Bangladesh J. Bot. **47**(3): 799-803, 2018 (September) Special **- Short communication**

VITAMIN DIVERSITY IN PINEAPPLE VARIETIES BASED ON CLUSTER AND PRINCIPAL COMPONENT ANALYSIS

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Keywords: Vitamin, Pineapple, Cluster analysis, Principal component analysis

Abstract

The diversity of vitamins in 11 pineapple varieties was assessed emplying cluster and principal component analysis. The cluster analysis classified the 11 varieties into three types: type 1 comprising Comte de Paris, Jinzuan, Shenwan, Comte de Paris red crown, Xiangshui, New Phuket, Smooth Cayenne, Phuket, and Golden pineapple; type 2 consisting of Mibao; and type 3 which included Golden Winter Sweet. The principal component analysis revealed that Golden Winter Sweet had the highest overall score of pineapple quality, followed by Smooth Cayenne and Mibao as the second and third highest score, respectively. The results provide a reference for vitamin-based selective breeding of pineapples.

Pineapple (*Ananas comosus* L. Merr.) is the third biggest tropical fruit, cultivated in tropical and subtropical areas for its attractive sweet flavor and high nutritional value. The fruits are rich in carbohydrates, proteins, and fats, as well as many minerals, such as calcium and phosphorus, and various vitamins (Zhao 2014).

Vitamins are low molecular organic compounds that play a unique and irreplaceable role in maintaining metabolism and some physiological processes important for human health. Vitamin A prevents night blindness; mild deficiency of vitamin A can result in blindness and severe deficiency can cause corneal ulcer, keratomalacia, and eventually blindness (Gamache *et al.* 1999, Han 1999). Vitamin C promotes the formation of human antibodies, enhances leukocyte phagocytic function, and increases human ability to cope with diseases, thus strengthening immune response of the human body (Zeng 2005). In addition, vitamin C can also prevent cancer and provide anti-aging protection (Bendich and Langseth 1995). Vitamin B3 is the most abundant vitamin within the B group of vitamins needed by human body and essential for hormone synthesis. This vitamin also maintains a healthy digestive system and skin; it is involved in the control of blood sugar, and improving memory, focus, and mood (Lappasand and Permezel 2011). Vitamin B12 is the only vitamin that contains a metal element. It functions in the prevention of fatty liver and promotes storage of vitamin A in the liver, maturation of cells, and metabolism (Luo *et al.* 2006). Its deficiency causes brain atrophy and cognitive dysfunction in the elderly (Vogiatzoglou *et al.* 2008). Vitamin B6 acts as a cofactor of enzymes and a powerful antioxidant (Mooney *et al*. 2009), and its deficiency results in chronic inflammation, enhanced oxidative stress, and disrupted metabolic response (Shen *et al*. 2010).

Although vitamins are essential for human metabolic processes, they are not synthesized by the human body. They are obtained from food, especially fruits, and therefore, their content in fruits is one of the important parameters used for evaluating fruit quality.

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Studies on fruit vitamins have primarily focused on the analysis of vitamin C, and in particular studies on pineapple vitamins have mainly focused on vitamin types (Li *et al*. 2012b), variation due to production areas and seasons (Li *et al*. 2013), and pineapple varieties (Li *et al*. 2012a); no studies on the diversity of vitamins have been reported. The present study aimed to analyze vitamin diversity of different pineapple varieties, providing scientific evidence for the evaluation, exploration, and utilization of pineapple varieties resources, as well as for the selective breeding of new pineapple species.

