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Assessment of Biochemical Changes during Postharvest Physiological Deterioration in Cassava Tubers

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ABSTRACT

Cassava roots have a short shelf life due to a process known as Post-Harvest Physiological Deterioration (PPD). PPD is a serious problem in cassava that renders the roots unmarketable, thereby reducing the economic value of the crop. This study was undertaken to determine physiological changes of PPD and identify cassava genotypes with delayed PPD that can be used for better shelf life. In the present study, 24 cassava genotypes were collected and assessed for PPD and other physiological changes. Tubers from different cassava genotypes were evaluated at 1,2,3,4 and 5 days after harvest for PPD and Hydrogen Cyanide (HCN). Genotypes CI-850 and YTP-1 were recorded minimum PPD of 9.81 per cent and 11.76 per cent and low production of HCN 12.54 ppm and 17.99 ppm respectively even at fifth day after harvest. In other hand, CI-850 (1.321 mg/g) and YTP -1(0.998 mg/g) tubers accumulated more antioxidant carotenoid. These genotypes were highly tolerant to PPD. These can be used as novel donor sources in breeding programmes aimed for developing PPD tolerant genotypes.

Key words: *Cassava, post harvest physiological deterioration, hydrogen cyanide, carotenoid, shelf life*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a staple for more than 800 million people and is one of the six most important crops in the world. Because of its tolerance to drought and poor soils, cassava's importance as a food security crop has been recognized[20]. Tolerance to extreme environments, such as drought and poor soils has earned its name as a "Famine reserve crop". Cassava tubers contain 98 per cent carbohydrate and appreciable amount of calcium and vitamin C. However, subsistence and commercial utilization of cassava are affected by its short shelf-life due to a rapid postharvest physiological deterioration process[14,15].

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PPD begins within 24 hours and rapidly renders the roots unpalatable and unmarketable[21]. Consequently, cassava roots need to be consumed soon after harvesting[15]. The short shelf-life severely limits the marketing options because it increases the likelihood of losses, marketing costs, and access to urban markets is limited to those close to the production sites[16]. The processes involved in PPD resemble typical changes associated with the plant's response to wounding that triggers a cascade of biochemical reactions, which are frequently oxidative in nature[1]. In cassava roots, an oxidative burst occurs immediately after harvest[14]. Other early events include increased activity of enzymes that modulate ROS levels, such as catalase, peroxidase, and superoxide dismutase[2,7,13]. Further evidence in support of a role of oxidative stress in PPD comes from the observation that cassava cultivars that have high levels of β-carotene (which quenches ROS) are less susceptible to PPD[18]. PPD begins with vascular streaking, which is a blue-black discoloration of the xylem parenchyma followed by general discoloration of the storage parenchyma. Five to seven days later microbial activity causes further deterioration. With this background, the present study was undertaken, to determined PPD, HCN and carotenoid content and also the associations between the PPD and HCN, PPD and total carotenoid content of selected cassava tubers were evaluated using linear regression analysis.

MATERIALS AND METHODS

Plant material

Twenty four cassava genotypes, TCMS 1, TCMS 2, TCMS 3, TCMS 4, TCMS 5, TCa 12-1, TCa 12-2, TCa 12-3, TCa 12-4, Ca 12-5, TCa 12-6, TCa 12-7, TCa 12-8, TCa 12-9, TCa 12-10, PDP -1, PDP-9, CI-823, CI-850, CMR 100, H740/92, MVD, H226 and YTP-1 were selected from cassava germplasm bank, Tapioca and Castor Research Station, Yethapur, Salem Tamil Nadu, India. Cassava tubers from twelve month old plants were harvested by digging the rhizosphere area and carefully removing the roots from the soil while avoiding any wounding. Root peduncles were removed and entire roots were stored under ambient conditions and protected from sun light.

