Malays. Appl. Biol. (2017) 46(3): 185–193

THE INFESTATION OF *Cylas formicarius* (FABRICIUS) (COLEOPTERA: BRENTIDAE) AND ITS EFFECT ON POST-HARVEST QUALITY OF STORAGE SWEET POTATOES

NUR AIDA HASHIM[1*], NURUL ADAWIYAH ZULKIFLI[1], KHADIJAH SAAD[1]
and NORASMAH BASARI[2]

[1]School of Food Science and Technology, Universiti Malaysia Terengganu,
21030 Kuala Nerus, Terengganu, Malaysia
[2]School of Marine and Environmental Sciences, Universiti Malaysia Terengganu,
21030 Kuala Nerus, Terengganu, Malaysia
[*]E-mail: aida.hashim@umt.edu.my

Accepted 8 September 2017, Published online 4 October 2017

ABSTRACT

Sweet potato is an important cash crop in Malaysia. The production and storage of sweet potato is facing huge problem from weevil, *Cylas formicarius* infestation. The attack of this weevil has caused massive losses due to reduction in sweet potato quality and consequently marketability. Therefore, this study was conducted to determine the number of sweet potato weevil (SPW) emerged from infested sweet potatoes and the post-harvest parameters of sweet potatoes when infested by the weevil. The healthy and damaged sweet potatoes were purchased from roadside stalls at Pengkalan Kubur, Besut, Terengganu. A mean of 361.0 ± 135.57 weevils emerged from two kilograms of damaged sweet potatoes throughout 66 days of observation. There was no significant difference between male and female weevils emergence ($p > 0.05$). The sex ratio male to female is 1:1.2. The post-harvest parameters of weevil infested and not-infested (control) sweet potato were not significantly difference in regards of total soluble solid (TSS) and pH value. Similarly, the total anthocyanin in purple sweet potato and total carotenoid in orange sweet potato also had no significant different between infested and control. Significant difference was observed in percentage of weight loss between weevil infested and control groups.

Key words: Sweet potato weevil, *Cylas formicarius*, post-harvest, quality, storage

INTRODUCTION

The sweet potato (*Ipomoea batatas* L.) is one of the most important tuber crops grown in the world (Ray & Ravi, 2005; Chalfant, 1990). The sweet potato is a dicotyledonous plant in the family Convolvulaceae (Tortoe, 2010). It is known as a tuberous root crop that crucial for food security as it is an important source of carbohydrate, vitamin C, β-carotene and a precursor of vitamin A (Jaarsveld *et al.*, 2005). The plant is cultivated in over 100 developing countries and ranks among the five most important food crops in over 50 of those countries such as Great Lakes, Central Africa, Madagascar and Malawi (FAOSTAT, 2011). It also widely grown in tropical and sub-tropical countries like China, USA, India, Japan, Indonesia, Philippines, Thailand, Vietnam and Nigeria (Nedunchezhiyan *et al.*, 2012; Ray & Ravi, 2005). China is the major producer of sweet potatoes with production reaching 75 million metric tons in 2011, it is approximately donates 73% of global production. The production of sweet potato in Malaysia is 55, 838 tons in 2012 (Agrofood Statistic, 2013). Malaysia is one of the countries that has high demand on sweet potato. Sweet potato is widely used in culinary industry to make chips, flour and various local cakes. To fulfil the demand, Malaysia had imported 5577 tons of sweet potatoes from other countries in 2009 (FAO, 2012).

Sweet potato can be stored for several months; however the losses of sweet potato are primarily due to external factors such as insects, rodents and fungus damage (Akintobi & Oyekale, 2013; Fuglie, 2007; Nderitu *et al.*, 2009; Smit & Matengo, 1995). In addition, roots and tubers are primarily affected by two types of postharvest deterioration which are primary physiological deterioration that cause the

---

* To whom correspondence should be addressed.

unmarketable and secondary deterioration due to microbial spoilage (Njoku *et al.*, 2007; Ndunguru *et al.*, 1998).

Sweet potato weevil (SPW), *Cylas formicarius* (Fabricius) is the major pest of sweet potato (Korada *et al.*, 2010). *Cylas formicarius* completes its life cycle on the sweet potato plant. Female adult weevils excavate small pits in the vines near the plant's crown above the soil or in exposed sweet potato roots. They lay their eggs there, one egg is laid per pit. Once the egg hatches, the larva tunnels within the host plant's tissue causing instant economic damage for the marketable sweet potato (Pillai *et al.*, 1993). Pupation then occurs within these tunnels. Adults emerge and begin feeding on the host plants leaves, leaf petioles and stems (Sethi *et al.*, 2003). In general, they complete their life cycle in 33 days (Korada *et al.*, 2010; Rajamma & Padmaja, 1981). Weevils feeding will cause the sweet potato roots to shrink due to water loss (Westby, 2002).

This insect not only causes damage in the field, but also in storage and quarantine (Talekar, 1982). Feeding by this weevil elicits terpenoid production in sweet-potato storage tubers that results in damaged, unpalatable tubers (Ray & Ravi, 2005; Mullen, 1984). The weevil causes 60-70% yield loss, and in some areas the damage to tubers can reach up to 90% (Korada *et al.*, 2010). It can affect all parts and all stages of plant growth.

