SCREENING OF BANANAS AND PLANTAINS (*MUSA* SPP.) FOR PROVITAMIN A CAROTENOIDS (PVACS)

Lorna E. Herradura, Ph.D., Rosario A. Del Valle and Jonalyn A. Pabuaya
Bureau of Plant Industry-Davao National Crop Research and Development Center
Bago Oshiro, Davao City, Philippines

ABSTRACT

Banana cultivars from Asia and Papua New Guinea and improved hybrids having orange, yellow orange, yellow and creamy-white pulp were used in the screening of proVitamin A carotenoids (pVACs). Fresh fruit samples were sent to the UPLB (Laguna, Philippines) for lyophilization. The lyophilized samples were then provided to the KULeuven (Belgium) for pVACs analysis using High Performance Liquid Chromatography (HPLC) technique.

Results showed that all banana and plantain cultivars analyzed contained proVitamin A carotenoids (pVACs). The cultivars with orange pulp color had the highest carotenoid content such as 'Muracho', 'Pusit', 'Bantol Red', 'Tudlo Tumbaga' are coming from the Philippines and 'Henderneyargh' and 'Katimor' coming from Papua New Guinea. The cultivars with creamy-white pulp color had the lowest carotenoid content including seeded bananas like 'Pisang Surung' and 'Kluai Pa' and other improved hybrid Cavendish- type cultivars such as 'FHIA-01' and 'FHIA-02'.

The regression and correlation analysis revealed that carotenoid content of the fruits is highly correlated with the pulp color. The pulp color can be a cheap and quick way to identify the carotenoid-rich banana cultivars.

Keywords**:** Banana cultivars, carotenoids,orange flesh banana**,** proVitamin A carotenoids (pVACs).

INTRODUCTION

Banana and plantains (*Musa* spp.) are the world's fourth largest staple fruit crops consisting of *Acuminata* (AA), a dessert type; *Balbisiana* (BB), a cooking type; and *Musa* x *paradisiaca* which includes the plantain type (AAB) cultivars. Banana fruits contain a high levels of proVitamin A carotenoids (pVACs) aside from Vitamin C, fiber and potassium. The common pVACs in plants are alpha-carotene and beta-carotene. These substances are converted in the body into Vitamin A. The presence of yellow orange to orange color in the pulp indicates a high level of Vitamin A.

The pVACs protect against Vitamin A Deficiency (VAD). They also protect against certain chronic diseases including diabetes, heart disease, night blindness and some type of cancer (Ford, *et al*., 1999 and Bertram, 2002). A deficiency of Vitamin A in the human diet affects an estimated of up to half a million children getting blind and more than 50% death in a year is associated with malnutrition (WHO, 2003). The malnutrition and deficiency can be reduced if Vitamin A sources are identified and promoted.

The Recommended Dietary Allowance (RDA) of Vitamin A in a human diet ranges from 400-600 µg/day for an average adult (King and Burgess, 1992). This can be achieved by eating 2 to 4 fingers of an orange-pulped bananas per day.

With the large number of banana collections maintained at the banana field genebank of BPI-DNCRDC in Bago Oshiro, Davao City (Philippines), a study was conducted in collaboration with UPLB (Philippines), Bioversity International (France) and Katholieke Universiteit Leuven (Belgium) to screen different banana collections for proVitamin A carotenoids (pVACs) analysis as natural Vitamin A sources.

OBJECTIVES

To screen banana and plantain cultivars for proVitamin A carotenoids pVACs) analysis

MATERIALS AND METHODS

Selection of cultivars

Thirty-four (34) banana cultivars from Asia and Papua New Guinea, and improved hybrids having orange, yellow orange, yellow, light yellow and creamy-white pulp colors were identified. The HarvestPlus color charts and Royal Horticultural Society (RHS) color fans were used to assess the pulp color of each cultivar. The color scale

used was: 10- Orange, 8- Yellow orange, 6- Yellow, 4- Light yellow and 2- Creamy-white.

Collection of fruit samples

Mature green fruit samples were taken from the bunch when one (1) ripe fruit was developed at six (6) fingers per cultivar. These were collected from the field genebank of the BPI-DNCRDC, Bago Oshiro, Davao City (Philippines).

