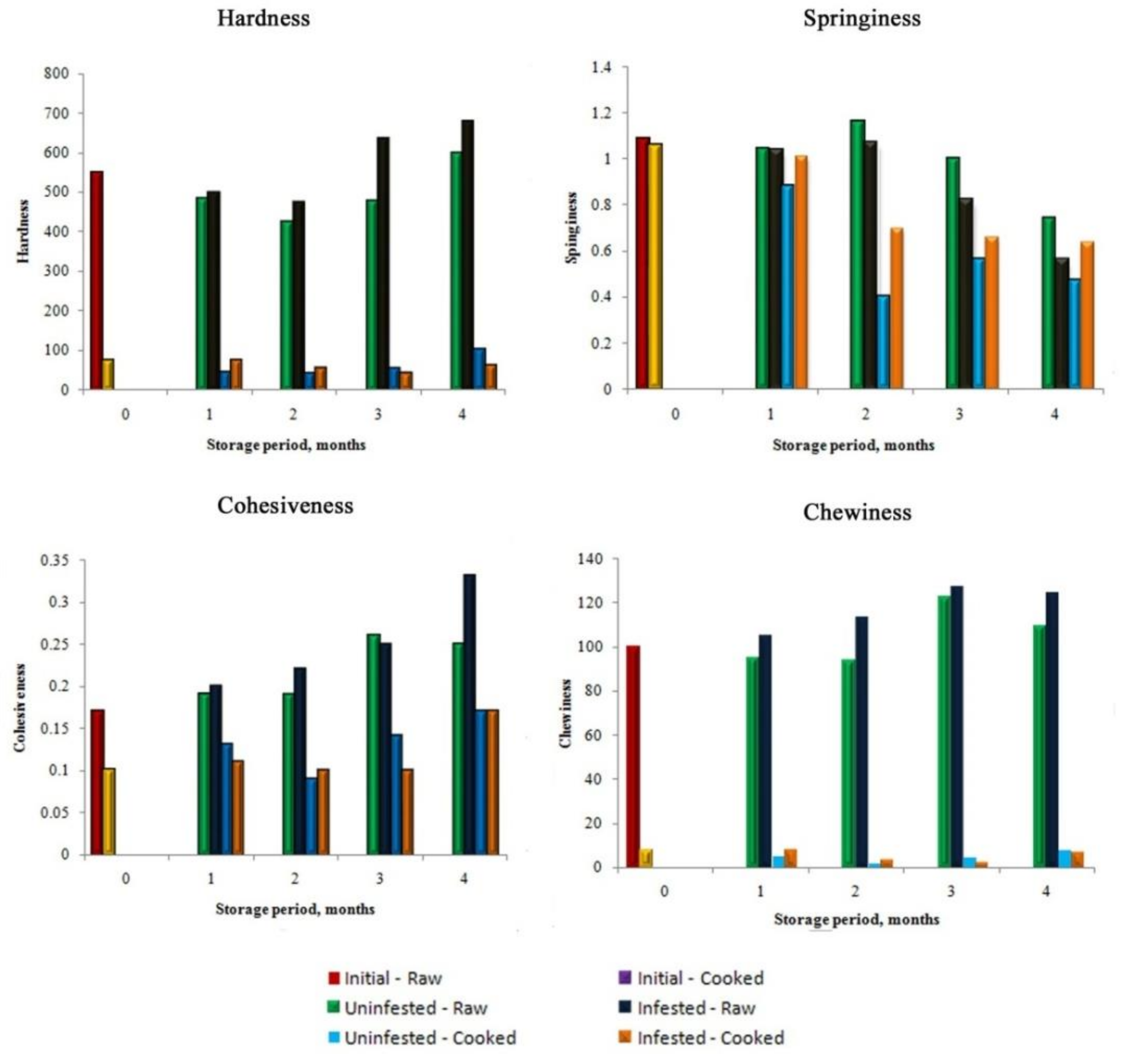

Fig 3. Texture profile of uninfested and infested raw and cooked tubers of elephant foot yam