Control methods used to control this weevil such as using toxic pesticides are effective but are not desirable to the environment. Pheromone traps are currently being used for monitoring (Reddy *et al.*, 2012; Yen & Hwang, 1990) but no effective control has been reached. Once introduced, *C. formicarius* will infest all roots in storage until they are completely destroyed. The infestation by this insect will lead to development of disease. In storage, problems such as insect infection, disease and physiological disorders will occur (Jeong, 2000). Therefore, the aims of this study are to determine the productivity of SPW adults from damage sweet potato and to measure the post-harvest parameters of sweet potato infested by the weevil.

MATERIALS AND METHODS

Study site

Damaged and healthy sweet potatoes from variety of vitato (orange flesh) and purple flesh were purchased from the farmer's stall in Pengkalan Kubor village, Besut, Terengganu. Besut is the largest sweet potato planting area in Terengganu, Malaysia involving 38.4 hectares of land (Anonymous, 2011).

All experiments were conducted in the Post-Harvest Laboratory, School of Food Science and Technology, University Malaysia Terengganu under ambient temperature (27°C–30°C).

Only damaged orange flesh sweet potatoes were used in SPW adult emergence experiment. Both healthy orange and purple flesh sweet potatoes were used in experiment to determine post-harvest parameters of SPW infested sweet potatoes.

The SPW emergence

Damaged sweet potatoes (orange-flesh) with signs of weevil infestation were used in the experiment. The sweet potatoes were sorted and cleaned from soil and SPW using soft brush. After cleaned, two kilograms of sweet potatoes were transferred into an insect cage measuring 30cm x 30cm x 30cm. The experiment consisted of three replications. The cages were observed daily for the emergence of adult SPW. The number of SPW were counted, sexed and recorded daily. The experiment was terminated when there is no more weevils emerge from the sweet potatoes after 66 days.

The post-harvest parameters of sweet potato infested by SPW

Eight kg of each healthy (no sign of weevil infestation) orange and purple flesh sweet potatoes were immersed in hot water 52°C–62°C for 10 min and allowed to air dry. The weight of each sweet potato was measured and only sweet potatoes weighing 250 ± 50g were chosen. The selected sweet potatoes were then placed in an individual plastic container (9 cm x 6 cm). A pairs of newly emerged SPW was introduced into each of the plastic container. For control, no weevil is introduced into the plastic containers. A total of 24 containers were prepared for each type of sweet potato (12 containers with weevil and 12 containers as control). The physicochemical analyses were done weekly for two months. All analyses were done in three replicates.

Weight loss

The percentage of weight loss in sweet potato was determined weekly by using electronic balances. The percentage of weight loss was determined by using formula below:

$$\text{Percentage (\%)} = \frac{(\text{Initial weight} - \text{final weight})}{\text{Initial weight}} \times 100\%$$

Total soluble solid (TSS) determination

The total soluble solid (TSS) values were determined using hand-held refractometer. Drops of the sweet potato extract were put on a clean eyepiece type refractometer glass and the °brix in percentage was recorded.

pH values

The pH values were determined following method by Ocloo *et al.* (2011). Approximately 5.0g dry basis was weighed into beakers and then mixed with 20.0 ml of distilled water. The suspensions were stirred for five minutes and left for 10 min. The pH of water phase was measured using a calibrated pH meter.

Total anthocyanin determination

Total anthocyanin content was determined by using the modified method by Giusti and Wrolstad (2001). The anthocyanin content was calculated based on the following equation:

Anthocyanin content (mg/100g of dry matter) = A x MW x DF x 100/ (ε x W)
Where A = absorbance,
MW = molecular weight of cyanidin-3-glucoside chloride ($C_{21}H_{21}ClO_{11}$, 449.2),
DF = dilution factor,
ε = molar absorptivity (26, 900),
W = sample weight (g)

Total carotenoid determination

One gram of sweet potato was mixed with one gram of magnesium oxide ground together with 40 ml of 100% acetone using mortar and pestle. The suspension was transferred into 50 ml falcon tube. The tube was placed in centrifuge machine at 2000 rpm for 5 min. The extract was decanted into 50 ml volumetric flask using 100% acetone to make up the extract. The absorbance was read at 750 nm, 662 nm, 645 nm, 520 nm and 470 nm by using UV-V is spectrophotometer.

Statistical analysis

All data were subjected to normality test performed in SPSS version 21. The number of adult weevils that emerged was daily sum up and mean. Paired t-test was used to determine the difference for mean total number of male and female SPW. For the post-harvest parameters, the Mann-Whitney U test was used to analyse the mean difference between infested and not infested sweet potato parameters within the eight weeks of experiment. A kruskal-Wallis test was used to test among the weekly parameters data.

RESULTS

The SPW emergence

The mean number of weevils emerged daily from two kilograms of sweet potatoes for 66 days of observation is shown in Fig. 1. The emergence of male and female weevils increased gradually and then decreased at the end of the observations. There was no significant difference in the number of emergence male weevils throughout the days of observation [χ^2 (65, N=163) = 80.075, $p > 0.05$]. In contrast, the emergence of female weevils was significantly different across all days of observation [χ^2 (65, N=198) = 86.086, $p < 0.05$].