Sending of fruit samples for lyophilization

The fruit samples packed with bubble film were sent to the University of the Philippines Los Baños (UPLB), Laguna (Philippines) for lyophilization. The lyophilization was done at ripening stage of the fruit.

Sending of lyophilized samples for pVACs analysis

The lyophilized samples were sent by the University of the Philippines Los Baños (UPLB), Laguna (Philippines) to the Katholieke Universiteit Leuven (Belgium) for pVACs analysis. The High Performance Liquid Chromatography (HPLC) technique developed by Davey*, et al*., 2006 was the method used in determining the pVACs content of each cultivar.

Statistical analysis of pulp color and carotenoid content

The Simple Linear Regression and Correlation analysis was used to determine the relationship between pulp color and carotenoid content of the fruit.

Photo documentation

Photo documentation of each sample was undertaken to illustrate the pulp color of the fruit at ripening stage. The photo standard developed by the Taxonomy Advisory Group (TAG) was used.

RESULTS AND DISCUSSIONS

Among the thirty-four (34) banana cultivars screened for proVitamin A carotenoids (pVACs) analysis using High Performance Liquid Chromatography (HPLC) technique, six (6) had orange pulp, five (5) yellow orange, eight (8) yellow, eight (8) light yellow and seven (7) cultivars with creamy-white pulp color (Table 1 and Appendix A).

Table 1. Banana cultivars from the banana field genebank of BPI-DNCRDC, Bago Oshiro, Davao City screened for proVitamin A carotenoids (pVACs) analysis.

Cultivar Name	Origin	Carotenoid content (nmol/gdw)	Number of cultivars
A. **Orange pulp color:**			**6**
➢ Muracho	Philippines	219.12	
➢ Pusit	Philippines	214.58	
➢ Bantol Red	Philippines	185.51	
➢ Henderneyargh	Papua New Guinea	173.43	
➢ Tudlo Tumbaga	Philippines	127.98	
➢ Katimor	Papua New Guinea	94.24	
B. **Yellow orange pulp color:**			**5**
➢ Pisang Papan	Indonesia	108.12	
➢ Kluai Khai Boran	Thailand	103.12	
➢ Oonoonoo Kengoa	Papua New Guinea	84.47	
➢ Lakem Connetnet	Papua New Guinea	79.83	
➢ Pisang Pelembang	Malaysia	73.86	
C. **Yellow color:**			**8**
➢ Torp	Papua New Guinea	98.10	
➢ Kluai Pa #26	Thailand	73.26	
➢ Señorita	Philippines	68.46	
➢ Galamay Señora	Philippines	71.42	
➢ Kotnar	Papua New Guinea	61.33	
➢ Oonoonoo	Papua New Guinea	60.77	
➢ Pokpok	Papua New Guinea	60.41	
➢ Walebo	Papua New Guinea	60.35	
D. **Light Yellow color**			**8**
➢ Komargh	Papua New Guinea	39.17	
➢ Pearly Shell	Philippines	36.09	
➢ Ambowga	Papua New Guinea	34.15	
➢ Umalag	Philippines	31.88	
➢ Pisang Talas	Malaysia	30.73	
➢ Kluai Pa #54	Thailand	22.40	
➢ Kluai Nam Tia	Thailand	21.98	
➢ Bata-Bata	Philippines	21.06	
D. **Creamy-white color:**			**7**
➢ Pisang Pulot	Malaysia	17.78	
➢ FHIA-01	ITC, Belgium	14.81	
➢ Kluai Namwa Khom	Thailand	11.97	
➢ AAcv Rose	ITC, Belgium	9.76	
➢ FHIA-02	ITC, Belgium	7.75	
➢ Pisang Surung	Malaysia	3.07	
➢ Kluai Pa	Thailand	2.73	
TOTAL			**34**

