Harvest Handling and Postharvest Conditions for Optimum Nutrient Quality in Mango: Minerals and Vitamins

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ABSTRACT: Good practices at harvest and postharvest could be useful in obtaining nutritious mango with high minerals and vitamins. The present study evaluated effect of harvest handling and postharvest conditions on the level of minerals and vitamins using standard methods. Ripe, half-ripe and unripe mangoes were harvested on parent plant and on ground around parent plant. The half-ripe and unripe mangoes were further divided to include heat ripened mangoes. The mango samples were separately stored naturally at $25\pm3°C$ and heat ripened at $37\pm5°C$ for 0 to 10 day after harvest (dah). The results show Ijebu-Mamu mangoes could cater for reference dietary intake of Vit C. Mango harvested on parent plant has highest level of minerals and vitamins than those picked on ground. Ripe mango has highest level of minerals, half-ripe mango presented highest level of vits. B_1 and B_2 and unripe mango has highest level of Fe and Vit. C. Heat caused increased level of minerals and reduced level of vitamins. The minerals show increased level from 0 to 4 or 6 dah while vitamins reduced from 0 till 10 dah. High level of minerals and vitamins was obtained with optimum integrated harvest and postharvest condition of half-ripe mango naturally ripened at 6 dah. The present results highlight effects of the assessed harvest handling and postharvest conditions and their co-optimization that might be necessary for high minerals and vitamins in mango.

Mango, *Mangifera indica*, belongs to Anacardiaceae of cashew family with about 83 genera consisting 860 species of fruiting trees. Mango is a large evergreen tree that grows to a height of 10 - 45 m; dome shaped with dense foliage and heavy branched from a stout trunk (Shah *et al.,* 2010). The fruit takes four to five months from flowering to ripen and is reported to bear fruits twice a year (Ahmed and Ahmed, 2014). The fruit is a large drupe with variation in shape and size, contains a thick yellow pulp, single seed and thick yellowish-red skin when ripe. Globally, mango is generally harvested green and then commercialised after a period of storage and as a climacteric fruit has a short shelf life and respiration peak of ripening process by 3 to 4 dah at ambient temperature (Narayana *et al*., 1996; Roy *et al*., 2019). In Nigeria, harvesting of mango fruits on parent plants before becoming fully ripened is a common handling process among farmers and traders in urban cities and if unripe are kept under heat and sold gradually as becoming ripened. At village settings, mangoes are harvested when ripened on the parent plants or naturally dropped, for home consumption and sales at local markets. Mango (*Mangifera indica*) is a global fruit for food, feed and folklore medicine and is regarded as the king of fruits and second most traded tropical fruits in the world due to its chemical and nutrient compositions. Mango is reported to be rich in water, sugars, fibre, minerals, vitamins, and antioxidants (Ara *et al*., 2014; Torres-Leon *et. al*., 2016) with various food products derived from it, such as pulp, beverage, wine, yoghurt, toffee, custard, and ice cream. Its peel, seed and kernel are reported to be rich in phytochemicals and possess antioxidant properties use in food, drink, and beverage preparations (Ravani and Joshi, 2013). Interestingly, mango has been an important herb in the Ayurveda medicine and its juice is use as a restorative tonic for heat stroke treatment (Shah et al., 2010). Its peel is use as animal feeds while seed, bark and leaves are use as folklore medicine in Nigeria. Thus, mango has the potential to serve as a millennial nutritious, healthy and safe food due to its rich content as mentioned above. However, various pre and postharvest conditions are reported to affect nutrient quality of mango and many techniques are developed to optimise these conditions for its best postharvest management for consumer acceptance. Subsequently, temperature and dah are found as key co-factors that affect mango nutrient quality and organoleptic properties (Baloch and Bibi, 2012**;** Herianus *et al*., 2003; Joshi *et al.,* 2017; Lee and Kader, 2000; Normand *et al.,* 2015; Okoth *et al*., 2013;

