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Mineral distribution in the fruits of the plantain plant (*Musa paradisiaca*) in relation to mode and degree of maturation

J. O. Offem & P. C. Njoku

Department of Chemistry, University of Calabar, PMB 1115, Calabar, Nigeria

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Mineral levels and moisture contents of *Musa paradisiaca* fruits (pulp and peel) have been monitored with time of development as fruits remained on the plant and as fruits ripened off the plant. Fruit bunches sampled from day 90 of bunch emergence had higher mineral levels than those sampled from day 60. The exceptions were P, Zn, and Cu whose levels were lower. Mg, Fe, K, Zn, and Cu increased in the peel to a maximum at day 96 before decreasing while in the pulp they kept increasing throughout. Al, Na, N and Mn increased in the pulp, reached a maximum at day 96, and decreased rapidly thereafter, whereas in the peel they increased steadily throughout. This is attributed to translocation of some of these minerals from the peel to the pulp and vice versa in addition to movements of such minerals from other parts of the plant to the fruits during growth. Moisture levels decreased for bunches that remained on the plants but the peel consistently had more moisture than the pulp. The point of minimum moisture content is concluded to correspond to the point of maximum maturation for these fruits (90 days after bunch emergence) and is here recommended as harvesting time. Maturation ripening was faster for bunches harvested from the plants than those on the plants, the rate increasing in the order of increasing injuries on the bunch.

INTRODUCTION

The plantain plant (*Musa paradisiaca*) which is a permanent crop in the tropics grows prolifically in the warm and humid southern parts of Nigeria. Optimum growth conditions for plantain has been reported as 27°C and 2000 mm rainfall per annum (Phillips, 1977). In Nigeria, the fresh, mature, unripe plantain pulp can be consumed roasted or boiled or fried into chips or prepared into porridge or sun-dried and milled into flour, specifically, for use in the preparation of a starchy Nigerian dish (Ukhun & Ukpebor, 1991). Ripe, peeled plantain can be eaten directly or boiled or sliced into flakes and deep-fried in vegetable oil.

Plantain fruits may be seen on plants virtually all the year round, especially as one moves from one part of the country to the other. This implies that, even during harsh weather conditions such as strong winds and high temperatures which are known to scorch the pseudostems of the plants, fruit-bunches at varying stages of maturation may still be seen hanging from the plants. Such plants often fall over as a result of broken pseudostems with fruits which may not be mature enough to give the desired flavours by any of the methods of preparation. Sometimes the farmers concerned allow such fruits to remain on the fallen plants for some time to improve the maturation. These, however, seldom attain that desired maturity found in normally grown plants. In every plantain market, therefore, bunches of plantain are found being sold which are at various stages of maturation with little or no scientific method to assist the customer or determine what he or she is buying.

Ketiku (1973) and Ladele *et al.* (1984) have published results of the chemical composition of 'Green' and 'ripe' plantains (*Musa paradisiaca*) but without their mineral compositions. However, the manganese content (Offem & Edet, 1989), phosphorus content (Offem & Edet, 1991) and carbonate-carbon content (Edet *et al.*, 1987) of some organs, including the fruit, of the plantain plant have been reported. In a series of works aimed at highlighting the chemical properties of the plantain fruit at any given state of maturation we intend to inform the consumer of the properties of the plantain being bought and to educate the farmer on how best to know the appropriate time to harvest a bunch. Here we present the work on the distribution of minerals in the fruits in relation to the mode and degree of maturation.