PPD evaluation

Cassava tubers were cut into transverse sections at 50% of the total length of each genotype on one, two, three, four and five days after harvest. A slice (0.3 cm average thickness) was cut from the distal end of each transverse section. Visual inspection was done according to Wheatly *et al*[22]., by assigning score between 0 and 100% to each slice based on the observed physiological deterioration of the central parenchyma surface of each slice.

Determination of total cyanide content

Total hydrogen cyanide (HCN) content of tuber was estimated by the method of Indian Standard, IS : 4706 - 1978 Part II[6] and expressed as ppm.

Total Carotenoid content

Total Carotenoid content of cassava tuber was estimated as per the method of Jensen[8], and expressed as mg g^{-1} fresh weight.

Statistical analysis

The data collected on the different characters from field experiments were statistically analyzed in a CRD (Completely Randomized Block Design). The critical difference (CD) was computed at five per cent probability. The associations between the PPD and HCN, PPD and total carotenoid content, and were evaluated using regression analysis.

RESULTS

Post-harvest physiological deterioration and hydrogen cyanide content were determined on one to five days after harvest in 24 cassava genotypes. There are significant difference was observed on PPD and HCN with respect to the genotypes. The mean PPD percent ranged from 5.32 to 66.54 (Table 1) at one to five days after harvest. Per cent of PPD in all the genotypes was gradually increased significantly in all the genotypes along with over production of HCN with the exception of CI-850, YTP-1 and H740/92. Among the genotypes, low per cent of PPD with less

production of HCN was observed in CI-850 (9.81% and 12.54 ppm) followed by YTP-1 (11.76 % and 17.99 ppm) and H740/92 (16.13 % and 21.87 ppm) even on fifth day after harvest. At the same time high intensity of PPD and more production of HCN was observed in H226 (91.72% and 783.67 ppm) and PDP-9 (90.21% and 711.9 ppm). Significant statistical difference was observed between the genotypes. The interaction between genotypes and days of storage was also significant. Cassava root obviously undergo considerable changes during storage. The genotypes included in this study showed similarity in some of these changes, whereas in others wide differences indicated the influence of genetic variation[19]. Particularly relevant was the rate of progress for PPD with values around 5.32 per cent for CI-850 and 66.54 for H226. As previous report indicated[11] PPD is accociated with HCN content. This study revealed that clear differences in HCN concentration between susceptible and tolerant genotypes which causes difference in intensity of PPD. In the present study, there is a strong positive association was observed between PPD and cyanide concentration. This was corroborated with previous reports[2]. In this investigation, the PPD-susceptible genotypes obtained peak at HCN concentration on third day after harvest but tolerant genotypes showed their peak accumulation only five days after harvest. This might be due to cassava tissues accumulate cyanogenic glucosides (linamarin 95% and lotaustralin 5%)[9,10]. Progressive accumulation of linamarin and subsequent degradation by enzyme linamarase to form HCN in cassava tubers might be the reason for obtaining increasing trend of HCN from first to fifth day after harvest[12]. Salcedo *et al*[17]., reported similar results which conforming the present finding.

The carotenoid content reduced drastically day by day in all the genotypes which accounted for 0.655 on first day, 0.476 on second day, 0.351 on third day, 0.291 on forth day and 0.180 mg g^{-1} (mean value) of fresh weight on fifth day after harvest (Table 2). Among the genotypes CI-850 maintained highest total carotenoid content (1.321 mg g^{-1} of FW) followed by YTP-1 (0.998 mg g^{-1} of FW) and H740/92 (0.912 mg g^{-1} of FW) even at fifth day after harvest. H226 and PDP-9 exhibited low content of carotenoid and they are statistically on par with each other. Deterioration of cassava roots requires oxygen and oxidative stress has been shown to be involved in PPD[13]. The genotype like CI-850 recorded high total carotenoid content. This might be due to the antioxidant property of the carotenoids delay the PPD in few days. The inverse association between total carotenoid concentration and PPD is encouraging because it suggests that cassava roots with higher total carotenoid levels are not only more nutritious, but may also be more marketable because of their reduced or delayed PPD[5]. This increased shelf life may only be one or two additional days and would not overcome the serious problem of marketing cassava roots. Nevertheless, it may still encourage farmers to grow yellow rooted pro-vitamin A cassava clones and should be pursued, particularly where cassava is used for human consumption[3].