Textural properties

Tubers after peeling and washing were cut into 15 mm cubes using a hand slicer and were cooked for 30 minutes in a boiling water bath. To avoid the direct contact with the bottom of the water bath, the cubes were taken in a wire mesh baskets for cooking. Cooked samples were allowed to cool at room temperature and the textural properties were determined using a TA HDi food texture analyser

(Stable Microsystems, Surrey, UK) with built-in Texture Expert Exceed software. Texture profile analysis was carried out at a test speed of 2 mm/s for 25% compression with a time lag of 1 s. From the Texture Profile Analysis (TPA) curve the following parameters were calculated according to the method of Bourne (2002): hardness (height of the force peak on the first compression cycle), springiness (distance by which a food recovers its height during the time between the end of the first bite and the start of the second bite), cohesiveness (ratio of the positive force areas under the first and second compressions) and chewiness (energy required to masticate a food, being the product of hardness, cohesiveness and springiness).

Statistical analysis

Statistical analysis was done by analysis of variance (ANOVA) in a random block design and pair-wise comparison was carried out by Duncan's multiple range test (DMRT, $P < 0.05$) using SPSS 17.0.

RESULTS

Infestation percentage

During the first two months of storage, the intensity of infestation was minimal and it ranged from 30-50%. Infestation increased rapidly and covered the entire tubers within four month of storage. A positive linear correlation between the infestation by mealy bug and storage period was noted (see Fig. 2).

Moisture

Moisture content of the tubers was high at harvest, but it declined on long term storage, particularly in the mealy bug infested tubers. The MC at the time of harvest was 81.83% but on 4 months after storage it reached to 74.15% in uninfested and 64.95% in infested tubers (Table 1).

Starch and sugar

Both the starch and sugar content decreased in accordance with the duration of storage. The infested tubers showed low values for starch and sugar than the uninfested tubers, especially after the third month of storage. The initial starch content (33.58%) gradually reduced by 11.25% for uninfested and 15.12% for infested tubers after second month, and 30.40% and 34.63% respectively, after four months of storage. The initial sample had 7.57% sugar which reduced to 5.06% for the uninfested set and 5.81% in the infested, after the fourth month of storage (Table 1).

Fibre

Fibre content of the initial sample gradually increased up to three months of storage for both infested and uninfested tubers; subsequently it declined (Table 1). The fibre content increased from 2.66 to 5.03% for the uninfested and 4.28% for the infested tubers at the end of 3rd month and further reduced to 4.21 and 3.86% respectively.

Ash

Although there was no significant difference in the ash content on storage in uninfested and infested batch, it was slightly higher for the infested tubers (Table 1) throughout the study period.

Swelling volume and solubility

Swelling volume of the flours, both infested and uninfested increased on storage, and recorded a hike from 11.25 to 15.00 ml/g in uninfested and 16.25 ml/g in infested, after four months of storage (Table 2). Solubility also increased from 9.28 to 12.50% in the uninfested and 16.18% in the infested tubers at the 4th month analysis.

Texture profile of raw and cooked tubers

Hardness of the raw uninfested tubers decreased from 550.07 to 421.57 N in the 2nd month of storage; thereafter an increasing trend was observed (Fig. 3). In case of infested raw tubers, the hardness decreased slightly from 550.07 N to 472.75 N after 2 months of storage and thereafter increased to 631.71 and 675.80 N in 3rd and 4th months, respectively. After 2 months of storage, when the tuber was cooked the hardness changed from 72.26 to 40.92 N in the uninfested tuber, and after 3rd and 4th months it was 53.83 and 98.68 N respectively. In the case of infested tubers when cooked, the hardness dropped down to 53.49 N after 2 months, subsequently increased to 60.51 N after 4 months.