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Table 1A. Changes in the mineral levels (based on weight of plant ash at 450°C) of developing fruits of *Musa paradisiaca* at various stages of maturation (bunch remaining on plant throughout and samples taken starting day 60)

Time after bunch emergence (days)	ppt												%m/m moisture	
	Ca		Mg		Fe		Al		K		Na		N		P		Mn		Zn		Cu			
	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel
60	17·8	19·2	15·7	16·6	8·1	8·7	9·4	11·2	26·3	28·4	1·2	1·6	22·8	20·6	11·6	12·2	4·8	10·0	37·5	39·3	16·2	17·4	50·3	52·7
70	19·4	20·6	15·5	16·9	9·3	10·1	9·5	11·8	27·2	29·2	1·8	2·1	26·2	22·3	11·9	11·5	4·9	11·7	38·7	40·4	20·7	22·1	49·1	51·5
80	20·1	21·8	15·8	17·0	13·7	11·6	9·9	12·1	28·5	29·9	2·7	3·2	29·6	23·8	12·2	12·6	5·2	12·3	39·2	41·3	25·5	28·8	48·0	51·0
90	22·5	24·1	16·6	17·5	15·1	12·9	10·8	12·6	29·7	30·5	3·1	3·6	33·9	25·2	12·8	11·8	7·4	13·5	41·9	42·6	30·2	32·7	47·5	48·9
92	24·7	24·9	16·5	17·8	16·6	14·3	12·7	14·3	30·4	29·6	3·3	3·8	34·7	30·8	13·2	12·5	9·2	15·6	44·7	43·8	36·9	33·4	47·2	48·3
94	25·1	25·8	16·8	17·6	19·7	15·5	14·6	15·9	31·8	28·7	3·5	3·5	35·6	31·1	14·0	12·9	9·8	16·1	48·1	44·7	39·5	35·6	47·0	48·3
96	26·6	27·2	17·2	18·1	21·2	16·3	15·2	17·4	32·6	30·1	3·8	3·3	36·1	30·7	14·6	13·2	10·6	17·9	50·3	46·1	41·7	37·4	47·0	48·8
98	27·4	27·7	18·1	17·7	22·6	15·8	14·5	17·8	36·1	28·4	3·4	3·8	36·4	30·3	15·0	13·4	9·4	19·7	52·7	47·6	40·3	38·1	47·6	50·6
100	30·8	30·2	18·6	17·2	22·8	15·2	13·6	18·2	37·5	25·2	3·1	4·0	36·2	31·4	14·8	13·3	9·0	22·3	53·5	46·9	42·9	36·5	49·7	51·8
102	30·8	30·2	18·6	17·2	22·8	15·8	13·6	18·2	37·5	25·2	3·1	4·0	36·2	31·4	14·8	13·3	8·6	25·1	53·5	46·9	42·9	36·5	52·9	54·3
104	32·0	28·5	19·4	16·3	33·8	13·1	12·4	18·9	41·2	20·4	2·2	4·4	36·5	30·6	14·9	13·4	8·1	26·2	56·7	50·2	44·3	39·5	54·6	56·7
106	32·8	28·1	19·7	16·4	35·2	11·6	11·7	21·5	40·8	19·9	2·2	4·8	36·1	31·0	15·3	13·7	8·3	27·7	59·2	51·6	45·5	36·1	61·3	63·4
108	33·4	27·4	20·2	16·1	36·7	11·1	11·3	22·1	44·6	18·5	2·0	4·7	36·4	31·3	15·2	13·5	7·7	29·5	63·5	53·5	46·7	38·6	62·4	63·8

Each value is the mean of duplicate analyses per plantain finger per each of the five bunches. Values are corrected to one decimal place.
% m/m moisture is based on dry sample at 105°C.

MATERIALS AND METHODS

The cultivation of the plantain plants used in this study has been described in a recent work (Offem & Njoku, 1992). The entire plantation was scanned and a total of twenty plants were identified and labelled. Their pseudostems were properly supported using fork-like sticks to prevent them from being blown down by strong winds and the fruits were used for this study. The plants were chosen on the basis of sighting an emerging bunch within a one-week (7 days) scan period. The exact day of sighting the bunch for each plant was recorded. Two types of experiments (1 and 2) were conducted using ten of the twenty plants per experiment. In experiment 1, the fruits of the ten plants, which were allowed to remain on the plants throughout the experimental period, were divided into two groups (five plants per group). In group one samples (Table 1A) each was analysed at the listed intervals, from day 60 after sighting the bunch), while in group two samples (Table 1B) analysis of the fruits did not commence until day 90 of sighting the emerging bunch when, for the purposes of this study, maturity was attained as preliminary investigations revealed.