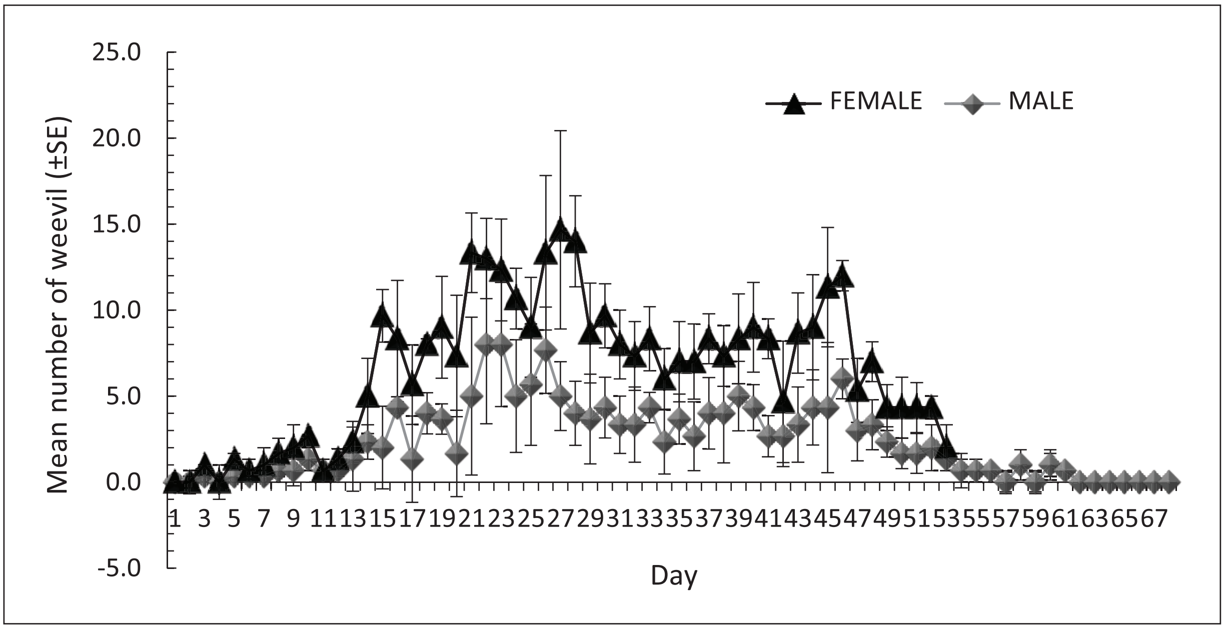

Fig. 1. Mean number of weevils emerged from damaged sweet potatoes during 66 days of observation.

At the end of observation, a mean total of 361±135.57 weevils emerged from two kilograms of damaged sweet potatoes, out of this number 163±65.36 were males and 198±70.21 were females (Fig. 2). There was no significant difference between male and female emergence, [t (4) = -0.372, $p>0.05$]. The sex ratio male to female is 1:1.2.

The post-harvest quality of sweet potato infested by SPW

The weight loss percentage of sweet potatoes increases with storage time (Fig. 3). The weight loss were significantly different among weeks of observation in infested orange sweet potato (χ^2 (7, N=3)=21.000, $p<0.05$), not-infested (control) orange sweet potato (χ^2 (7, N=3)=21.000, $p<0.05$), infested purple sweet potato (χ^2 (7, N=3)=21.000, $p<0.05$) and not-infested (control) purple sweet potato (χ^2 (7, N=3)=21.000, $p<0.05$) groups. The percentage of weight loss between infested and non-infested was significantly different for orange ($p<0.05$) and purple sweet potatoes ($p<0.05$) starting from week 3 until week 8 of observations.

Overall, the total soluble solid (TSS) values decrease overtime for both infested orange and purple sweet potatoes (Fig. 4). The TSS values were significantly different among weeks of observation in infested orange sweet potato (F (7, 16)=17.071, $p<0.05$), not-infested (control) orange sweet potato (F (7, 16)=15.460, $p<0.05$), infested purple sweet potato (F (7, 16)=34.974, $p<0.05$) and not-infested (control) purple sweet potato (F (7, 16)=54.751, $p<0.05$) groups. However, no significant differences was observed in TSS values between infested and non-infested groups in each week of observation for both orange and purple sweet potatoes. Similarly, there was no significant difference in pH values between infested and not-infested of orange and purple sweet potatoes (Fig. 5) in each week of observations ($p>0.05$).