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Salvia-Trujillo *et al.*, 2011). Also, mango is considered to be consumed at all stages of fruit development from the tiny immature to the fully mature fruit and its nutritional value is reported to differ with varieties and developmental stages including maturity and ripening (Ravani and Joshi, 2013). However, these studies are mostly on organoleptic and functional properties but are scantily available on mineral and vitamin level of mango fruits and at harvest handling conditions. Furthermore, suitable integrated harvest handling and postharvest conditions to have the best nutrient quality in mango has not been recognized. Consequently, the present study was carried out to evaluate harvest handling and postharvest conditions on the level of selected minerals and vitamins in mango fruits obtained from Ijebu-Mamu farmland Ijebu-North, Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area: Ijebu-Mamu farmland along Ijebu-Ode-Ibadan high way, Ijebu-North, Ogun State, geographical coordinates Latitude 7° 5` 0`` North and Longitude $3^o$ 55` 0`` East was chosen for the study because it is a major ancient farmland and its farm produces serves over 100 Ijebu communities.

Sample Collection and Preparation: Harvest and Handling conditions: The harvest was conducted during 2017/2018 season. Matured ripe, half-ripe, and unripe mango fruits were hand-plucked on parent plants (Before dropping) and also, hand-picked on the ground around parent plants (after dropping). The before dropping mango samples were labelled accordingly: ripe mango on plant (RMP), half-ripe mango on plant (R2MP) and unripe mango on plant (UMP) and after dropping as ripe on ground (RMG), half-ripe mango on ground (R2MG) and unripe mango on ground (UMG). The R2MP, R2MG, UMP and UMG samples were further divided to include heat ripen samples, half-ripe mango on plant heat ripened (R2MPHR), half-ripe mango on ground heat ripen (R2MGHR), unripe mango on plant heat ripened (UMPHR)) and unripe mango on ground heat ripened (UMGHR). The mango samples were kept in sterile polythene bags and immediately transported into the Laboratory of Department of Chemical Sciences, Tai Solarin University of Education, Ijagun, Ogun State, Nigeria.

Postharvest conditions: At the destination, the RMP, R2MP, UMP, RMG, R2MG, and UMG, samples were kept on shelf at ambient temperature 25 ± 3^oC and relative humidity (RH), $80\pm11\%$ while the R2MPHR,

UMPHR R2MGHR, and UMGHR samples were wrapped in polyester sacks, placed in local baskets and kept in a closed dark room with a temperature range of 35 ± 5^oC and $55\pm7\%$ RH and both were stored at 0 to 10 dah. Preparation of samples: Three fruit samples from each of RMP, R2MP, R2MPHR, UMP, UMPHR, RMG, R2MGR, R2MGHR, UMG, and UMGHR, visually observed to be healthy, devoid of wounds and signs of spoilage were selected for nutritional analysis. The selected samples were washed under tap, peeled and the fleshy pulp cut into pieces using sterilized stainless knife. One and ten grams of fleshy pulp sample was crushed into pulp and stored in labelled amber bottle for immediate analysis of minerals and vitamins, respectively.

Collection of data: Data are collected every 2 dah over 0-10dah for ripening status, minerals and vitamins in three replicates at the Laboratory of Chemical Science.

Reagents: Deionised water, distilled water, dichloroethene, hydrochloric acid (HCl), trioxonitrate (v) acid, tetraoxosulphate vi acid (H_2SO_4), sodium acetate, potassium chloride (KCl), metaphosphoric acid, iodine solution were of AOAC standard obtained from local vendor. Nitrate salt of metals were from Buck Scientific, USA; and riboflavin, thiamine, vitamin C standards, diastase enzyme were from Sigma, Aldrich.

Determination of mineral content: 1g pulp sample was digested with 100 mL of 1M HNO_3. The digestion was heated for 2 hrs. The digested extracts were filtered and the filtrate made up to 50 mL with deionised water. The filtrates were analysed for sodium (Na), potassium (K), calcium (Ca), iron (Fe), phosphorus (P), copper (Cu), manganese (Mn), and zinc (Zn) using Atomic Absorption Spectrophotometer (AAS, Buck, 200 Model).