Table 1. Biochemical parameters of uninfested and mealy bug infested tubers of elephant foot yam during storage period

Storage period (months)	Moisture (%)		Starch (%)		Sugar (%)		Fibre (%)		Ash (%)	
	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested	Uninfested	Infested
0	81.83±0.66^{a}		33.58±0.00^{a}		7.57±0.06^{a}		2.66±0.19^{c}		4.84±0.02^{a}	
1	80.73±0.04^{a}	80.35±0.49^{a}	31.58±0.46^{b}	31.57±0.16^{b}	6.79±0.10^{b}	6.79±0.00^{b}	2.71±0.15^{c}	2.54±0.28^{c}	4.59±0.03^{a}	5.19±0.03^{a}
2	80.64±0.29^{a}	71.55±0.62^{bc}	29.80±0.00^{c}	28.50±1.53^{d}	6.18±0.00^{c}	6.15±0.04^{c}	4.47±1.23^{ab}	3.39±1.17^{bc}	4.51±1.45^{a}	5.23±1.42^{a}
3	76.47±4.67^{ab}	67.59±0.21^{cd}	27.52±0.12^{d}	27.60±0.19^{d}	6.11±0.06^{c}	5.92±0.03^{d}	5.03±1.28^{a}	4.28±0.22^{ab}	4.76±0.79^{a}	5.40±0.89^{a}
4	74.15±1.20^{b}	64.92±4.78^{d}	23.37±0.08^{e}	21.95±0.14^{f}	5.81±0.03^{d}	5.06±0.02^{e}	4.21±0.52^{ab}	3.86±0.16^{abc}	4.98±0.00^{a}	5.40±0.40^{a}

Means with the same letter in a parameter are not statistically significant by DMRT ($P < 0.05$)

Table 2. Swelling volume and solubility of uninfested and mealy bug infested elephant foot yam tubers during storage

Storage periods	Swelling volume		Solubility	
	Uninfested	Infested	Uninfested	Infested
0	11.25±1.76^{c}		9.28±1.45^{a}	
1	12.50±0.00^{bc}	13.75±1.76^{abc}	11.34±3.40^{a}	14.06±0.00^{a}
2	12.50±0.00^{bc}	12.50±1.76^{bc}	11.00±3.80^{a}	14.43±0.00^{a}
3	13.75±1.76^{abc}	15.00±0.00^{ab}	10.46±0.22^{a}	15.93±3.09^{a}
4	15.00±0.00^{ab}	16.25±1.76^{a}	12.50±1.76^{a}	16.18±2.56^{a}

Means with the same letter in a parameter are not statistically significant by DMRT ($P < 0.05$)

There was not much change in the springiness values of the raw uninfested tubers till the 3rd month of storage; the changes was from 1.09 to 1.00, and further dropped to 0.74 after the 4th month (see Fig. 3). While in the raw infested tubers, there was no appreciable change for the first two months of storage, but a drastic reduction was observed on 3rd and 4th month of storage. But in case of cooked samples, the value reduced from 1.06 to 0.47 for the uninfested tubers and to 0.64 for the infested tubers in the 4th month of storage.

Cohesiveness of the raw uninfested tubers increased from 0.17 to 0.19 after the second month and increased to 0.26 on the 3rd month of storage (Fig. 3). Similarly, in the case of raw infested tubers the initial value (0.17) gradually increased to 0.33 after 4th month. There was no significant change in the cohesiveness of uninfested cooked tubers on storage. Infested cooked tubers did not change its value till the 3rd month; however it increased slightly to 0.17 after 4th month of storage.

Chewiness of the raw uninfested tubers reduced from 100.00 to 94.24 during the first two months, and later increased on 3rd and 4th months to 122.78 and 109.79 respectively (Fig.3). In the case of infested raw tubers, chewiness increased on storage and showed maximum value of 127.05 at the third month. For the cooked uninfested samples, the values decreased from 7.81 to 1.53 after 2 months and then increased to 8.01 after 4th month of storage. When the infested tubers were cooked, the chewiness increased from the initial stage (7.81) to 8.23 at the first month, subsequently the value declined. However, the chewiness again increased to 6.78 at 4th month of storage

DISCUSSION

Generally, all tubers are prone to rapid moisture loss on storage (Ravi and Aked 1996). High respiratory activity of tubers on storage contributes to the severe water loss from the tissues (Coursey 1968). Moisture loss at a rate of 6-10% was recorded in tubers of *D. dumetorum* even 72 h after harvest (Afoakwa and Sefa-Dedeh 2002). Treche and Agbor-Egbe (1996) recorded a moisture loss of 31% in *D. rotunda* and 35% in *D. dumetorum* after 110 days of storage.