Regression analysis showed PPD is negatively and significantly associated with total carotenoid content ($R^2 = 0.730$, $P < 0.01$) (Fig 1). A significant proportion of the variability in PPD, therefore, could be explained by the total carotenoid content. The association between PPD and the HCN content of roots was significant and positive, although one to five day after harvest ($R^2 = 0.907$, $P < 0.01$) (Fig 2). HCN content was negatively correlated with total carotenoid content ($R^2 = 0.782$, $P < 0.01$) and presented in Fig. 3. Relation between PPD and a few agronomic traits have been suggested, such as a positive relation between desirable traits, HCN, total carotenoid content and the percent of PPD. Furthermore, the level of carotenes in the roots seems to be negatively correlated with the level of PPD[22]. The low susceptibility may be due to the antioxidant properties of the carotenoids which quench reactive oxygen species (ROS). ROS are involved in oxidative stress leading to PPD in cassava roots[4,18]. The

average values for PPD and HCN content are in accord with those observed in other studies[19]. The variation in the total carotenoid content of cassava roots observed in this study is also consistent with those reported by Chavez *et al*[4]. Like Van Oirschot *et al*[21]., we also found that PPD was positively and significantly related with the HCN in the roots, although our association was strong (R^2=0.995). In important finding was the good correlation between the total carotenoid content of the roots and the reduced or delayed PPD after 3-5 days. This might be due to the antioxidant property of the carotenoids.

Table 1: Postharvest physiological deterioration (%) of 24 cassava genotypes

Genotypes	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	MEAN
TCMS 1	12.76	36.78	55.71	65.29	74.32	48.97
TCMS 2	22.61	49.19	62.48	68.91	79.9	56.62
TCMS 3	17.88	42.55	59.41	67.99	79.88	53.54
TCMS 4	25.77	51.19	68.99	78.9	89.41	62.85
TCMS 5	20.11	47.81	64.69	74.77	88.98	59.27
TCa 12-1	2.87	17.91	27.1	30.44	47.85	25.23
TCa 12-2	0.98	11.35	18.25	30.83	35.75	19.43
TCa 12-3	8.67	27.21	46.72	50.38	65.28	39.65
TCa 12-4	3.87	20.19	28.91	34.04	51.87	27.78
TCa 12-5	1.89	19.54	26.88	34.19	46.32	25.76
TCa 12-6	0.94	7.27	10.39	17.26	20.22	11.22
TCa 12-7	5.91	24.15	33.19	45.27	55.19	32.74
TCa 12-8	10.53	34.76	51.79	60.72	67.32	45.02
TCa 12-9	7.95	26.87	41.21	48.74	59.55	36.86
TCa 12-10	2.63	19.89	28.27	36.28	49.73	27.36
PDP -1	18.17	42.67	60.19	67.38	81.47	53.98
PDP-9	25.91	51.05	68.9	76.16	90.21	62.45
CI-823	27.81	51.18	63.75	75.3	89.99	61.61
YTP-1	0.67	2.76	7.53	10.16	11.76	6.58
H226	10.91	35.08	53.9	62.77	69.74	46.48
H740/92	0.88	5.89	9.63	11.99	16.13	8.9
MDV	19.72	45.8	57.21	75.83	84.21	56.55
CMR 100	31.98	52.85	74.17	81.98	91.72	66.54
CI- 850	0.27	1.78	5.81	8.91	9.81	5.32
MEAN	11.37	29.53	41.99	50.46	60.27	38.73
SEd	0.098	0.224	0.307	0.356	0.427	
CD (0.05)	0.195	0.446	0.612	0.709	0.851	