The pineapple varieties that were studied are: Comte de Paris, Smooth Cayenne, Golden, Mibao, Red head of Comte de Paris, Xiangshui, Golden Winter Sweet, Shenwan, Phuket, New Phuket, and Jinzuan. The fruits were harvested at yellow ripening stage (fruitlets well developed, green skin area covers between 20 and 80% of the fruit) from the germplasm repository located at the South Subtropical Crop Research Institute in Guangdong Province. All the pineapple varieties were grown utilizing the same standard cultivation practice. Three replicates, each consisting of five fruits, were used from each variety for the experiments. Vitamin A, vitamin C, vitamin B3, vitamin B12, and vitamin B6 were extracted from pineapple fruits and quantified according to the methods described by Li *et al.* (2012b). The R-type cluster analysis of the vitamin content in the 11 pineapple varieties was conducted using the Pearson's correlation coefficient distance clustering method, and the results were presented in a tree diagram. All the data were first normalized and then subjected to principal component analysis to generate the analytical expressions of each principal component (PC) and the overall PC scores. All the analyses were conducted with software SPSS 16.0 (IBM Corp., Armonk, NY, USA).

The vitamin contents of different pineapple varieties are shown in Table 1.

Table 1. Comparison of the contents of five vitamins in different pineapple varieties (mg/100 g FW).

Name	Vitamin A	Vitamin C	Vitamin B3	Vitamin B12	Vitamin B6
Comte de Paris	0.38e	17.78de	0.89e	-	0.69bc
Smooth Cayenne	0.35d	9.99a	0.60c	0.66c	0.71c
Golden pineapple	0.24c	22.39fg	0.58c	0.40b	1.43e
Mibao	0.25c	16.91d	0.91e	1.21e	3.02f
Comte de Paris red crown	0.16a	17.69de	0.90e	0.84d	0.49ab
Xiangshui	0.19b	23.09g	0.38a	-	1.04d
Golden Winter Sweet	0.18ab	11.18b	2.35f	-	6.71g
Shenwan	0.25c	21.45f	0.76d	0.20a	0.45a
Phuket	0.25c	18.60e	0.49b	-	0.66bc
New Phuket	0.24c	16.80d	0.45b	-	0.78c
Jinzuan	0.35d	14.28c	0.76d	1.20e	0.59abc

Different letters in the same column indicate significant difference according to Duncan’s multiple range text ($p < 0.05$, $n = 3$).

The results of the cluster analysis of the above data are shown in Fig. 1. At a correlation coefficient distance of 2, the pineapple varieties were classified into three types: type 1 comprising Comte de Paris, Jinzuan, Shenwan, Comte de Paris red crown, Xiangshui, New Phuket, Smooth Cayenne, Phuket, and Golden pineapple; type 2 consisting of Mibao, and type 3, which included Golden Winter Sweet. The first two types were closely related and distant from the third type.

The contents of the five vitamins in the 11 selected pineapple varieties were subjected to PCA. As shown by the eigenvalues and contribution percentages (Table 2), the first PC (PC1) explained

45.922% and the second (PC2) explained 30.515% of the variation, with the two combined explaining up to 76.436% of the variation. Therefore, the two PCs may be extracted.

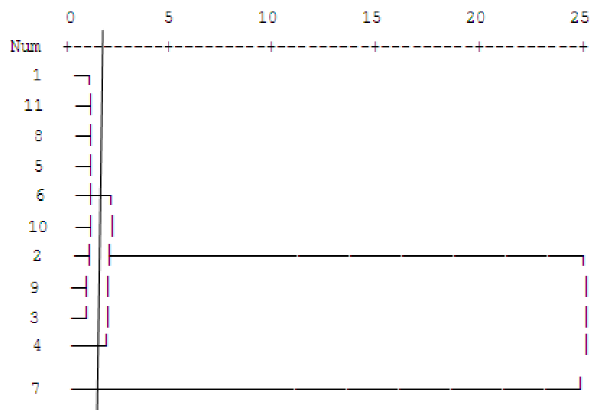

Fig. 1. A cluster diagram of the vitamin content in fruits of different pineapple varieties.1: Comte de Paris, 2, Smooth Cayenne, 3, Golden pineapple, 4. Mibao, 5. Comte de Paris red crown, 6. Xiangshui, 7. Golden Winter Sweet, 8. Shenwan, 9. Phuket, 10. New Phuket, 11. Jinzuan.

Table 2. Eigenvalues and contribution percentages of the principal components.