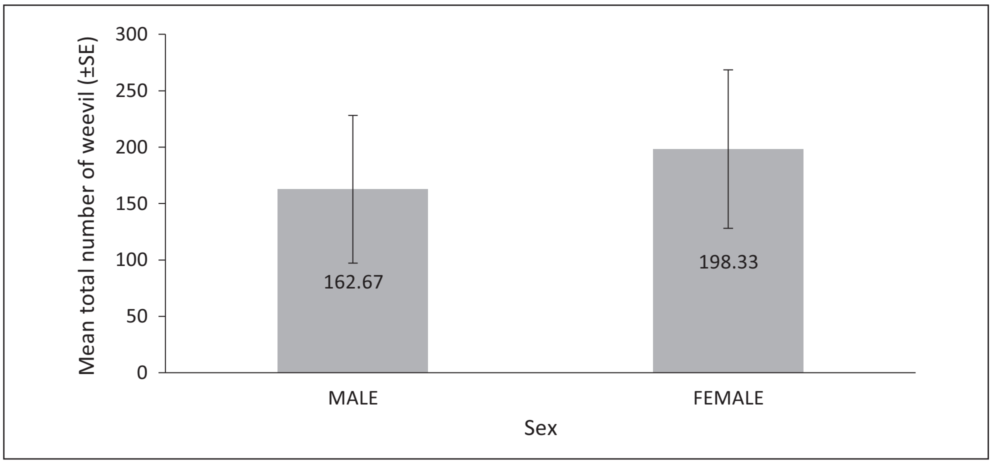

Fig. 2. Mean (± S.E.) total number of male and female SPWs emerged from damaged sweet potatoes.

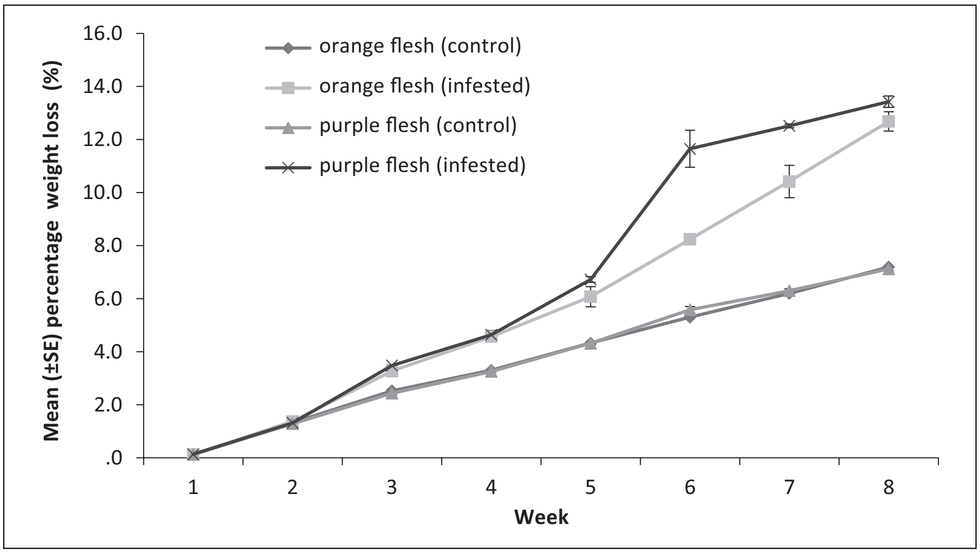

Fig. 3. Mean (± S.E.) percentage weight loss of sweet potato (orange and purple flesh) with and without weevil for eight weeks of observations.

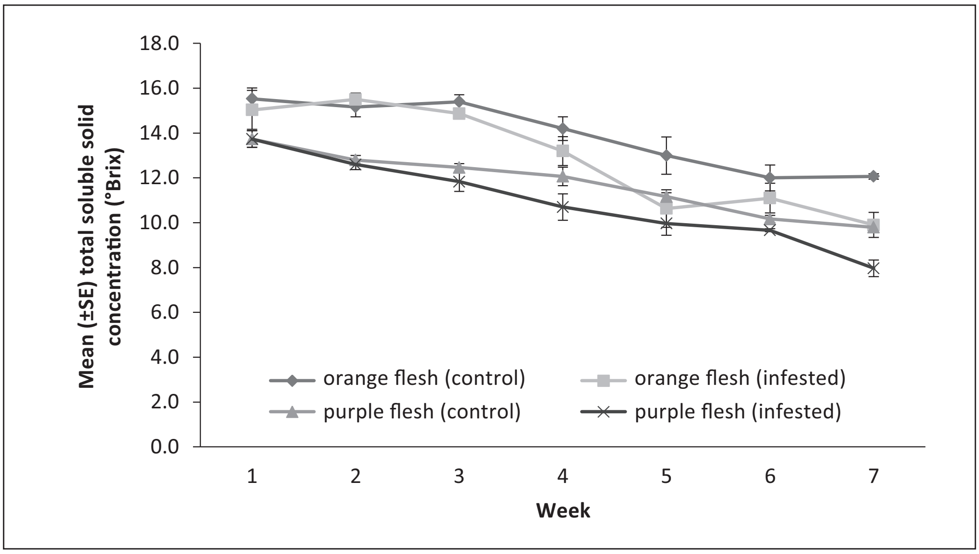

Fig. 4. Mean total soluble solid (± S.E.) of sweet potato (orange and purple flesh) with and without weevil for eight weeks of observations.