In experiment 2, the ten plants were similarly divided into two groups of five and while group one fruits were analysed from day 60 of bunch emergence to day 90 before bunches were harvested from the plants, group two fruits remained intact until they were harvested on day 90. The harvested bunches of both groups were separately covered with leaves in a shade within the plantation and allowed to ripen. During this period, samples were taken for analysis at the intervals listed in the Tables.

Sampling of each fruit bunch for analysis was done systematically. At each sampling stage, the central fingers in the top row of the second hand of each bunch were analysed first, followed by those to the left and then the right in that order, until the top row was exhausted before beginning with the bottom row, also in that order. Counting of the hands on the bunch hanging from the plant in the natural position followed a spiral direction (Gottreich *et al.*, 1964). All harvesting was done at noon with a sharp steel knife which was also, used for cutting off plantain fingers from the bunch and ensuring that both tips of the fingers were sliced off completely. Each finger was washed thoroughly with deionized water. These were individually and carefully separated into peel and pulp and allowed to dry at room temperature. Each component was chopped into tiny pieces on a wooden board ensuring that dust particles and extraneous matter were not introduced. The chopped pieces were homogenized in an electric blender (National Model MX-29 IN) for 10 min and put in a porcelain boat of known weight and weighed before allowing them to dry at 105°C to constant weight. They were allowed to cool at 50°C before cooling in a desiccator to room temperature prior to weighing. Percentage moisture content was calculated from this.

Each dry sample powder was ashed at 450°C for 3 h using a Muffle Furnace (Gallenkamp model) with temperature range 0 to 1100°C, and stored in a desiccator until required. About 0·5 g of the oven-dried and ground ash sample was accurately weighed and evaporated to dryness in a porcelain crucible with 5 ml concentrated HNO_3. Thereafter, 2 ml 50% HCl was added to dissolve the residue after which 20 ml of deionized water was added with warming. The resulting solution was filtered through a Whatman No. 44 ashless filter paper into a 100 ml flask and the residue washed thoroughly with hot deionized water. The filtrate, when cooled to room temperature, was diluted to volume, and the solution was used for analysis.

The metallic elements were determined using a computerized 181-70 Zeeman Atomic Absorption spectrophotometer, while phosphorus was determined by the vanado-molybdate colorimetric method (AOAC, 1984) using a Pye Unicam UV/visible SP6 series, Model 450

Table 1B. Changes in the mineral levels (based on weight of plant ash at 450°C) of developing fruits of *Musa paradisiaca* at various stages of maturation (bunch remaining on plant throughout and sample taken starting day 90)