Orange pulp color

Of the cultivars analyzed, the higher carotenoid contents were observed on cultivars with orange pulp color. 'Muracho', a Philippine cultivar having orange pulp color, obtained the highest carotenoid content with 219.12 nmol/gdw. This is AAB plantain type cultivar with potential for cooking but can also be used as dessert and for chip processing. The orange color of the pulp and eating quality of 'Muracho' is comparable to 'Lakatan' and 'Tindok', a dessert and cooking plantain type, respectively, both Philippine cultivars. This conforms with the report of Lusty, *et al*., 2006 that plantains are significant sources of proVitamin A carotenoids (pVACs). Other cultivars with orange pulp color having higher carotenoid content were 'Pusit' (214.58 nmol/gdw), 'Bantol Red' (185.51) and 'Tudlo Tumbaga' (127.98), all Philippine cultivars that can be used for dessert purposes. The 'Henderneyargh' and 'Katimor' also having an orange pulp color obtained a carotenoid content of 173.43 and 94.24, respectively. These cultivars are both introduced from Papua New Guinea. Both can be used as dessert, cooking and chips (Table 1, Figure 1 and Figure 2).

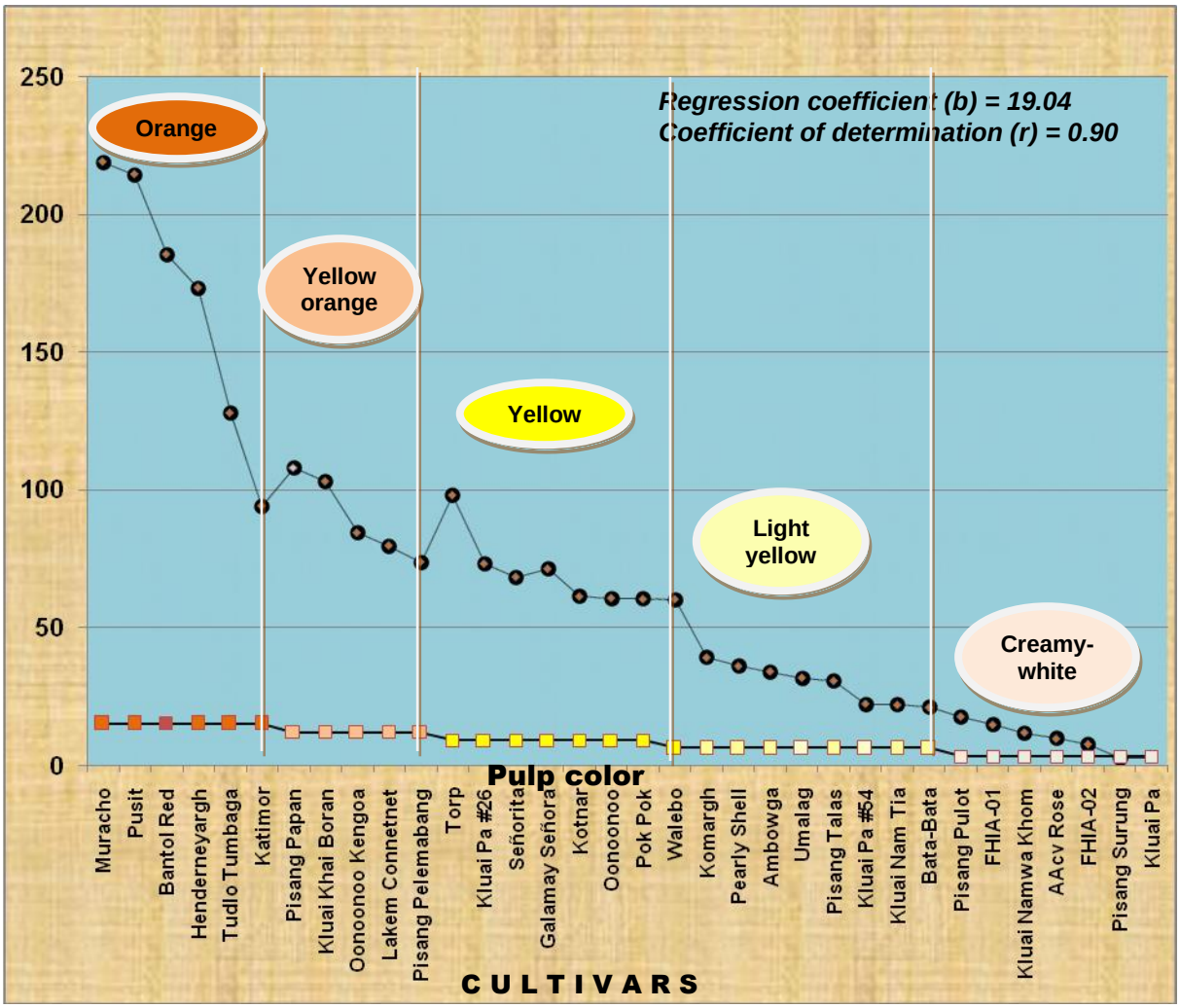

Figure 1. Banana cultivars from the field genebank of BPI-DNCRDC, Bago Oshiro, Davao City screened for proVitamin A carotenoids (pVACs) analysis.

Yellow orange pulp color

The cultivars with yellow orange pulp were observed from genome having AA, AAA and some AAB dessert types. These are ‘Pisang Papan’, ‘Kluai Khai Boran’, ‘Oonoonoo Kengoa’, ‘Lakem Connetnet’ and ‘Pisang Pelembang’ which were introduced from Indonesia, Thailand, Papua New Guinea and Malaysia, respectively. The carotenoid content of these cultivars ranged from 60.35 to 73.26 nmol/gdw (Table 1 and Figure 1).

Yellow pulp color