Table 2: Total carotenoid content (mg g^{-1} of FW) of 24 cassava genotypes

Genotypes	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	MEAN
TCMS 1	0.654	0.512	0.308	0.183	0.110	0.35
TCMS 2	0.421	0.196	0.121	0.115	0.082	0.19
TCMS 3	0.573	0.276	0.189	1.115	0.100	0.45
TCMS 4	0.412	0.179	0.138	0.119	0.079	0.19
TCMS 5	0.533	0.376	0.266	0.182	0.108	0.29
TCa 12-1	0.718	0.488	0.276	0.179	0.125	0.36
TCa 12-2	0.823	0.787	0.567	0.309	0.212	0.54
TCa 12-3	0.611	0.412	0.259	0.183	0.137	0.32
TCa 12-4	0.714	0.512	0.364	0.217	0.137	0.39
TCa 12-5	0.736	0.510	0.347	0.187	0.103	0.38
TCa 12-6	0.854	0.732	0.521	0.218	0.119	0.49
TCa 12-7	0.892	0.743	0.537	0.278	0.122	0.51
TCa 12-8	0.644	0.378	0.218	0.136	0.127	0.30
TCa 12-9	0.687	0.370	0.219	0.173	0.118	0.31
TCa 12-10	0.725	0.549	0.418	0.211	0.111	0.40
PDP -1	0.521	0.317	0.223	0.121	0.117	0.26
PDP-9	0.312	0.117	0.107	0.093	0.036	0.13
CI-823	0.301	0.135	0.118	0.086	0.026	0.13
YTP-1	0.998	0.953	0.912	0.836	0.712	0.88
H226	0.636	0.468	0.247	0.168	0.135	0.33
H740/92	0.912	0.823	0.712	0.703	0.541	0.74
MDV	0.517	0.321	0.275	0.169	0.115	0.28
CMR 100	0.212	0.129	0.085	0.059	0.019	0.10
CI-850	1.321	1.143	0.998	0.932	0.821	1.04
MEAN	0.655	0.476	0.351	0.291	0.180	0.391
SEd	0.0043	0.0033	0.0025	0.0019	0.0015	
CD (0.05)	0.0086	0.0065	0.0049	0.0039	0.003	