Time after bunch emergence (days)	ppt														ppm				%m/m moisture	
	Ca		Mg		Fe		Al		K		Na		N		P		Mn		Zn		Cu			
	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel
90	28·8	29·3	20·5	21·2	26·1	17·4	12·2	12·9	40·3	37·2	2·3	2·8	46·1	40·3	8·1	9·4	8·6	19·2	35·2	36·6	23·6	24·2	47·7	48·1
92	27·9	30·5	21·6	23·5	26·8	18·7	13·5	13·7	43·1	35·6	1·9	2·9	45·3	41·7	8·7	9·3	9·1	22·6	36·0	37·4	25·1	23·7	46·5	47·8
94	30·5	31·9	21·3	24·6	26·3	20·5	13·9	14·5	42·8	38·2	2·0	3·7	47·8	43·4	9·3	9·9	10·8	21·5	36·6	35·3	24·7	25·8	47·3	48·9
96	31·8	36·6	22·7	25·3	26·9	22·6	14·3	15·2	44·5	39·1	2·6	3·5	50·3	44·9	9·5	10·3	11·8	23·8	37·2	34·2	25·9	23·1	48·7	49·1
98	32·2	34·1	23·4	24·1	27·4	23·1	15·6	16·8	46·2	40·3	1·8	3·3	51·7	34·3	9·0	10·9	13·1	27·5	38·3	33·7	26·4	22·7	49·8	50·3
100	32·7	35·6	24·5	22·8	28·8	25·0	17·5	18·1	48·6	37·4	2·2	3·7	53·5	47·5	9·8	11·7	17·2	29·1	37·5	30·8	30·8	20·3	51·4	53·1
102	33·4	32·5	26·1	21·1	29·1	25·2	18·2	19·3	47·8	32·5	3·0	2·8	54·2	46·1	10·3	11·2	18·5	28·5	38·9	31·6	31·6	22·1	52·7	54·6
104	34·5	30·3	26·8	20·3	30·7	24·2	19·7	20·7	50·7	28·6	3·2	4·0	50·3	44·8	10·6	12·1	18·2	30·6	39·6	32·7	33·2	26·4	53·3	55·4
106	35·3	31·7	27·6	19·4	32·4	23·6	19·1	21·3	51·3	25·3	2·7	3·8	57·5	42·3	11·4	12·6	19·7	31·3	40·7	33·6	34·9	27·4	53·9	55·1
108	38·1	32·9	25·2	21·7	35·6	20·4	18·2	22·7	53·8	24·6	2·9	4·9	51·8	40·7	12·3	12·8	19·3	32·5	43·1	35·1	36·7	30·5	54·5	55·8
110	37·9	29·5	29·7	20·8	38·2	18·6	17·3	23·5	52·1	25·1	3·4	5·0	60·7	40·9	12·9	12·3	18·7	33·8	44·8	38·3	36·1	30·1	54·8	56·1
112	38·4	28·1	30·4	18·2	40·4	18·0	17·5	24·6	54·2	23·7	3·1	4·6	61·3	41·4	13·2	11·9	16·4	34·6	43·7	39·1	39·2	31·6	57·1	58·3
114	38·1	29·8	28·3	19·6	42·3	17·5	16·3	24·8	54·9	22·5	3·5	4·7	62·5	39·7	12·6	12·7	14·9	34·1	46·2	40·6	40·0	33·7	59·5	58·9
116	37·8	33·5	28·8	17·2	44·7	17·1	16·4	23·7	55·1	23·4	3·2	5·1	66·4	38·3	12·1	23·2	12·6	37·2	46·8	41·2	39·7	33·3	61·2	62·3
118	38·3	32·6	29·3	18·0	44·1	16·4	15·9	25·1	54·2	24·8	3·3	5·2	65·4	36·5	11·9	13·8	13·1	38·5	47·7	40·4	41·3	38·2	62·8	61·5
120	38·0	29·4	30·6	17·5	43·2	18·2	14·7	24·6	56·3	25·7	2·9	5·8	68·7	33·1	10·7	12·6	11·7	41·0	45·3	39·8	42·9	37·7	63·3	65·0

Each value is the mean of duplicate analyses per plantain finger per each of the five bunches. Values are corrected to one decimal place.
% m/m moisture is based on dry sample at 105°C.

spectro-photometer. A Zeiss flame photometer was used to determine sodium and potassium and the Kjeldahl method was used for nitrogen. Soil analysis and description for this plantation has been given previously (Offem & Njoku, 1992).

RESULTS AND DISCUSSION

Before discussing the results of this investigation, it is perhaps relevant to point out that Awan & Ndubizu (1978) investigated some storage conditions of 'fully matured', fresh, unripe plantains and found that plantains stored at room temperature ripened in 14 days while those treated with purafil and those refrigerated, ripened after 21 days (Ndubizu, 1976). In the same manner, George (1985) reported that fruits harvested when 'firm and green' could be maintained at ambient temperature in this unripe (preclimacteric) condition for days or weeks, but once the climacteric respiratory rise commences, they ripen rapidly and spontaneously, turning full yellow in 3–4 days. Consequently the potential storage life of plantain, he concluded, is determined by the preclimacteric period (PCP) or the greenlife of the fruits. We observed in this work that all the fruits studied could unequivocally be described as 'fully matured' or 'firm and green' at 90 days after bunch emergence, even though this description could be applied equally to fruits in the age range 84–94 days since bunch emergence without any serious contradiction. Even though not specified, Awan & Ndubizu (1978) and George (1985) could have used plantain samples harvested within this age bracket.