The cultivars with yellow pulp color were ‘Kluai Pa #26’, ‘Señorita’, ‘Galamay Señora’, ‘Kotnar, Oonoono’, ‘Pokpok’ and ‘Walebo’. These cultivars are both local and introduced in origin. The carotenoid content of these cultivars ranged from 60.35 to 73.26 nmol/gdw (Table 1 and Figure 1).

Light yellow pulp color

The cultivars having light yellow pulp color were observed on AAA Cavendish type and non-Cavendish cultivars potential as dessert type. Their carotenoid content ranged from 21.06 to 39.17 nmol/gdw (Table 1 and Figure 1).

Creamy-white pulp color

The lowest carotenoid contents were observed on cultivars with creamy-white pulp color. These were on seeded (AAw) cultivars like ‘Pisang Surung’ and ‘Kluai Pa’, improved hybrids (‘FHIA-01’ and ‘FHIA-02’), silk (‘Pisang Pulot’), and other Awak cultivar (‘Kluai Namwa Khom’). The lowest carotenoid content was observed at 2.73 nmol/gdw (Table 1 and Figure 1).

Statistical Analysis

The regression and correlation analysis showed a positive regression coefficient (b) which reveals that in every increase of color intensity of the pulp of the fruit, there was an average increase of 19.04 nmol/gdw of the carotenoid content with the coefficient of determination (r) of 0.90. This means that the association or relationship between the pulp color and the carotenoid content of the fruits is strong and are highly correlated. It also shows that about 81% of the carotenoid content was due to pulp color and the remaining 19% due to unknown factors. This implies that the more intense the orange pulp color, the higher the carotenoid content, which conforms with the reports of Englberger, *et al*., 2003 and study of Francis, *et al*., 1976 that carotenoid content increased with the intensity of pulp color of the fruit. The pulp color of the fruit was directly proportional to the carotenoid content of the fruit. Thus, pulp color of the fruit provides an easy selection aid in identifying the carotenoid-rich banana cultivars (Figure 1).