Insect infestation accelerates the damage to the stored products in addition to the natural storage damage (Barak and Harein 1981). Tubers, especially with high moisture content, are always prone to insect infestation. The stored EFY tubers infested by *R. amophophalli* were succumbed to reduction in moisture and sudden shriveling (Palaniswami 1994). Present study revealed that moisture loss was minimal at the initial stage of storage, but as the infestation increased this loss also increased considerably. In the infested tubers there was 20.62% moisture loss as against only 9.38% in the uninfested tubers on 4th month after storage. Post harvest weight loss of yam tubers at rate of 21.60% due to insect infestation in addition to normal respiration was reported (Vasquez and Buyser 2007). As the damage by insect infestation leads to mechanical injury on the tuber, it facilitates fast rate of water loss. In the case of grains, the reduction in moisture content may be attributed to the metabolic activity of insects and pathogenic infection as a result of insect infestation (Howe 1973). Insect pests in grains directly attack and reduce the quality and indirectly provide avenues for fungal growth which in turn leads to increased respiration and loss of moisture (Odogola 1994).

During storage of tubers, the reserve carbohydrate (starch) gets hydrolyzed into sugars and this will be utilized for sprouting (Sundaresan et al. 1990). Ravindran and Wanasundera (1992) observed a gradual reduction in starch content for tubers of *Dioscorea alata* and *Dioscorea esculenta* when stored for 150 days. Similarly, Sundaresan et al. (1990) studied biochemical changes in three species of stored yam tubers and observed a significant decline in starch content according to the storage period. They observed that the rate of reduction of starch in tubers of *Dioscorea rotunda* as 24.95% during the second month and became 28.33% after 4 months of storage. Such rapid degradation of starch from tubers of *D. dumetorum* on storage was also reported by Sefa-Dedeh and Afoakwa (2002).

In the present investigation also a significant ($P < 0.05$) reduction in the starch and sugar was noticed which can be attributed to the early sprouting of both infested and uninfested tubers. Ikediobi and Oti (1983) reported that the sprouting-associated degradation of sugar for energy via. the glycolytic pathway and the TCA cycle accounts for the steady decline in tuber starch throughout the storage. Otherwise, starch and sugar content of the infested tubers were less compared with the uninfested in the last 2 months of storage. Sucking pests feed the sugary juice from their host, and depletion of the sugar would be compensated from the reserved starch by hydrolysis. Increased mealy bug infestation during the last 2 months contributes to the intense loss in sugar content and consequent decline of starch. El-Dein et al. (2009) and Eid et al. (2011) observed reduction in sugar level and subsequent decline in total carbohydrate when pink mealy bug, *Saccharicoccus sacchari* Cockerell feed on sugarcanes.

While storing tubers for long period an increase in the fibre content was reported by Brillouet et al. (1981). Afoakwa and Sefa-Dedeh (2002) reported that the increase in fibre content contributes to the hardening phenomenon of the stored tubers. Present study also showed an increasing trend of hardness according to storage period. Quality change study in cassava chips infested by insects showed that the crude fibre content underwent reduction with insect infestation, the reduction being more pronounced in fully infested chips (Premkumar et al. 1996). These results were attributed to the utilization of crude fibre during insect feeding. The slight variation of fibre content among uninfested and infested tubers in the present study might be due to the feeding of mealy bugs.

Ash content of the *D. dumetorum* increased on storage and explained that such increase was due to the decreased moisture content (Medoua et al. 2005). During storage of tubers, the infested tubers significantly lost their MC faster than uninfested tubers, which in turn contributed for slightly higher ash. Increased ash content in nutritional composition of wheat kernel due to khapra beetle infestation was also reported (Ahmedani et al. 2009).