Tables 1A–2B present results of changes in mineral levels of the plantain fruits with stages of maturation according to the procedures described in experiments 1 and 2. In Tables 1A and 1B both samples had their bunches remaining on the plants throughout the experimental period but a quick glance at the results on day 90 after bunch emergence (and the subsequent samples) reveals that the mineral levels in both the pulp and peel are higher for 1B samples than for 1A samples with the exceptions of P, Zn and Cu in which they are lower. The moisture content is also higher for group 1B samples. This could possibly be explained on the basis of the injuries inflicted on the 1A bunches earlier on, when samples for analysis on days 60, 70 and 80 from bunch emergence were harvested. Such injuries could have hindered free movement of minerals and involved some of them in the healing processes. This is in agreement with earlier findings: Perring *et al.* (1984) observed the concentration of Ca to be lower in all zones of apples with water core disease and the proportions of Ca in such affected apples were higher in the outer zones and much lower in the core zones. On the hand, Biddappa (1984) found the concentrations of Cr, Pb, Ba, Bi, Ga, Sr, and Li to be significantly higher in diseased coconut palms.

In experiment 1, sample harvesting and analysis ended on day 108 after bunch emergence for 1A plants as opposed to day 120 for 1B plants. The degree of ripeness (degree of maturation) was, however, similar at both days for the respective samples. This was when samples were so over-ripe that they were at the brink of becoming rotten. In other words, 1A samples ripened earlier (92–98 days after bunch emergence, and had faster rates of maturation/ripening than the 1B samples which started ripening only after day 106, in most cases. Again this could be explained in terms of the wounds on the bunches.

When the elements are taken individually, one observes that Ca increased steadily in the pulp of 1A

Table 2A. Changes in the mineral levels (based on weight of plant ash at 450°C) of ripening fruit of *Musa paradisiaca* with time (fruit samples taken at intervals prior to harvesting of bunch on day 90)

Time after bunch emergence (days)	ppt																ppm				%m/m moisture	
	Ca		Mg		Fe		Al		K		Na		N		P		Mn		Zn		Cu			
	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel
60	18·3	20·1	15·3	17·2	8·4	8·9	9·5	11·0	26·5	28·1	1·5	1·9	30·1	20·4	11·7	12·3	4·7	10·2	37·5	40·2	16·4	17·1	49·7	52·4
70	19·9	21·3	15·7	16·5	10·9	9·7	10·2	11·8	27·2	29·6	2·1	2·5	30·7	22·5	11·9	11·2	5·0	12·3	38·7	41·6	20·2	22·9	49·0	51·5
80	21·7	22·5	16·3	17·1	13·5	11·3	11·8	12·5	28·5	30·4	2·7	3·1	31·4	23·8	12·0	11·6	5·9	13·7	39·6	42·8	26·8	27·5	48·2	50·8
90	23·2	25·0	17·1	17·8	15·3	13·2	10·7	13·0	30·1	31·3	3·3	3·8	33·7	25·6	12·7	11·9	8·2	14·1	42·1	43·3	30·6	33·0	47·3	49·3
92	23·6	25·3	17·5	18·3	15·9	13·5	13·1	14·1	32·4	32·8	3·2	3·6	34·4	26·1	13·2	12·3	9·9	14·8	43·2	42·5	31·4	33·6	44·8	46·2
94	24·4	24·5	17·2	18·5	16·2	13·1	13·3	14·5	35·8	30·1	3·1	3·7	32·6	27·4	13·7	11·7	9·1	13·5	43·8	42·9	22·7	38·2	43·7	47·5
96	25·8	23·6	17·0	18·6	16·7	12·7	12·8	15·7	39·6	27·4	3·4	3·8	30·2	30·7	14·1	10·2	10·6	12·6	42·7	43·2	20·1	40·6	46·2	49·3
98	26·4	23·1	16·7	18·9	17·3	12·3	12·1	16·2	41·9	20·5	3·3	3·5	28·7	31·2	14·3	9·5	11·2	11·1	43·5	42·7	14·8	37·4	51·5	53·5
100	26·6	22·8	15·8	19·1	18·5	12·0	11·2	18·9	44·7	18·7	3·5	3·6	24·5	32·8	14·5	7·8	11·7	10·3	43·9	43·1	13·7	39·2	58·1	60·6
102	26·3	22·5	15·4	19·3	20·6	11·6	10·6	20·1	45·3	16·9	3·4	3·7	23·6	33·7	14·8	6·4	12·0	9·1	43·6	43·0	10·2	42·6	62·8	64·4