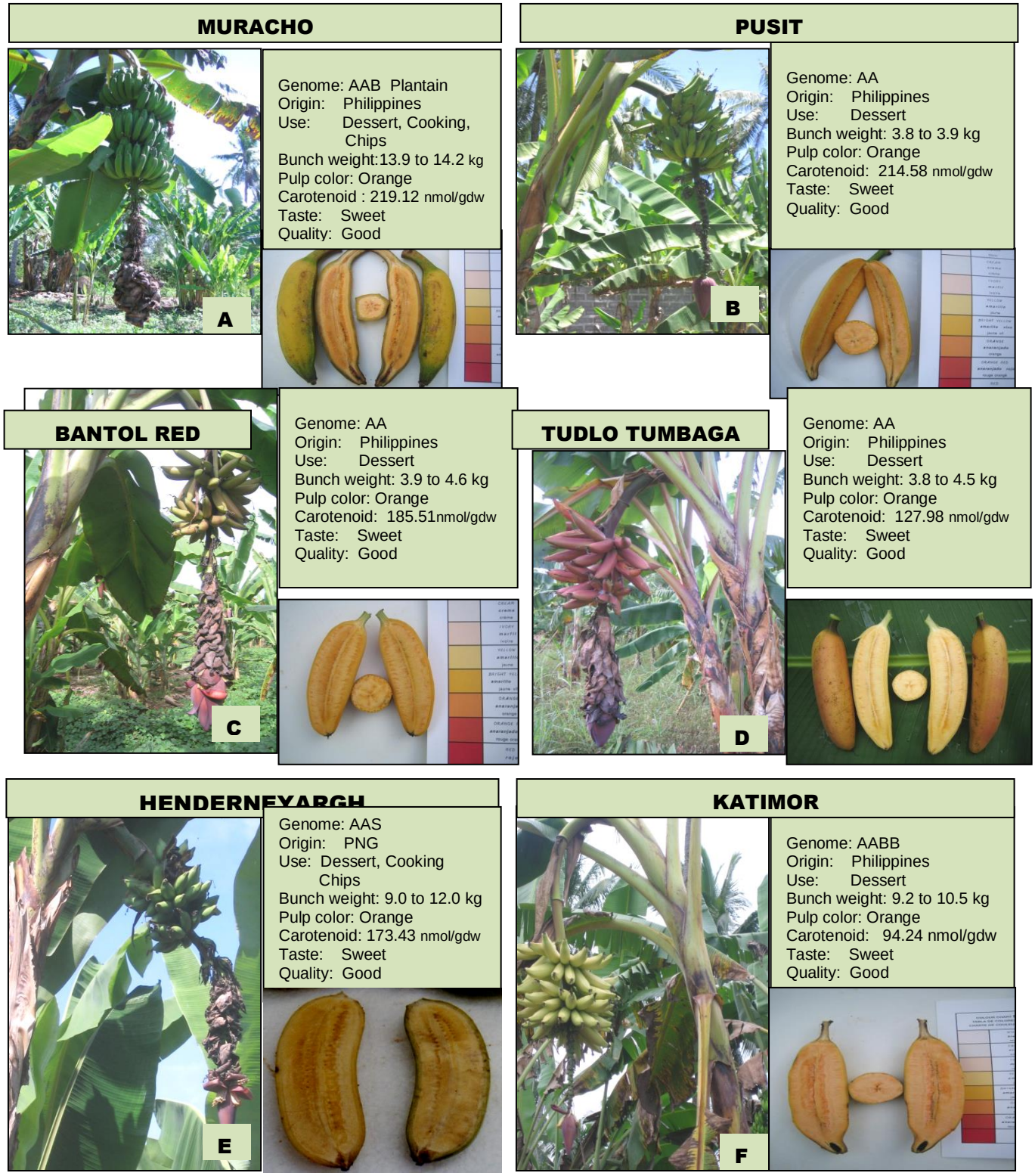

Figure 2. Banana cultivars with high carotenoid contents from Philippines (A to D) and Papua New Guinea (E to F).

CONCLUSIONS

Banana cultivars with orange pulp color had the highest carotenoid content like ‘Muracho’, ‘Pusit’, ‘Bantol Red’, ‘Tudlo Tumbaga’ from the Philippines and ‘Henderneyargh’ and ‘Katimor’ from Papua New Guinea. Cultivars with creamy-white pulp color had the lowest carotenoid content including seeded cultivars like ‘Pisang Surung’ and ‘Kluai Pa’ and other improved hybrid Cavendish- type cultivars such as ‘FHIA-01’ and ‘FHIA-02’.

All banana cultivars analyzed contained proVitamin A carotenoids (pVACs). The carotenoid content of the fruits varied on the intensity of pulp color. The more intense the orange color of the pulp, the higher the carotenoid content. Therefore, the carotenoid content of the fruits of bananas is dependent on its pulp color. The pulp color of the fruit can be an easy and cheap way to identify the carotenoid-rich banana cultivars.