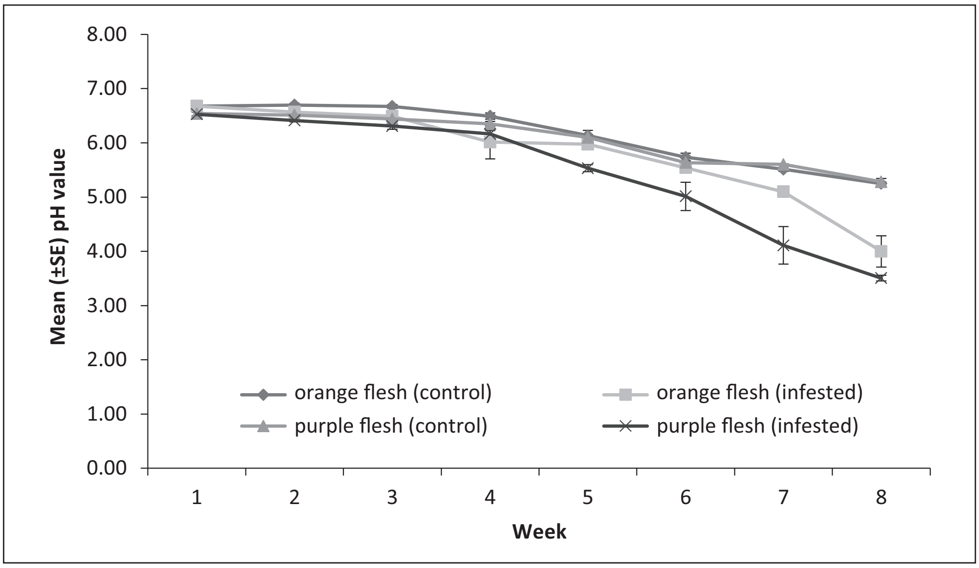

Fig. 5. Mean (± S.E.) pH value of sweet potato (orange and purple flesh) with and without weevil infestation for eight weeks of observations.

The total anthocyanin (Fig. 6) and the mean total carotenoid (Fig. 7) content in stored sweet potatoes decreased with storage period for purple and orange sweet potatoes respectively. There was no significant differences [Z=-0.630, p>0.05] in total anthocyanin between infested and not-infested sweet potatoes. No significant differences [Z=-0.945, p>0.05] was also observed in total carotenoid between infested and not-infested sweet potatoes.

DISCUSSION

In the present study, more than 300 weevils successfully emerged from the damaged sweet potatoes. Female weevils were found to emerge first followed by male weevils. The sex ratio of male to female is 1:1.2 with no significant difference between both male and female weevils emergence per two kg of sweet potato. The females emerged in this study, were higher compared to study done by Mullen (1981) and Subramanian (1959) where they recorded sex ratio male to female of 1:1.02.

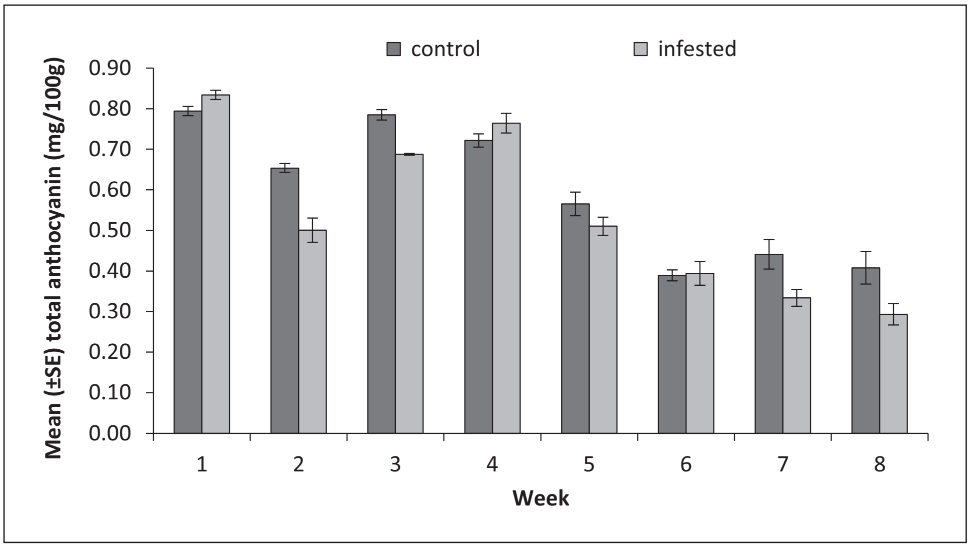

Fig. 6. Mean (± S.E.) total anthocyanin of purple flesh sweet potato with and without weevil infestation for eight weeks of observations.