Each value is the mean of duplicate analyses per plantain finger per each of the five bunches. Values are corrected to one decimal place.
% m/m moisture is based on dry sample at 105°C.

samples throughout the experimental time whereas, in the peel, it increased up to a peak at days 100–102 when it started declining. For 1B samples, Ca increased steadily in the pulp reaching a peak (approx. 38·1 ppt) at day 108 and, practically remained constant at a mean of about 38 ppt thereafter. The same trend is observed in the peel which had a maximum Ca content of 32·9 ppt at day 108 and stabilized at a mean of about 30·5 ppt thereafter. There was more Ca in the peel than in the pulp up to day 100 for both 1A and 1B samples but thereafter it was the pulp that had more Ca.

The levels of Mg, Fe and K increased in the peel of 1A samples up to day 96 and levels of Zn and Cu up to day 98 before decreasing steadily for the rest of the experimental period while the levels of these elements in the pulp increased gradually throughout. On the other hand, Al, Na and Mn increased in the pulp to a maximum at day 96 and N to a maximum at day 98 before decreasing rapidly throughout whereas they increased steadily throughout in the peels.

Increases and decreases of all the elements followed quite a different pattern for 1B samples. For example, Mg in the pulp increased to a maximum at day 100 and remained virtually constant thereafter whereas in the peel it increased up to day 96 before stabilizing thereafter. Fe increased in the pulp throughout the experimental time but increased in the peel up to day 102 before decreasing rapidly, and so on. It would appear that in addition to the rapid movement of some of these elements from other parts of the plant to the fruits and vice versa during maturation and senescence, there is some translocation of these minerals from the peel to the pulp and vice versa. Perring and Pearson (1984) observed a similar trend and reported differences in concentration gradients of Ca, Mg and P between Cox's-orange pippins and Spartan apple fruits. While 'Spartan' apples had higher proportions of Ca and P in the core, 'Cox' apples had higher proportions of P in the inner cortex. They also observed that differences in Mg gradients varied with age. Similarly Diver *et al.* (1984) noticed that the contents of N,K,P and Zn in pecan fruits increased slowly until the 10th week after full bloom, then rapidly until fruit maturity, while Ca, Mg and Mn accumulation in the fruit was linear throughout fruit development. Fe, they reported, increased as the fruit matured. The kernel contained more N, P, Zn and Fe at maturity than the shuck or shell while K, Mn, Ca and Mg were highest in the shuck. Ferguson (1980), measured the concentrations of Ca, Mg, K and P in the fruit of the kiwifruit (*A. chinesis* Planch) at intervals over the growing period and observed that maximum Ca content was reached sooner than for the other nutrients while K and P continued to move into the fruit over the whole growing season. They further assessed the mineral distribution in the mature fruit and found a marked gradient of Ca content, which was highest at the basal end of the fruit; K and Mg did not show such marked patterns. The skin and seeds (with surrounding flesh) had the highest concentrations of Ca and Mg; K was proportionately higher in the flesh than the other nutrients. Our results agree to some extent with these findings and those of Lewis (1980).