RECOMMENDATIONS

Mass production of identified carotenoid-rich banana cultivars for promotion/introduction
Aside from being eaten fresh, other processing techniques/methods must be undertaken.
Impact assessments of the promoted or introduced carotenoid-rich banana cultivars must be donE

BIBLIOGRAPHY

Bertram, J. S. 2002. Lectures presented in the 13th International Symposium on Carotenoids. Honolulu, Hawaii, USA. Pure and Applied Chemistry 74 (8): 1369- 1478.

Davey, M. W., E. Stals, G. Ngoh-Newilah, K. Tomekpe, C. Lusty, R. Markham, R. Swennen and J. Keulemans. 2007. Sampling strategies and variability In fruit pulp micronutrient contents of West and Central African bananas and plantains (*Musa* species). Journal of Agricultural and Chemistry 55 (2007) 2633- 2644.

Davey, M. W., I. Mellidou and J. Keulemans. 2009. Considerations to prevent the breakdown inand loss of fruit carotenoids during extraction and analysis In *Musa*. Journal of Chromatography A 1216 (2009) 5759-5762.

Davey, M. W., I. Van Den Bergh, R. Markham, R. Swennen and J. Keulemans. 2009. Genetic Variability in *Musa* fruit for proVitamin A carotenoids, lutien and mineral micronutrient contents. Food Chemistry 115 (2009) 806-813.

Dignan, C. A., J. M. Burlingame, J.M. Arthur, R.S. Quigly and G.C. Milligan. 1994. The Pacific Island Food Consumption Table. South Pacific Commision, Noumea, New Caledonia.

Englberger, L. 2002. Promotion of Vitamin A rich foods in Pohnpei, Federated State of Micronesia: Sight and life. Newsletter 4: 13-17.

Englberger, L. 2003. Carotenoid-rich banana in Micronesia. Infomusa: 12 (2): 25.

Francis, F. J., and C.T. Smith. 1976. Relationship between flesh color and pigment content in squash. Journal of American Society of Horticultural Science. 81: 408-414.

Food and Agriculture Organization of the United Nations (FAO). 1981. Food composition tables for use in Africa. FAO, Rome, Italy.

IPGRI-INIBAP and CIRAD. 1996. Descriptors for Banana (*Musa* spp.). International Plant Genetic Resources Institute, Rome Italy / International Network for the Improvement of Banana and Plantain, Montpellier, France / Centre de Coopération Internationale en Recherche' Agronomique pour de Développement, Montpellier, France. 55pp (with insert).

King, F. S. and Burgess, A. 1992. Nutrition for Developing Countries. Oxford University Press, Oxfoed, UK.

Lloyd-Puryear, M., Humphrey, K. P., K. West, K. Aniol, J. Mahoney and D. G. Keenum.1989. Vitamin A Deficiency and anemia among Micronesian children. Murt Res 9: 1007-1016.

Lusty, C., E. Akyeampong, M. W. Davey, G. Ngoh Newilab and R. Markham. 2006. A staple foods with nutritious appeal. Infomusa 15 (2): 39-42

Rodrigues-Amaya, D. B. 1997. Carotenoids and Food Preparation: The retention of pVACs in prepared, processed and stored foods. OMNI project 88p.

Royal Horticultural Society, 1996, c.1986. R. H. S. Colour Chart (ed. 1, 2). Royal Horticultural Society, London.

Taxonomy Advisory Group. 2008. Guidelines for documentation the minimum set of photos for bananas. IPGR-INIBAP and CIRAD. Montpellier, France. 6p.

Valmayor, R. V., R. R. C. Espino; and O. C. Pascua. The wild and cultivated bananas of the Philippines. Los Baños, Laguna: PARRFI and BAR, 2022. 242p.

World Health Organization (WHO). 2003. Joint WHO/FAO Expert consultation on diet nutrition and prevention of chronic disease. Geneva, Switzerland.

_____ Banana. Available from http://ods.od.nih.gov/factsheets/vitamina.asp.

Appendix A. Banana cultivars from the field genebank of BPI-DNCRDC, Bago Oshiro, Davao City screened for proVitamin A carotenoids (pVACs) analysis.