Present study showed that swelling volume and solubility of the flour from infested and uninfested categories increased on storage. During storage of tubers, intrinsic enzymes break down some of inter molecular bonds in starch molecules leading to higher swelling (Singh et al. 2005; Aprianita et al. 2009). Swelling volume of the flour collected from infested tuber showed higher values than the flour extracted from uninfested tubers. The starch consists of amorphous crystalline regions where some hydrogen bonds might be broken down by the amylolytic enzymes produced by the mealy bug and causing increased swelling volume. Several insects, especially those feed on starchy food (Strobl et al. 1998; Franco et al. 2000) hydrolyze starch using amylolytic enzymes as they are key enzymes in this process (Henrissat et al. 2002). Mehrabadi et al. (2010) reported that while feeding, the sunn bugs, *Eurygaster integriceps* Puton inject amylolytic enzymes into the wheat causing breakdown of the gluten which reduces the quality of the flour. Even, the post hardening and sprouting of the tubers *D. dumetorum* lead to an increased swelling volume of their flour samples (Medoua et al. 2005). This was also confirmed by the solubility values which increased steadily in the starch of infested tuber. Due to the enzymatic action triggered by the pest, the broken starch can soluble faster.

Texture profile analysis revealed an increasing trend in hardness for both categories, but the infested tubers were harder than that of the uninfested tubers in their native form. an increase in hardness was observed for *D. dumetorum* tubers on storage and attributed this change to the declining moisture and starch content (Sefa-Dedeh and Afoakwa 2002). Rapid water removal from the tubers might have caused the cell wall polysaccharides to shrink, permitting greater interactions by means of hydrogen bonding and Van der Waals forces, resulting in cell rigidity in the form of thickening of cell walls and middle lamella in the cells of tubers and lignification of the tissues during storage

(Afoakwa and Sefa-Dedeh 2001). Loss of water associated with the storage of tubers was responsible for the shriveling of tubers and the alteration of texture of the edible tissues (Ikediobi and Oti 1983). Due to the attack of the mealy bug the tubers of *Amorphophallus* shrink, shrivel and often cooking quality is also affected (Palaniswami 1994). This was in agreement with present study as it was revealed that the reduction in moisture and starch content has contributed to an increase in hardness of the infested tubers. An increase in hardness for the taro cormels during different types of storage and attributed it to the biochemical reactions occurring between various components present in the tubers (Sajeev et al. 2004) as reported by other workers (Hussain et al. 1984; Haris et al. 1992; Sudhakaran et al. 1994). Springiness of the tubers decreased according to the increase in hardness. But, cohesiveness and chewiness increased according to the increase in hardness.

REFERENCES

Afoakwa, E.O. and Sefa-Dedeh, S. 2001. Chemical composition and quality changes occurring in *Dioscorea dumetorum* pax tubers after harvest. Food Chem. 75: 85-91.

Afoakwa, E.O. and Sefa-Dedeh, S. 2002. Textural and micro structural changes associated with post harvest hardening of trifoliate yam *(Dioscorea dumetorum)* pax tubers. Food Chem. 77: 279-284.

Ahmedani, M.S., Haque, M.I., Afzal, S.N., Aslam, M. and NAZ, S. 2009. Varietal changes in nutritional composition of wheat kernel (*Triticum aestivum* L.) caused by Khapra beetle infestation. Pakistan Journal of Botany, 41(3): 1511-1519.

AOAC, Official Methods of Analysis (2nd edn). (1975). Association of Official Analytical Chemists, Washington, DC

Aprianita, A., Purwandari, U., Watson, B. and Vasiljevic, T. 2009. Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. International Journal of Food Research, 16: 507-520.

Barak, A.V. and Harein, P.K. 1981. Insect infestation of farm-stored shelled corn and wheat in Minnesota. Journal of Economic Entomology, 74: 197-202.

Bourne M.C. 2002 Food Texture and Viscosity; Concept and Measurement, Academic Press, New York.