Looking at Tables 2A and 2B where bunch samples were harvested from the plants on day 90 after bunch emergence and allowed to continue with their maturation process out of the plants, a completely different pattern of mineral distribution as well as rate of ripening emerged. The 2A bunches, from which sample fingers were harvested periodically from day 60 after bunch emergence, completed their ripening process as early as day 102 while 2B bunches which were intact all through and only harvested on day 90 did not complete their ripening process until about day 110. When compared with experiment 1, this means that the rate of maturation and subsequent ripening increases in the order 2A samples >2B >1A >1B samples. The level of injuries on the bunches followed this order.

Harvesting the bunch from the plant at maturity obviously accelerates the rate of ripening of fruits and early injuries on the bunch also accelerate ripening. It would appear that the halt in the transport of minerals

Table 2B. Changes in the mineral levels (based on weight of plant ash at 450°C) of ripening fruit of *Musa paradisiaca* with time (no fruit samples taken until bunch was harvested on day 90)

Time after bunch emergence (days)	ppt												ppm				%m/m moisture	
	Ca		Mg		Fe		Al		K		Na		N		P		Mn		Zn		Cu			
	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel	Pulp	Peel
90	28·7	29·5	20·3	21·6	26·5	17·8	12·6	13·2	40·3	37·1	2·4	2·8	45·7	39·4	8·5	9·5	8·7	18·2	35·3	36·8	23·8	24·6	48·7	50·3
92	30·6	31·6	19·6	22·2	27·2	17·1	13·7	14·2	41·2	34·1	2·5	2·9	43·6	40·3	8·9	9·2	10·2	19·5	35·7	37·2	21·3	26·3	47·5	48·1
94	32·1	30·3	19·1	22·9	27·9	16·6	14·1	14·9	43·5	33·2	2·8	3·1	42·3	41·7	9·5	9·1	10·7	19·0	34·8	37·5	20·6	28·2	48·3	48·9
96	33·8	29·2	18·3	23·4	29·5	16·3	13·3	15·6	45·8	30·6	3·1	2·9	40·8	43·2	9·7	8·7	11·4	17·3	34·4	37·9	19·9	36·2	50·4	52·4
98	35·5	28·7	17·4	23·7	31·7	15·8	12·5	15·8	46·1	28·2	3·4	2·6	38·6	45·6	9·9	8·3	11·9	16·7	33·7	38·8	18·7	38·3	51·6	53·3
100	35·6	25·2	16·8	24·1	31·2	15·6	11·6	17·0	47·3	21·6	3·3	2·7	37·7	46·1	10·3	7·8	12·6	16·0	33·1	40·3	17·3	39·5	53·1	55·1
102	36·1	25·7	16·3	24·5	32·9	15·7	11·1	16·5	47·8	19·3	3·2	3·1	37·2	47·9	11·6	7·5	12·4	15·0	32·9	41·2	15·4	37·8	53·8	57·2
104	35·8	25·3	15·6	24·8	33·6	15·2	11·8	17·3	49·7	18·2	3·5	3·5	34·2	50·2	12·3	7·2	13·0	15·7	31·7	43·1	13·6	40·1	55·4	59·9
106	35·7	24·9	14·5	25·0	33·5	14·8	11·3	17·6	52·3	15·7	2·9	3·3	30·8	51·8	14·6	6·6	13·6	15·1	32·4	44·7	14·1	42·3	59·7	60·7
108	36·0	25·2	14·0	25·6	33·8	14·5	10·8	18·2	55·6	18·3	3·3	2·8	28·6	51·2	15·3	6·1	14·1	14·9	32·0	45·8	11·3	42·7	61·2	62·5
110	35·9	25·4	13·7	25·4	34·3	14·1	10·5	19·3	54·9	11·1	3·4	3·5	27·5	52·3	11·8	5·8	13·9	14·3	31·8	46·6	10·6	41·9	63·5	65·3

Each value is the mean of duplicate analyses per plantain finger per each of the five bunches. Values are corrected to one decimal place.
% m/m moisture is based on dry sample at 105°C.

from other parts of the plant to the bunch, and vice versa, as a result of cutting the bunch off the plant, has the effect of dehydrating the bunch stalk (tending towards rotting) which facilitates the ripening process.