Cultivar Name	Origin	Genome / Subgroup	Caro-tenoid content (nmol/gdw)	USE / PURPOSE		
				Type	Taste	Quality
A. Orange pulp color: 1. Muracho	Philippines	AAB Plantain	219.12	Dessert Cooking Chips	Sweet Sweet Sweet	Good Good Very good
2. Pusit	Philippines	AA	214.58	Dessert	Sweet	Good
3. Bantol Red	Philippines	AA	185.51	Dessert	Sweet	Good
4. Henderneyargh	PNG	AAS	173.43	Dessert Cooking Chips	Sweet Sweet Sweet	Good Good Very good
5. Tudlo Tumbaga	Philippines	AA	127.98	Dessert	Sweet	Good
6. Katimor	PNG	AABB Plantain	94.24	Dessert Cooking Chips	Sweet Sweet Sweet	Good Good Very good
B. Yellow orange pulp color: 1. Pisang Papan	Indonesia	AAA	108.12	Dessert	Sweet	Good
2. Kluai Kai Boran	Thailand	AAB	103.12	Dessert	Slightly sweet	Good
3. Oonoonoo Kengoa	PNG	AA	84.47	Dessert	Sweet	Good
4. Lakem Connetnet	PNG	AAA	79.83	Dessert	Sweet	Good
5. P. Pelembang	Indonesia	AAA	73.88	Dessert	Sweet	Good
C. Yellow pulp color: 1. Torp	PNG	AAA	98.10	Dessert	Sweet	Good
2. Kluai Pa #26	Thailand	AA	73.26	Dessert	Very sweet	Very good
3. Seňorita	Philippines	AA	68.46	Dessert	Very sweet	Very good

Cultivar Name	Origin	Genome / Subgroup	Caro-tenoid content (nmol/gdw)	USE / PURPOSE		
				Type	**Taste**	**Quality**
4. Galamay Seňora	Philippines	AAB Mysore	71.42	Dessert	Sweet	Good
5. Kotnar	PNG	AAA	61.33	Dessert	Sweet	Good
6. Oonoonoo	PNG	AA	60.77	Dessert	Sweet	Fair
7. Pok Pok	PNG	AAB Plantain	60.41	Cooking Chips	Slightly sweet Sweet	Good Very good
8. Walebo	PNG	AAA	60.35	Dessert	Sweet	Good
D. Light yellow pulp color: 1. Komargh	PNG	AAA	39.17	Dessert	Sweet	Good
2. Pearly Shell	Philippines	AAA Cavendish	36.09	Dessert	Sweet	Good
3. Ambowga	PNG	AAS	34.15	Dessert	Sweet	Good
4. Umalag	Philippines	AAA Cavendish	31.88	Dessert	Very sweet	Very good
5. Pisang Talas	Malaysia	AA	30.73	Dessert	Sweet	Good
6. Kluai Pa #54	Thailand	AA	22.40	Dessert	Sweet	Good
7. Kluai Nam Tia	Thailand	AA	21.98	Dessert	Sweet	Good
8. Bata-Bata	Philippines	AA	21.06	Dessert	Sweet	Good
E. Creamy-white pulp color: 1. Pisang Pulot	Malaysia	AAB	17.78	Dessert	Very sweet	Very good
2. FHIA-01	Honduras	AAAB Cavendish	14.81	Dessert Chips	Sweet Sweet	Good Good
3. K. Namwa Khom	Thailand	ABB Awak	11.97	Dessert	Sweet	Good

Cultivar Name	Origin	Genome / Subgroup	Caro-tenoid content (nmol/gdw)	USE / PURPOSE		
				Type	Taste	Quality
4. AAcv Rose	Belgium	AA	9.76	Dessert	Sweet	Good
5. FHIA-02	Honduras	AAAB Cavendish	7.75	Dessert Chips	Sweet Sweet	Good Good
6. Pisang Surung	Malaysia	AAw Seeded	3.07	Seeded	Sweet	Poor
7. Kluai Pa	Thailand	AAw Seeded	2.73	Seeded	Sweet	Poor