Principal component	Eigenvalue	Contribution (%)	Cumulative contribution (%)
1	2.296	45.922	45.922
2	1.526	30.515	76.436
3	0.808	16.168	92.604
4	0.272	5.447	98.051
5	0.097	1.949	100.000

Using the retrieved factor-loading matrix, factor loads were divided by the square roots of the Eigenvalues to generate Eigenvectors of the pineapple vitamins (Table 3). According to the Eigenvectors, it was clear that PC1 primarily reflected the compositional variations of vitamins B3 and B6, while PC2 primarily indicated those of vitamins A, C, and B12.

Table 3. A factor-loading matrix and Eigenvectors of the vitamins in pineapple fruits.

	Factor loads		Eigenvector	
	Principal component 1 (PC1)	Principal component 2 (PC2)	Principal component 1 (PC1)	Principal component 2 (PC2)
Vitamin A	–0.328	0.763	–0.216	0.618
Vitamin C	–0.598	–0.692	–0.395	–0.56
Vitamin B3	0.961	–0.006	0.634	–0.005
Vitamin B12	–0.042	0.669	–0.028	0.542
Vitamin B6	0.951	–0.136	0.628	–0.11

A multiplication of the eigenvectors of pineapple vitamins (Table 3) by normalized data gives the expressions of PC1 and PC2:

F1 = -0.216ZX1 - 0.395 ZX2 + 0.634 ZX3 - 0.028 ZX4 + 0.628 ZX5,

F2 = 0.618 ZX1 - 0.560 ZX2 - 0.005 ZX3 + 0.542 ZX4 - 0.110 ZX5.

Using the contribution percentage of each PC (calculated as the percentage of each PC Eigenvalue in the total Eigenvalue of PCs) as a weight to compute a composite model of PCs, a PC-based comprehensive evaluation index was obtained.

$F = \lambda 1 \times F1 + \lambda 2 \times F2 + \ldots + \lambda n \times Fn$.

In this study, the PC-based comprehensive evaluation index for pineapple vitamins was F = 0.459F1 + 0.305F2.

Table 4. Principal component scores of the pineapple varieties.

Varieties	F1	Rank	F2	Rank	F	Rank
Comte de Paris	–0.5816	7	0.5625	4	–0.0954	5
Smooth Cayenne	–0.1373	4	2.0706	2	0.5688	2
Golden pineapple	–0.7341	8	–0.8341	10	–0.5916	9
Mibao	0.6215	2	0.7759	3	0.5222	3
Comte de Paris red crown	–0.0215	3	–0.3519	5	–0.1172	6
Xiangshui	–0.9937	11	–1.7689	11	–0.9961	11
Golden Winter Sweet	4.3604	1	–0.6284	7	1.8106	1
Shenwan	–0.7816	10	–0.7901	9	–0.6000	10
Phuket	–0.7514	9	–0.6441	8	–0.5416	8
New Phuket	–0.5606	6	–0.4974	6	–0.4092	7
Jinzuan	–0.4201	5	2.1058	1	0.4497	4

Vitamin compositional scores in the PCs and their ranks can provide objective information regarding the vitamins in each pineapple species and the overall ranks for each species, as shown in Table 4. The species with the highest score in PC1 was Golden Winter Sweet, followed by Mibao, indicating that they had the highest load in PC1 and demonstrating that the two species contained relatively high vitamin B3 and B6 content. Jinzuan and Smooth Cayenne were the two species having the highest and second highest loads in PC2, respectively, demonstrating that these two species had a relatively high level of vitamins A, C, and B12. According to the PC-based comprehensive evaluation index, the pineapple species were sorted in decreasing order from high to low as follows: Golden Winter Sweet, Smooth Cayenne, Mibao, Jinzuan, Comte de Paris, Comte de Paris red crown, New Phuket, Phuket, Golden pineapple, Shenwan, and Xiangshui.

Fruits are plant-derived food with high nutritional value, and due to their richness in biologically active components they are able to regulate body functions and improve body metabolism. Vitamins, which are low molecular weight organic compounds necessary for maintaining normal metabolism and some specific physiological processes in human body, will attract increasing attention of consumers as one of the important indicators of fruit quality.