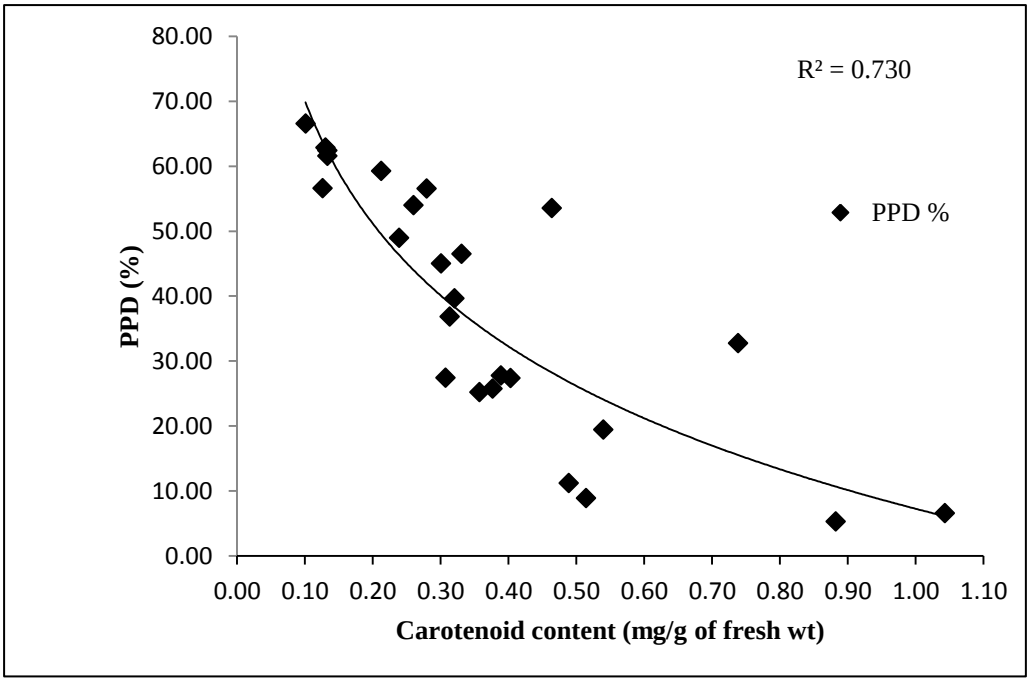

Fig 1: Association between PPD (%) and total carotenoid content of 24 cassava genotypes. The regression analysis was measured based on PPD

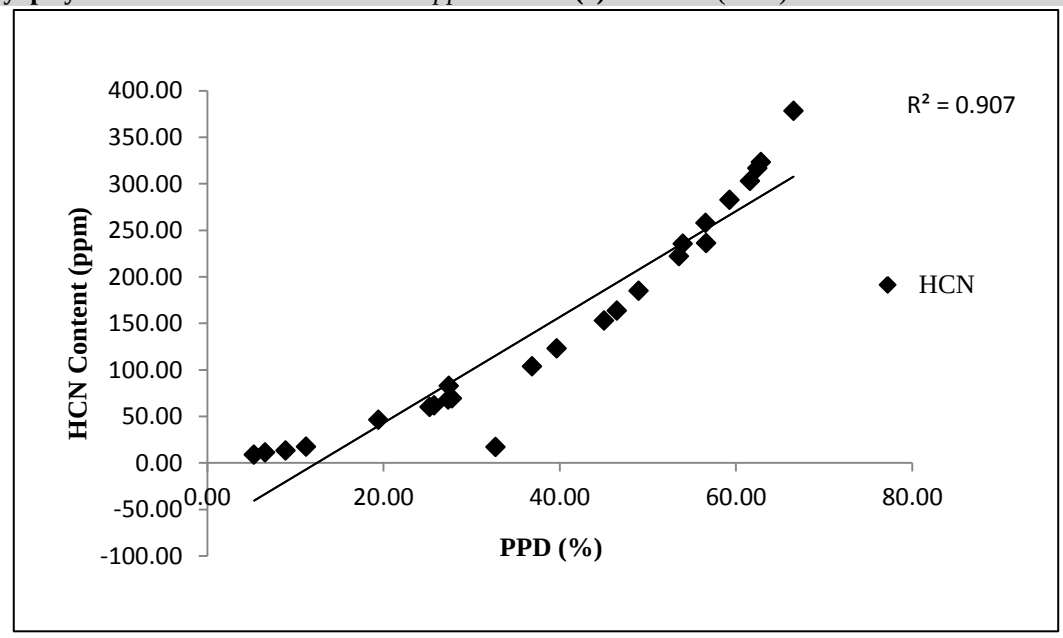

Fig. 2: Association between HCN content (ppm) and PPD (%) of 24 cassava genotypes. The regression analysis was measured based on PPD