Bradbury, J.H. and Holloway, W.D. 1988. Chemistry of Topical Root Crops: Significance for National and Agriculture in the Pacific. Australian Centre for International Agriculture Research, 51-99.

Brillouet, J.M., Treche, S. and Sealy, L. 1981. Alterations in cell wall constituents of yams *Dioscorea dumetorum* and *D. rotundata* with maturation and storage conditions relation with post-harvest hardening of *D. dumetorum* yam tubers. Journal of Food Science, 46: 1964-1967.

Coursey, D.G. 1968. Low temperature injury in yams. Journal of Food Technology, 3: 143-150.

Danzig, E.M., Gavrilov, I.A. and Trapeznikova, I.V. 2008. A new pest from a greenhouse of St. Petersburg, *Rhizoecus dianthi* Green (Homoptera, Pseudococcidae), with karyotype data. Entomological Review, 88(6): 676-678.

Eid, M.A., EL Shabrawy, H.A. and Yakoub, R.S. 2011. An attempt to study the impact of pink mealy bug infestation *Saccharicoccus sacchari* Ckll. on chemicals and allelochemicals of some sugarcane cultivars. Academic Journal of Entomology, 4(1): 23-29.

EL-Dein, G., Sanaa, H.M., Ibrahim, A.M. and Moharum, F.A. 2009. Effect of *Saccharicoccus sacchari* (Cockerell) infestation levels on sugarcane physical and chemical properties. Egyptian Academic Journal of Biological Sciences, 2(2): 119-123.

Franco, O.L., Rigden, D.J., Melo, F.R., Bloch, C., Silva, C.P. and Grossi-De-Sa, M.F. (2000). Activity of wheat α-amylase inhibitors towards bruchid α-amylases and structural explanation of observed specificities. European Journal of Biochemistry, 267: 1466-1473.

Haris, P.J., Ferguson, P.R., Roberton, A.M., Mckenzie, R.J. and White, J.B. 1992. Cell wall histochemistry and anatomy of taro. Australian Journal of Botany, 40: 207-22.

Henrissat, B., Deleury, E. and Coutinho, P.M. 2002. Glycogen metabolism loss: a common marker of parasitic behavior in bacteria. Trends in Genetic, 18: 437-440.

Howe, R.W. 1973. Loss of viability of seed in storage attributable to infestations of insects and mites. Seed Science Technology, 1: 562-586.

Hussain, M., Norton, G. and Neale, R.J. (1984). Composition and nutritive value of cormels of *Colocasia esculenta* (L) Schott. Journal of the Science of Food and Agriculture, 35: 1112-1119.

Ikediobi, C.O. and Oti, E. 1983. Some biochemical changes associated with post harvest storage of white yam *(Dioscorea rotundata)* tubers. Journal of the Science of Food and Agriculture, 34: 1123-1129.

Medoua, G.N., Mbome, I.L., Agbor-Egbe, T. and Mbofung, C.M.F. 2005. Physicochemical changes occurring during post-harvest hardening of trifoliate yam (*Dioscorea dumetorum*) tubers. Food Chem. 90: 597-601.

Mehrabadi, M., Bandani, A.R. and Saadati, F. 2010. Inhibition of Sunn pest, *Eurygaster integriceps*, α-amylases by α-amylase inhibitors (T-αAI) from Triticale. Journal of Insect Science, 10: 179.

Mishra, R.S., Nedunchezhiyan, M., Swam, T.M.S. and Edison, S. 2002. Mass multiplication technique for producing quality planting material of *Amorphophallus paeoniifolius.* Tropical Science 34: 371-376.

Odogola, W.R. (1994). Post harvest management and storage of food legumes, Technical Systems for Agriculture, NCR City Printers, Zimbabwe.

Palaniswami, M.S. and Pillai. K.S. 1979. New Records of Mealy Bugs-*Pseudococcous citriculus* and *Rhizoecus* species as pest on elephant foot yam under storage. Journal of Root Crops, 5: 62.