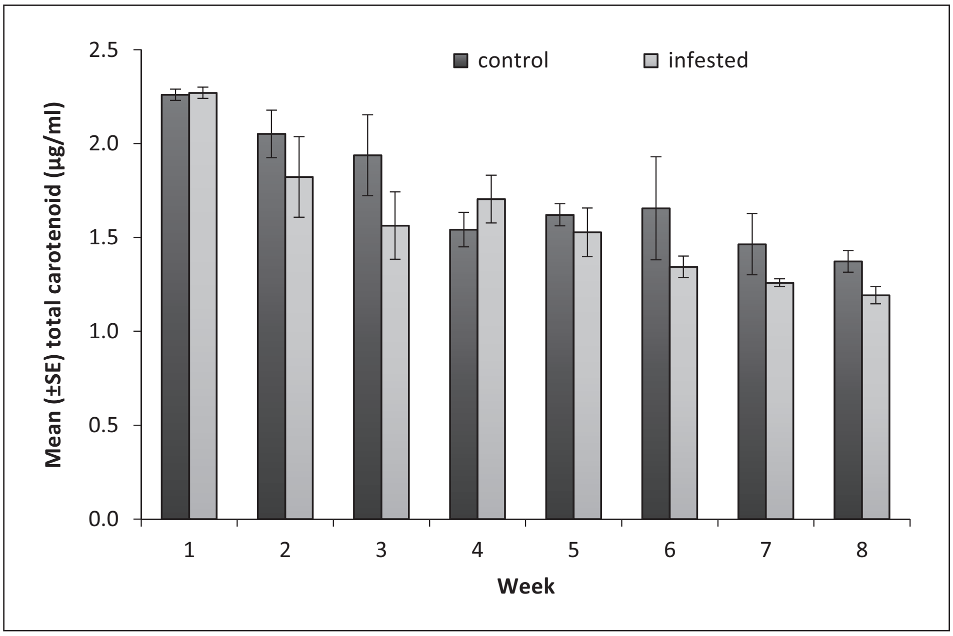

Fig. 7. Mean (± S.E.) total carotenoid of orange flesh sweet potato with and without weevil infestation for eight weeks of observations.

The finding of this study indicated that damaged sweet potatoes if not properly disposed, it can turn into breeding host of the pest and probably, leads to the outbreak in nearby cultivation areas or infested storage roots. A single female can lay up to 179 eggs throughout its life time (Mullen, 1981). As our study recorded 198 females successfully emerged from the experiment, and with fecundity of 179 eggs per female could produce a total of 35442 eggs. Even if only 50% of the eggs hatched and successfully reach adult stage, and with adult emergence sex ratio of 1:1.2, this could produce 9666 females that can continue to lay 1730214 (1.73 millions) eggs. Mullen (1981) reported the mean generation duration from egg to adult of 84.7, 33, and 33.7 days at 20, 27 and 30°C, respectively. Subramanian (1959) recorded life cycle duration of 36 to 43 days under undefined condition. In Indonesia, female weevils have been reported to survive a maximum of 113 days (Franssen, 1935) while in the Philippines males survived 63–120 days and females 81–107 days (Gonzales, 1925). In India, the males and females survived for 94 and 109 days, was reported respectively (Subramanian, 1959). The aforementioned population estimation is only for two generations of the weevil in duration of two to three months. With the long life span and high survival, it is not surprising that the pest can cause huge damage and loses to sweet potato cultivation and storage if the damaged sweet potatoes not properly disposed.

In this study, the post-harvest quality of sweet potato was also determined. The percentages of weight loss were significantly different between infested and non-infested sweet potatoes. A gradual increase in weight loss towards the end of experiment was observed. This finding is in accordance with Emam and Attia (2010) as the longer the storage periods, the higher the weight loss of sweet potato. Ray and Ravi (2005) reported that the decline in starch content with storage period and giving to respiration and transpiration contributed to weight loss and alteration of internal and external appearance of the potatoes. Because starch is used as a respiratory substrate, the starch content decreased during storage and subsequently the dry matter also decreased (Ray & Ravi, 2005). Storage period was found to be effective in this respect.

The TSS value is commonly used to determine the concentration of sugar in product. There was no significant difference in the TSS values obtained from both infested and non-infested sweet potatoes. The TSS value increased with prolongation storage then it began to decrease due to the moisture loss through transpiration and the conversion of starch to sugars (Zhang *et al.*, 2002). The utilization of sugars in respiration occurs at the end of storage period which a-amylase plays a key point in starch degradation during storage.

This study indicated that the sweet potatoes had a pH of 7 at the first week. The pH of sweet potato was not significantly different for both infested and non-infested sweet potatoes over storage period. According to Chen *et al.* (2003), the pH of sweet potatoes is ranging from 5 and 7. Tsakama *et al.* (2010) reported that high pH starches increased the solubility that stimulates degradation and absence of monovalent ions and cations. The mean pH of 5 and below at week 7 and 8 indicated that the sweet potato was acidic compared to the pH 6-7 at early week. High solubility caused by the high pH of starches, due to increased hydrophilic characters of starch at these pH values (Adebowale *et al.*, 2005).

Orange flesh sweet potato is rich source of β-carotene (Suda *et al.*, 2003). Purple-fleshed varieties are rich source of anthocyanins and phenolic compounds (Friedman & Levin, 2009). The present study indicated that total anthocyanin and total carotenoid values between infested and non-infested sweet potato was not significantly different. The vitamin A content of fresh root was determined as 0.015 mg/g on fresh weight basis and it was slightly higher than 0.01 mg/g reported by Eka (1998). The influence of post-harvest storage on the vitamin content of different crops is not well understood according to Wilcox (2006) but ascorbic acid and β-carotenes are known to fluctuate considerably. The changes in ascorbic acid content of fresh roots might be because vitamin C is the most sensitive of all vitamins to processing condition and can easily oxidize when exposed to favourable conditions for oxidation (Wilcox, 2006) thus making the values to vary from the initial values. According to Ray and Ravi (2005) there is a gradual decrease in ascorbic acid content of sweet potato after storage. The stability of anthocyanin from sweet potato extracts depends on temperature, light levels and pH (Cevallos & Cisneros, 2003).