In this study, the cluster analysis categorized the varieties of pineapples into three classes, with two classes consisting of a single variety. According to the PCA results, PC1 was correlated with vitamin B3 and vitamin B6 content and PC2 with vitamin A, vitamin C, and vitamin B12 content. Pineapple variety Golden Winter Sweet had the highest contents of vitamin B3 and vitamin B6, and it was classified into one of the two single-member classes, which was corroborated by the eigenvector of PC1. The other single-member class included only Mibao, characterized by the second highest content of vitamin B3 and vitamin B6, and the highest content of Vitamin B12, which was explained by the eigenvectors of PC1 and PC2. The remaining varieties clustered together in one class based mainly on the information for PC2.

The cluster and principal component analysis of the pineapple vitamins segregated Golden Winter Sweet in a single category as the variety with the highest overall score of principal components. Thus, this variety may serve as a good study material for vitamin-based selective breeding of pineapples and may speed up the breeding process.

Acknowledgments

This study was supported by the grant from Nonprofit-Industry Research Projects of the Ministry of Agriculture (No. 201203021); the Fund of Agricultural Ecological Environmental Protection of Ministry of Agriculture in 2017 and 2018;Natural Science Foundation of Hainan Province (No. 20153115); Central Public-interest Scientific Institution Basic Scientific Research Fund for Chinese Academy of Tropical Agricultural Sciences (No. 1630062017017, 1630062017025); the Operation Funds for Integrated laboratory of SSCRI.

References

Bendich A and Langseth L 1995. The health effects of vitamin C supplementation. Journal of the American College of Nutrition **14**: 124-136.

Gamache P, Freeto S and Acworth I 1999. Coulometric-array HPLC analysis of lipid-soluble vitamins and antioxidants. American Clinical Laboratory **18**: 18-19.

Han YS 1999.Advances of the function of beta-carotene and carotenoid. Journal of China Agricultural University **4**: 5-9.

Lappas M and Permezel M 2011. The anti-inflammatory and antioxidative effects of nicotinamide, a vitamin B3 derivative, are elicited by FoxO3 in human gestational tissues: implications for preterm birth. Journal of Nutritional Biochemistry **22**: 1195-1201.

Li MM, Bu JJ, Zhang XM, Liu SH, Li YH, Lu XH, Wu QS, Sun WS and Sun GM 2013. Comparison of vitamin contents in winter and summer fruits of two pineapple varieties in different areas. Journal of Fruit Science **30**: 803-807.

Li MM, Zhang XM, Liu SH, Li YH, Lu XH, Wu QS, Sun WS and Sun GM 2012a. Analysis of five kinds of vitamins content in 11 different pineapple fruits. Chinese Journal of Tropical Crops **33**: 1659-1662.

Li MM, Zhang XM, Wei CB and Sun GM 2012b. Determination of eight kinds of vitamins in pineapple fruit by HPLC. Chinese Journal of Tropical Crops **33**: 375-381.

Luo B, Chen B, Ding L, Tang F and Yao SZ 2006 HPLC-ESI-MS analysis of Vitamin B12 in food products and in multivitamins-multimineral tablets. Analytica Chimica Acta **562**: 185-189.

Mooney S, Leuendorf JE, Hendrickson C and Hellmann H 2009. Vitamin B6: a long known compound of surprising complexity. Molecules **14**: 329-351.

Shen J, Lai CQ, Mattei J, Jose MO and Katherine LT 2010. Association of vitamin B6 status with inflammation, oxidative stress, and chronic inflammatory conditions: the Boston Puerto Rican Health Study. American Society for Nutrition **91**: 337-342.

Vogiatzoglou A, Refsum H, Johnston C and Smith DSM 2008.Vitamin B12 status and rate of brain volume loss in community-dwelling elderly. Neurology **71**: 826-832.

Zeng XY 2005. The physiological function and guarantee measures of vitamin C. Food and Nutrition in China **4**: 52-54.

Zhao WF 2014. Fruit Production Technology. Chongqing University Press: Chongqing, China, 334-369.

(Manuscript received on 25 May, 2018; revised on 14 August, 2018)