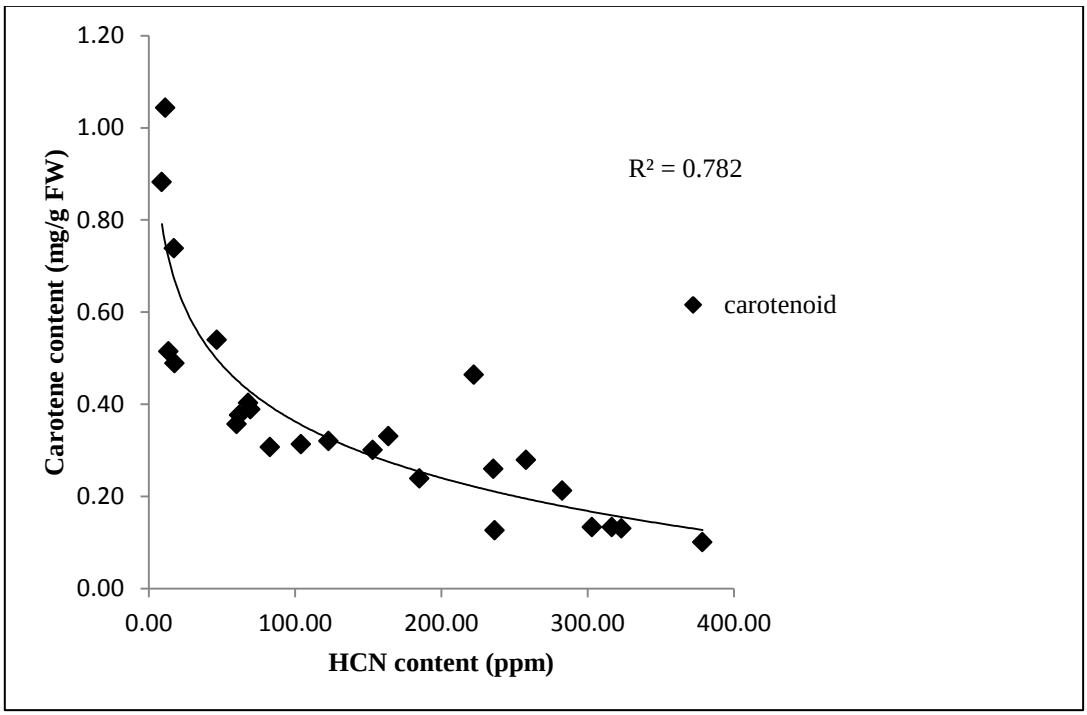

Fig. 3: Association between Carotenoid content (mg g^{-1} of FW) and HCN content (ppm) of 24 cassava genotypes. The regression analysis was measured based on PPD

CONCLUSION

This study provides further evidence for positive and negative relationship of HCN and carotenoid content with PPD. This study proved the variability existed among cassava genotypes for PPD, although there were no cassava genotypes with complete tolerance or resistance to PPD. CI-850 and YTP-1 had low reaction to PPD. These cassava genotypes can be used as novel donor sources in breeding programmes aimed for developing PPD tolerant genotypes.