Based on our findings, infestation of sweet potato by *C. formicarius* can degrade post-harvest qualities such as weight loss, TSS and pH. Although the appearance of infested sweet potatoes showed sign of severe damaged due to weevil feeding activities, changes in the parameters values such as TSS, pH was not significantly different with the control. Therefore, more study need to be conducted to clearly obtain reduction value on the post-harvest quality of sweet potato.

CONCLUSION

In conclusion, emergence of male and female weevils has a huge impact to sweet potato plantation since it can destroy the tubers, which cause severe yield loss. The data on weevils' emergence together with post-harvest assessment in this study are important information to farmers and traders and communities as an alert system from improper disposal of damage sweet potato.

ACKNOWLEDGEMENTS

We deeply indebted to the staff of Laboratory for Agro-Food Pest and Diseases Management, Universiti Malaysia Terengganu for their technical assistance. This research was funded by Ministry of Higher Education Malaysia under Research Acculturation Grant Scheme (RAGS, Vot 57131).

REFERENCES

Adebowale, K.B., Owalabi, B., Olayinka, O. & Lawal, O. 2005. Effect of heat-moisture treatment and annealing on physicochemical properties of red sorghum starch. *Africa Journal Biotechnology,* **4**: 928-933.

Agrofood Statistic. 2013. Malaysia Organization Agricultural (MOA). Available from: http://www.moa.gov.my/documents/10157/2489444/BUKU+PERANGKAAN+AGROMAKANAN+2013.pdf [Accessed on 15 March 2017].

Akintobi, D.C.A. & Oyekale, K.O. 2013. Evaluation of effect of neem plant on insect pests control and yield in sweet potato production. *Journal Agriculture Science Developments,* **2(5)**: 47-53.

Anonymous. 2011. Vitato sweet potato a lucrative crop for farmers. Bernama News [online]. Available from: https://my.news.yahoo.com/vitato-sweet-potato-lucrativecrop-farmers-072227149.Html [Accessed on 20 September 2014].

Cevallos, C.B.A. & Cisneros, Z.L.A. 2003. Stability of anthocyanin-based aqueous extracts of Andean purple corn and red-fleshed sweet potato compared to synthetic and natural colorants. *Food Chemistry*, **86**: 69-77.

Chanlfant, R.B. 1990. Ecology and management sweet potato insects. *Annual Revision Entomology*, **35**: 157-180.

Chen, Z., Schols, H. & Horgan, A. 2003. Physiochemical properties of starches obtained from three varieties of Chinese sweet potatoes. *Journal Food Science*, **68**: 431-437

Eka, O.U. 1998. Root and Tubers. In: Nutritional Quality of Plant Foods. Osagie, A.U. and Eka, O.U. (Eds.). Benin: Post-Harvest Research Unit, University of Benin Nigeria. pp. 1-31.

Emam, M.S. & Attia, M.M. 2010. Influence of harvesting date and some postharvest treatments on quality and storage ability of sweet potato roots. *Annual of Agriculture Science, Moshtohor*, **48(2)**: 175-185.

FAO (Food and Agriculture Organization). 2012. Global production and consumption of root and tuber. Available from: http://faostat.fao.org/ [Accessed on 25 August 2014].

FAOSTAT (Food and Agriculture Organization Statistic). 2011. Available from: http://teca.fao.org/sites/default/files/technology_files/The%20most%20serious%20insect%20pest%20of%20sweet%20potato%20and%20their%20management.pdf. [Accessed on 26 December 2014].

Franssen, C.J.H. 1935. Insect Pests of the Sweet Potato Crop in Java. (Inseeten, sehadelijk aan het batätengewas op Java.). *Land-bouw*, **10**: 205-225 pp.

Friedman, M. & Levin, C.E. 2009. Analysis and biological activities of potato glycoalkaloid, calystegine alkaloids, phenolic compounds and anthocyanin. In: Advances in potato Chemistry and technology. Singh, J. and Kaur, L. (Eds.). Academic Press, Elsevier Inc., New York. pp. 127-161.

Fuglie, K.O. 2007. Priorities for sweet potato research in developing countries: Results of survey. *Journal Horticulture Science*, **42(5)**: 1200-1206.

Giusti, M.M. & Wrolstad, R.E. 2001. Anthocyanins characterization and measurement with UV visible spectroscopy. In: Current Protocols in Food Analytical Chemistry, 1st ed. Wrolstad, R.E. (Ed.). John Wiley & Sons, Inc., New York. pp. F1.2.1–F1.2.13.

Gonzales, S.S. 1925. The sweet potato weevil (*Cylas formicarius*, Fabr). *Philippine Agriculturist*, **14**: 257-281.

Jeong, B.C. 2000. Current roles of sweet potato and its earlier harvesting by improvement PE film mulch cultivation in Korea. In: Potential of Root Crops for Food and Industrial Resources, Proceedings of 12th Symposium of International Society of Tropical root crops, 10-16 September 2000, Tsukuba, Japan. p 350.