In most cases, mineral levels were higher for bunches which remained on the plants than those off the plants at any given ages of the bunches. This is as should be expected as the latter bunches are excised from the main stream of mineral flow. Nevertheless, the results show marked drift of some minerals from the pulp to the peel and vice versa in the cut samples as ripening progressed. Perring (1984) and Ferguson & Watkins (1983) observed similar trends. Perring (1984) found the levels of Ca to decline in the core and increase in the cortex during the first four months of harvesting and storage of apple fruits. K levels increased in the inner cortex, while those of P increased in the inner cortex and, during the first two months of storage, in the core. Mg declined steadily in the peel and outer cortex with corresponding increases towards the fruit centre.

These changes, according to Perring (1984), were mainly independent of storage conditions which was the case in the present study. Ca and Mg moved to the core region when core browning developed towards the end of storage period. On the other hand, Ferguson & Watkins (1983) who measured the levels and distribution of Ca, Mg and K in stored apple fruits after post-harvest vacuum-infiltration of Ca or Mg bitter pit control, observed that the highest concentration of each cation occurred in the skin and core while the lowest was in the outer cortex. They also found that the concentrations of all three cations in the outer cortex increased during storage.

Ladele *et al.* (1984) noticed a gradual increase in the protein content of plantain pulp, calculated from Kjeldahl Nx 6·25, from 'green' plantains to 'just ripe' and then to 6 days thereafter. Our steady increase in nitrogen in the pulp of plantain (Tables 1A and 1B) confirms this trend but Tables 2A and 2B show initial increases up to the ripening stage when nitrogen levels started declining. Offem & Edet (1991) observed an increase in phosphorus content of *Musa paradisiaca* fruits from unripe to ripe fruits, which is confirmed by the pulp of our samples in both experiments 1 and 2. Working with 'Williams' banana, Turner & Barkus (1983) observed that a large proportion (20–30%) of N, P and K were located in the fruit, Ca, Mg and Mn accumulated in the trash (29–44%) and roots were high in Na, Cu and Zn (29–50%). Looking at our work side by side with a recent work (Offem & Njoku, 1992) our findings corroborate those of Turner & Barkus (1983).

Moisture level in plantain pulp and peel decreased steadily, in bunches that remained on the plants from respectively 50·3% and 52·7% on day 60 (1A samples) to a minimum of 47·0% on days 94 and 96 for pulp and 48·3% on day 92 and 94 for peel when it rose rapidly (onset of ripening) and continued to rise for the rest of the experimental time. The peel consistently had more moisture than the pulp. The point at which minimum moisture content of peel is achieved while the bunch is still growing on the plant could here be confirmed as the point of maximum maturity of the plantain fruit. For plantain pulp of bunches that were severed from the plant, moisture content increased continuously throughout the experiment after an initial drop 2 days after harvesting. Awan & Ndubizu (1978) observed moisture contents of plantain to increase from 49·4 to 57·5% from the time of harvest to 14 days of storage. Similarly, Ladele *et al.* (1984) reported a moisture content increase of 50% in 'green' plantain to 60% in fruits of 6 days after the 'just ripe' situation.

In conclusion we would suggest that farmers be vigilant in their plantations to observe the time of bunch emergence for each plant and allow about 90 days from that time before harvesting the bunches. Fruits from 90 day-old bunches, or thereabouts, have the best ratios of mineral levels for human diets. Also, the high levels of some minerals in the plantain peel

makes it attractive for incorporation into animal feeds and also in '*otong*' soup in which, it constitutes one of the major ingredients. The latter is a delicacy amongst the Efik and Qua people of south-eastern Nigeria.

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