Determination of Thiamine (Vit. B_1): Fifty millilitres of 0.1 M H_2SO_4 was added to 1 mL of 10 g pulp and the mixture was mixed and 5 mL diastase / 0.5 M sodium acetate solution/ ice was added and further kept in ice for 2 hr and the digest was made up to 100 mL (Salvia-Trujillo *et al.*, 2011). The resulting mixture was filtered through No.42 Whatmann filter paper and 10 mL upper layer was discarded. Five millilitre acidified potassium chloride solution was added to 10 mL filtrate and mixed, thoroughly. Serial dilutions of thiamine standards were prepared and their absorbance and that of samples were measure at 285 nm wavelength using a fluorescent UV spectrophotometer. The amount of thiamine in the

samples was extrapolated from the derived calibration graph of absorbance measures.

Determination of Riboflavin (Vit B₂): Five millilitres of 5 M HCl was added to 1 mL 10 g pulp sample and followed by addition of 5 mL dichloroethene. The mixture was shaken, allowed to settle and made up to 100 mL with deionized water and heated in a steam bath for 30 min. The mixture was cooled, made up to 100 mL with deionized water, filtered and decant 20 mL upper layer. Two millilitres of the filtrate was made up to 250 mL with deionized water and series of standard solutions of riboflavin were prepared. Absorbance of samples and standards were measured at 460 nm using a fluorescent UV spectrophotometer.

Determination of Ascorbic acid (Vit. C): Vitamin C in the 10 g pulp samples was determined using Iodometric titration by adding 10 mL metaphosphoric acid to 5 mL pulp extract samples, the mixture was then blended for 3 min and filtered, 20 mL filtrate was pipetted into a beaker and 3 drops of starch indicator was added and titrated against 0.1 M iodine solution and a blue-black colour indicated the end point.

Data Management: Collected data was subjected to Statistical Analysis System University Edition 3 (SAS, 2019), and Z test using Excel sheet.

RESULTS AND DISCUSSION

General level of minerals and vitamins content of mango and contribution to dietary reference intake:
Table 1 provides the descriptive statistics of minerals and vitamins obtained in 100 g FW mango fruit from Ijebu-Mamu and visual values indicate high level of K and Vit. C, appreciable quantity of Ca, P and Na, while other minerals and vitamins are low in quantity and Zn wasn't detected at all. Whatsoever, values obtained were considered for their contribution to DRI based on the RDA / Al needed for an individual to keep healthy and well-nourished as presented in Table 1.

Incomparably, the high level of K could only provide an average range value of 11.9 to 15.7% AI across all age groups in 1 to 2 cup of mango (165 to 330 g) while level of Cu could cater for 14.3 to 32.3 % RDA/AI across age groups. Mango could contribute a proportion of 11 to 20% RDA Vit. B₁ and 13 to 23% Vit. B₂. Only vitamin C content of Ijebu-Mamu mango suffices RDA across ages and even, surpasses in almost all age groups. Therefore, at present, less than one-third cup of mango (~46 g) and one-half cup (76.5 g) could cater for 15 and 25 mg/d Vit. C RDA for 1-3

y and 3-8 y children, respectively, one cup adequately takes care of 45 g/d for teenagers, and one and a half cup provides somewhat greater than 100 RDA for the rest of age groups evaluated (Table 1). Nevertheless, the presence of these minerals and vitamins in the assessed mangoes of Ijebu-Mamu supports the findings that mango consumption was associated with better nutrient intakes and diet quality due to its high Vit C, an antioxidant that scavenges reactive oxygen and low sodium content that prevents high blood pressure.

The range amount of minerals and vitamins detected at present in Ijebu Mamu mango is within diverse reported levels in literatures and the evaluated differences are attributes of geographical zones, varieties, maturity, ripening, agricultural practices, genetic, genetic by environment and post-harvest technology (Ara *et al.*, 2014; Okoth *et al.,* 2013; Shi *et al.*, 2015; Sogi *et al.*, 2012).

Effect of differential harvest / handling and postharvest conditions on minerals and vitamins content of mango: Table 2 shows level of Na, K, Ca, Fe, Mn and Vitamins is higher when mango fruits are before-dropping while level of P and Cu is higher in after-dropping. This result indicates nutrition feeding of mangoes while on parent plants (PFAF, 2017) with perhaps simultaneous catabolic and anabolic processes that release and uptake specific minerals as cofactor during photosynthesis.