Palaniswami, M.S. 1994. Pests of edible aroids, yams and Chinese potato, Advances in Horticulture, Vol. 8 – Tuber crops, Malhotra publishing house, New Delhi, 490-491.

Premkumar, T., Moorthy, S.N, Balagopalan, C., Jayaprakas, C.A. and Rajamma, P. 1996. Quality changes in market cassava chips infested by insects. Journal of Stored Product Research, 32, 183-186.

Raja, K.C.M., Abraham, E. and Sreemulanathan. 1978. Post harvest storage of cassava tubers under modified environmental conditions. Journal of Root Crops, 4(1): 1-6.

Rajamma, P., Jayaprakas, C.A. and Palaniswami, M.S. 2002. Annual Report, Central Tuber Crops Research Institute 2001-2002, Thiruvananthapuram.

Ravi, V., Aked, J. and Balagoplan, C. 1996. Review on tropical root and tuber crops I. Storage methods and quality changes. Critical Reviews in Food Science and Nutrition 36(7): 661-709.

Ravi, V. and Aked, J. 1996. Review on tropical root and tuber crops II. Physiological disorders in freshly stored roots and tubers. Critical Reviews in Food Science and Nutrition, 36(7): 711-731.

Ravi, V., Ravindran, C.S., Suja, G., James George., Nedunchezhiyan, G., Byju, G. and Naskar, S.K. 2011. Crop physiology of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst. Nicolson)). Advances in Horticulture Science, 25(1): 51-63.

Ravindran, G. and Wanasundera, J.P.D. 1992. Chemical changes in yam tubers (*Dioscorea alata* and *D. esculenta*) during storage. Tropical Science, 33: 57-62.

Sajeev, M.S., Manikantan, M.R., Kingsly, A.R.P., Moorthy, S.N. and Sreekumar, J. 2004. Texture analysis of taro (*Colocasia esculenta* L. Schott) cormels during storage and cooking. Journal of the Science of Food, 69, 315-321.

Sajeev, M.S., Sreekumar, J., Moorthy, S.N., Suja, G. and Shanavas, S. 2008. Texture analysis of raw and cooked tubers of short-duration lines of cassava by multivariate and fractional conversion techniques. Journal of the Science of Food and Agriculture, 88, 569-580.

Schoch, T.J. 1964. in Methods in Carbohydrate chemistry: Swelling power and solubility of granular starches (Whistler, R. L., Smith, J. R., & Wolform, M. L., eds.), Academic Press, New York, 106-108.

Sefa-Dedeh, S. and Afoakwa, E.O. 2002. Biochemical and textural changes in trifoliate yam *Dioscorea dumetorum* tubers after harvest. Food Chemistry, 79, 27-40.

Singh, N., Kaur, L., Ezekiel, R. and Guraya, H.S. 2005. Micro structural, cooking and textural characteristics of potato (*Solanum tuberosum* L.) tubers in relation to physicochemical and functional properties of their flours. Journal of the Science of Food and Agriculture, 85: 1275-1284.

Strobl, S., Maskos, K., Betz, M., Wiegand, G., Huber, R., Gomis-Ruth, F.X. and Glockshuber. R. 1998. Crystal structure of yellow mealworm α-amylase at 1.64 Å resolution. Journal of Molecular Biology, 278: 617-628.

Sudhakaran, P.R., Babu, L. Nambisan, B. 1994. Biochemical nature of sweet potato, yam, aroids and coleus. Advances in Horticulture Vol. 8 – Tuber crops, Malhotra publishing house, New Delhi, 575-587.

Sundaresan, S., Babu, L. and Nambisan, B. 1990. Biochemical changes in yam tubers during storage. Journal of Root Crops Special, 265-269.

Treche, S. and Agbor-Egbe, T. 1996. Biochemical changes occurring during growth and storage of two yam species. International Journal of Food Sciences and Nutrition, 47: 93-102.

Vasquez, E.A., Buyser, M.A. 2007. Post harvest Losses in Greater Yam (*Dioscorea alata* L.) due to insect pests. Journal of Root Crops, 33(2): 114-118.