REFERENCES

1. Beeching, J.R., Yuanhuai, H., Gómez-Vázquez, R., Day, R.C. and Cooper, R.M., Wound and defense responses in cassava as related to post-harvest physiological deterioration, in ecent Advances in Phytochemistry. Phytochemical Signals in Plant-Microbe Interactions, Ed by Romeo JT, Downum KR and Verpporte R. Plenum Press, New York-London, **32:** 231-248 (1998).
2. Buschmann, H., Rodriguez, M.X., Thome, J. and Beeching, J., Accumulation of hydroxycoumarins during post-harvest deterioration of tuberous roots of cassava (Manihot esculenta Crantz). *Annals of Botany.*, **86:** 1153-1160 (2000).
3. Ceballos, H., Morante, N., Jaramillo, G., Lenis, J.I., Calle, F. and Perez, J.C., Mejoramiento genetico de la yucca, in La Yuca en el Tercer Milenio, Ed by Ospina B and Ceballos H. CIAT, Cali, Colombia, (2002).
4. Chavez, A.L., Sanchez, T., Jaramillo, G., Bedoya, J.M., Echeverry, J.and Bolanos, E. A., Variation of quality traits in cassava roots evaluated in landraces and improved clones. *Euphytica*, **143:** 125–133 (2005).
5. Cortes, D.F., Reilly, K., Okogbenin, E., Beeching, J.R., Iglesias, C. and Tohme, J., Mapping wound-response genes involved in post-harvest physiological deterioration (PPD) of cassava (Manihot esculenta Crantz). *Euphytica*, **128:** 47- 53 (2002).
6. Indian Standard, Methods of Test for Edible Starches and Starch Products. Part II, Chemical Methods, IS : 4706 (Part II) – (1978).
7. Iyer, S., Mattinson, D.S., Fellman, J.K., Study of the early events leading to cassava root postharvest deterioration. *Tropical Plant Biol.*, **3:** 151–165 (2010).
8. Jensen, A., Chlorophylls and Carotenoids. In : Hellebust, A and J.S. Crargie (eds.) Handbook of Phytological Methods, Cambridge Univ. Press, London, pp. 59-70 (1978).
9. McMahon, J., White, W. and Sayre, R.. Cyanogenesis in cassava (Manihot esculenta). *J. Exp. Bot.*, **46:** 731–741 (1995).
10. Mkpong, O.E., Yan, H., Chism, G. and Sayre, R.T., Purification, characterization, and localization of linamarase in cassava. *Plant Physiol.*, **93:** 176-181 (1990).
11. Mlingi, N.L.V. and Bainbridge, Z., Reduction of cyanogen levels during sun-drying of cassava in Tanzania. *Acta Horticulturae*, **375:** 233-239 (1994).
12. Moller, B.L., Functional diversifications of cyanogenic glucosides. *Current opinion in plant biology*., **13:** 338-47 (2010).
13. Reilly, K., Han, Y., Tohme, J. and Beeching, J.R., Isolation and characterization of a cassava catalase expressed during post-harvest physiological deterioration. *Biochim Biophys Acta*., **1518:** 317-323 (2001).
14. Reilly, K., Gomez-Vasquez, R., Buschmann, H., Tohme, J. and Beeching, J.R., Oxidative stress responses during cassava post-harvest physiological deterioration. *Plant Molecular Biology*, 669-685 (2004).
15. Reilly, K., Bernal, D., Cortes, D.F., Gomez-Vasquez, R., Tohme, J., Beeching, J.R., Towards identifying the full set of genes expressed during cassava post-harvest physiological deterioration. *Plant Mol Biol*., **64:** 187–203 (2007).
16. Rickard, J.E.., Physiological deterioration of cassava roots. J. Sci. *Food Agric*., **36:** 167-176 (1985).
17. Salcedo, A., Del Valle, A., Sanchez, B., Ocasio, V., Ortiz, A., Marquez, P., Siritunga, D., Comparative evaluation of physiological post-harvest root deterioration of 25 cassava (Manihot esculenta) accessions: visual vs. hydroxycoumarins fluorescent accumulation analysis. *African Journal of Agricultural Research*, **5:** 3138-3144 (2010).
18. Sanchez, T., Chavez, A.L., Ceballos, H., Rodriguez-Amaya, D.B., Nestel, P. and Ishitani, M., Reduction or delay of post-harvest physiological deterioration in cassava roots with higher carotenoid

content. *Journal Science and Food Agriculture*, **86:** 634–639 (2006).

19. Sanchez, T., Dufour, D., Moreno, J. L., Pizarro, M., Aragón, I. J., Domínguez, M.. Changes in extended shelf life of cassava roots during storage in ambient conditions. *Postharvest Biology and Technology*, **86:** 520–528 (2013).
20. Sayre, R., Beeching, J. R., Cahoon, E. B., Egesi, C., Fauquet, C., Fellman, J., Fregene, M., Gruissem, W., Mallowa, S. and Manary, M., The BioCassava plus program: biofortification of cassava for sub-Saharan Africa. *Annu Rev Plant Biol*., **62:** 251–272 (2011).
21. Van Oirschot, Q.E.A., O'Brien, G.M., Dufour, D., El-Sharkawy, M.A. and Mesa, E., The effect of pre-harvest pruning of cassava upon root deterioration and quality characteristics. *J Sci Food Agric*., **80:** 1866-1873 (2000).
22. Wheatley, C. and Schwabe, W., Scopoletin involvement in postharvest deterioration of cassava roots (Manihot esculenta Crantz). *Journal of Experimental Botany*, **36:** 783- 791 (1985).