These processes are likely reduced or halt at after dropping from parent tree while some postharvest enzymatic and non-enzymatic processes were perhaps initiated such as Calvin cycle after light reactions and ATP hydrolysis to increase P (Berg *et al.*, 2007)**.**

Same Table 2 shows disparity in distribution of highest level of the assessed minerals and vitamins among the handling conditions with RMP having highest level of Na and Ca, R₂MP has highest level of Vit B₁, R₂MPHR has highest Ca, Mn and Vit B₂, and UMP has highest level of Vit C. Noteworthy, mango is commonly harvested green while firm on parent plant and ripened with postharvest management (Kader and Mitcham, 2008). Therefore, the assessed handling conditions are somewhat nutrient-specific and worth evaluating for best harvest handlings practice in mango. Table 2 also shows ripe mango have highest level of minerals except Fe, half-ripened mango presented highest level of vits. B₁ and B₂ and unripe mango have highest level of Fe and Vit. C.

Table 1: Descriptive statistics for level of minerals and vitamins in mango fruits from Ijebu-Mamu and their Daily food intake (DI) and contributions to Dietary Reference Intake (RDI)

Nutrient	Mean mg 100 g⁻¹FW	SD	Min	Ma	DI mg/d⁺	SD	Min	Max	%DRI
		Descriptive Statistics			**Daily Food Intake and contribution to DRI**				
	Level of nutrients				**14-18 y males 2 cup**				
Na	4.11	0.56	2.9	5.04	0.01	0	0.01	0.02	0.7
K	225.37	13.37	198.6	256.1	0.74	0.04	0.66	0.85	15.7
Ca	23.47	2.47	17.3	27.8	77.44	8.16	57.09	91.74	6.0
P	5.8	0.86	3.96	7.58	19.14	2.84	13.07	25.01	1.5
Cu	0.05	0.01	0.03	0.08	172.15	44.84	99	264	19.3
Fe	0.42	0.06	0.26	0.55	1.39	0.2	0.86	1.82	12.6
Mn	0.06	0.02	0.03	0.09	0.19	0.05	0.1	0.3	8.6
Vit_C	32.68	6.47	17.67	47.37	107.83	21.34	58.31	156.32	143.8
Vit B1	0.05	0.03	0	0.13	0.16	0.15	0	1.65	13.3
Vit B2	0.06	0.03	0	0.13	0.18	0.11	0	0.43	13.8

Daily Food Intake and contribution to DRI

1-3 y 1 cup	DI	SD	Min	Max	%DRI¶	**14-18 y female 1 ½ cup**			
Na g/d	0.01	0	0	0.01	**1**	0.01	0	0.01	0.01	**0.7**
K g/d	0.37	0.02	0.33	0.42	**12**	0.56	0.03	0.49	0.63	**11.9**
Ca	38.72	4.08	28.55	45.87	6	58.08	6.12	42.82	68.81	4.5
P	9.57	1.42	6.53	12.51	2	14.36	2.13	9.8	18.76	1.1
Cu µg/d	86.08	22.4	49.5	132	25	129.11	33.63	74.25	198	15.0
Fe	0.7	0.1	0.43	0.91	10	1.04	0.15	0.64	1.36	6.9
Mn	0.1	0.03	0.05	0.15	**8**	0.14	0.04	0.07	0.22	**8.8**
Vit C	53.92	10.7	29.16	78.16	359	80.87	16.01	43.73	117.24	124.4
Vit B1	0.08	0.08	0	0.83	16	0.12	0.12	0	1.24	12.0
Vit B2	0.09	0.06	0	0.21	18	0.14	0.08	0	0.32	14.0