Korada, R.R., Naskar, S.K., Palaniswami, M.S. & Ray, R.C. 2010. Management of sweet potato weevil [*Cylas formicarius* (Fab)]: An overview. *Journal of Root Crops*, **36(1)**: 14-26.

Mullen, M.A. 1981. Sweet potato weevil, *Cylas formicarius elegantulus* (Summers): development, fecundity, and longevity. *Annals of the Entomological Society of America*, **74(5)**: 478-481.

Mullen, M.A. 1984. Influence of sweet potato weevil infestation on the yields of twelve sweet potato lines. *Journal of Agricultural Entomology*, **20**: 217-226.

Nderitu, J., Silai, M., Nyamasyo, G. & Kasina, M. 2009. Insect species associated with sweet potatoes (*Ipomoea batatas* (L.) Lam) in Eastern Kenya. *International Journal Sustainable Crop Production*, **4(1)**: 14-18.

Ndunguru, G.T., Thomson, M., Waida, R., Rwaiza, E. & Westby, A. 1998. Methods for examining the relationship between quality characteristics and Trinidad **75**: 129-133.

Nedunchezhiyan, M., Byju, G. & Naskar, S.K. 2012. Sweet potato agronomy. In: Fruits, Vegetables and Cereal Science and Biotechnology. Special Issue: Global Science Books. pp. 1-10.

Njoku, S.C., Muoneke, C.O., Okpara, D.A. & Agbo, F.M.O. 2007. Effect of intercropping varieties of sweet potato and okra in an ultisol of southeastern Nigeria. *African Journal Biotechnology*, **6(14)**: 1650-1654.

Ocloo, F.C.K., Otoo, G., Nkansah, R.M., Mahami, T., Odonkor, S. & Quayson, E.T. 2011. Functional and physicochemical characteristics of starch obtained from gamma-irradiated sweet potato (*Ipomea batatas* L.). *Journal Agriculture Food Technology*, **1(7)**: 116-122.

Pillai, K.S., Rajamma, P. & Palaniswami, M.S. 1993. New technique in control of sweet potato weevil using synthetic sex pheromone in India. *International Journal Pest Management*, **39**: 84-89.

Rajammana, P. & Padmaja, G. 1981. Annual Report: Central Tuber Crops Research Institute, Trivandrum, India. pp. 109-115.

Ray, P.K. & Ravi, V. 2005. Post harvest spoilage of sweet potato and its control measure. *Critical Review of Food Science and Nutrition*, **35**: 623-644.

Reddy, G.V.P., Gadi, N. & Taianao, A.J. 2012. Efficient sex pheromone trapping: cathing the sweet potato weevil, *Cylas formicarius*. *Journal of Chemical Ecology*, **38(7)**: 846-853.

Sethi, K., Mohanty, A.K., Naskar, S.K. & Nedunchezhiyan, M. 2003. Efficacy of IPM technology over farmers/traditional practices in management of sweet potato weevil (SPW) in tribal areas of Orissa. *The Orissa Journal of Horticulture*, **31(2)**: 65-68.

Smit, N.E.J.M. & Matengo, L.O. 1995. Farmers' cultural practices and their effects on pest control in sweet potato in South Nyanza, Kenya. *International Journal Pest and Management,* **41**: 27.

Subramanian, T.R. 1959. Observations on the biology of *Cylas formicarius* Fabricius at Coimbatore. *Madras Agricultural Journal*, **46**: 293-297.

Suda, I., Oki, T., Masuda, M., Kobayashi, M., Nishiba, T. & Furuta, S. 2003. Physiological functionality of purple-fleshed sweet potato containing anthocyanins and their utilisation in foods. *Japan Agricultural Research Quality,* **37**: 167-173.

Talekar, N.S. 1982. Effects of a sweet potato weevil (Coleoptera: Curculionidae) infestation on sweet potato root yields. *Journal of Economic Entomology*, **75**: 1042-1044.

Tortoe, C. 2010. Microbial deterioration of white variety sweet potato (*Ipomoea batatas*) under different storage structures. *International Journal of Plant Biology*, **1(1)**: 10-15.

Tsakama, M., Mwangweia, A.M., Manani, T.A. & Mahungu, N.M. 2010. Physicochemical and pasting properties of starch extracted from eleven sweet potato varieties. *Africa Journal Food Science Technology*, **1(4)**: 90-98.

Wilcox, B.F. 2006. Fundamentals of Food Chemistry 1st Edition, Vol. 1-2. Yola: Paraclete Publishers Nigeria

Westby, A. 2002. Cassava utilization, storage and small-scale processing. Natural Resources Institute, University of Greenwich, United Kingdom.

Yen, Y.P. & Hwang, J.S. 1990. Improved synthesis method and bioactivity of sex pheromone of sweet potato weevil (*Cylas formicarius eleganthus*). *Plant Protection Bulletin*, **32**: 239-241.

Zhang, Z., Wheatley, C.C. & Corke, H. 2002. Biochemical changes during storage of sweet potato roots differing in dry matter content. *Post-harvest Biology and Technology*, **24**: 317-325.