4-8 y Children 1 ½ cup						**19-50 y male, 2 cup**			
Na	0.01	0	0.01	0.01	**0.83**	0.01	0	0.01	0.02	**0.7**
K	0.56	0.03	0.49	0.63	**15**	0.74	0.04	0.66	0.85	**15.7**
Ca	58.08	6.12	42.82	68.81	5.8	77.44	8.16	57.09	91.74	7.7
P	14.36	2.13	9.8	18.76	2.9	19.14	2.84	13.07	25.01	2.7
Cu	129.11	33.6	74.25	198	32.3	172.15	44.84	99	264	19.1
Fe	1.04	0.15	0.64	1.36	10.4	1.39	0.2	0.86	1.82	17.4
Mn	0.14	0.04	0.07	0.22	**9.3**	0.19	0.05	0.1	0.3	**8.5**
Vit C	80.87	16.0	43.73	117.24	323.5	107.83	21.34	58.31	156.32	119.8
Vit B1	0.12	0.12	0	1.24	20.0	0.16	0.15	0	1.65	13.3
Vit B2	0.14	0.08	0	0.32	23.3	0.18	0.11	0	0.43	13.8

9-13 y male/female teenager 1 ½ cup						**19-30 y female, 2 cup**			
Na	0.01	0	0.01	0.01	**0.7**	0.01	0	0.01	0.02	**0.7**
K	0.56	0.03	0.49	0.63	**12.4**	0.74	0.04	0.66	0.85	**15.7**
Ca	58.08	6.12	42.82	68.81	4.5	77.44	8.16	57.09	91.74	7.7
P	14.36	2.13	9.8	18.76	1.2	19.14	2.84	13.07	25.01	2.7
Cu	129.11	33.6	74.25	198	18.4	172.15	44.84	99	264	19.1
Fe	1.04	0.15	0.64	1.36	13.0	1.39	0.2	0.86	1.82	7.7
Mn‡	0.14	0.04	0.07	0.22	**11.6/12**	0.19	0.05	0.1	0.3	**10.6**
Vit C	80.87	16.0	43.73	117.24	179.7	107.83	21.34	58.31	156.32	143.8
Vit B1	0.12	0.12	0	1.24	13.3	0.16	0.15	0	1.65	13.3
Vit B2	0.14	0.08	0	0.32	15.6	0.18	0.11	0	0.43	13.8

31-50 y female, 1 ½ cup						**51+ y female 1 ½ cup**			
Na	0.01	0	0.01	0.01	**0.8**	0.01	0	0.01	0.01	**0.8**
K	0.56	0.03	0.49	0.63	**11.9**	0.56	0.03	0.49	0.63	**11.9**
Ca	58.08	6.12	42.82	68.81	5.8	58.08	6.12	42.82	68.81	4.8
P	14.36	2.13	9.8	18.76	2.1	14.36	2.13	9.8	18.76	2.1
Cu	129.11	33.6	74.25	198	14.3	129.11	33.63	74.25	198	14.3
Fe	1.04	0.15	0.64	1.36	5.8	1.04	0.15	0.64	1.36	13
Mn	0.14	0.04	0.07	0.22	**7.8**	0.14	0.04	0.07	0.22	**7.8**
Vit C	80.87	16.0	43.73	117.24	107.8	80.87	16.01	43.73	117.24	107.8
Vit B1	0.12	0.12	0	1.24	10.9	0.12	0.12	0	1.24	10.9
Vit B2	0.14	0.08	0	0.32	12.7	0.14	0.08	0	0.32	12.7

*SD, Standard deviation; Daily food intake (DI) and contributions to Dietary Reference Intake (RDI). Recommended Dietary Allowances (RDAs) are in ordinary text and Adequate Intakes (AIs) are in **bold text**. The RDI reports is adapted from www.nap.edu*

This suggests half-ripen mangoes have not received enough mineral nutrition on parent plant and ripening and heat caused released of more minerals due to their presence as co factor of enzymes for synthesis of

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organic substances and anabolism of key metabolites necessary for full ripening while Vit C was very high in unripe mango and driven into simple sugars syntheses during ripening (Berg *et al.,* 2007; Sogi *et al.,* 2012; Kong and Singh, 2013). In corroboration, studies on quality of mangoes at different ripening stages have shown reducing Vit C with increasing ripening (Baloch and Bibi, 2012; Okoth *et al.,* 2013; Wafula *et al.,* 2015). Increased heat from ambient temperature 25±3°C, 80±11% RH to 35±5°C, 55±70% RH caused increased level of minerals except P, reduced level of vitamins and no impact on level of Cu (Table 2). Vitamins followed expected result as most heat labile substances while few minerals showed disparity according to their biological system requirement or bioavailability (Kramer, 1977). Studies have shown that heat increases cellular respiration that initiates and increases enzymatic reactions for breaking down of complex organic molecules to generate minerals, and also, using up some microminerals for syntheses of phytochemicals during ripening process and also heat treatments reduced fruit sensory quality, leading to loss of flavour and nutrient quality (Baloch and Bibi, 2012; Escribano and Mitcham, 2014; Yi *et al.,,* 2020). The minerals show increase in level from 0 dah to a peak at 4 or 6 dah except Na and Mn that increases till 10 and 8 DAH, respectively, while vitamins reduces from 0 till 10 dah (Table 2). The present results suggest releasing of minerals at shorter dah followed by their channelling into metabolic processes and perhaps with presence of microorganisms scavenging the nutrients for their metabolic processes at lengthy dah while the assessed vitamins undergone destructive oxidation (Kramer, 1977).

Table 2: Comparative level of minerals and vitamins for mode of harvest, handling, ripe, heat, and DAH

Obs	Harvest Condition	Freq	Na	K	Ca	p	Cu	Fe	Mn	Vit C	Vit B$_1$	Vit B$_2$
	Harvest											
1	Before dropping	90	4.39[a]	229.70[a]	24.10[a]	5.52[b]	0.05[b]	0.45[a]	0.061[m]	33.44[m]	0.05[m]	0.06[m]
2	After dropping	90	3.83[b]	221.04[b]	22.77[b]	6.08[a]	0.06[a]	0.40[b]	0.057	31.91	0.04	0.05
	Handling											
1	RMP	18	4.71[a]	234.46[abcd]	25.73[a]	5.82[abcd]	0.050[ab]	0.4[b]	0.052[bc]	33.00[bc]	0.062[ab]	0.077[a]
2	R2MP	18	4.53[a]	234.04[abc]	23.40[bcd]	5.62[bcd]	0.048[bc]	0.44[b]	0.064[a]	34.68[ab]	0.077[a]	0.062[abc]
3	R2MPHR	18	4.63[a]	237.07[a]	24.51[ab]	5.47[cd]	0.045[c]	0.45[ab]	0.067[a]	30.26[bc]	0.042[bc]	0.080[a]
4	R2MGHR	18	4.15[b]	228.58[bcd]	23.92[bc]	6.06[abc]	0.063[a]	0.39[c]	0.066[a]	29.03[c]	0.041[bc]	0.029[c]
5	UMPHR	18	4.09[b]	226.53[cde]	24.26[abc]	5.35[d]	0.045[c]	0.48[a]	0.062[ab]	31.44[bc]	0.024[c]	0.042[cde]
6	RMG	18	3.76[c]	223.73[def]	23.91[bc]	6.32[a]	0.064[a]	0.34[d]	0.052[bc]	31.6[bc]	0.058[ab]	0.068[ab]
7	UMP	18	3.97[bc]	216.41[fg]	22.61[cde]	5.36[d]	0.045[c]	0.47[a]	0.048[d]	37.83[a]	0.041[bc]	0.054[bcd]
8	R2MG	18	3.88[bc]	219.42[efg]	22.48[cde]	6.21[ab]	0.060[a]	0.38[c]	0.059[ab]	32.88	0.047[bc]	0.031[c]
9	UMGHR	18	3.72[c]	221.32[def]	22.11[e]	5.88[abcd]	0.056[ab]	0.44[b]	0.059[ab]	30.85[bc]	0.034[c]	0.069[ab]
10	UMG	18	3.67[c]	212.15[g]	21.44[de]	5.92[abcd]	0.047[c]	0.43[b]	0.051[bc]	35.19[ab]	0.042[bc]	0.039[de]
	Ripe											
1	Half-Ripen	48	4.10[a]	225.76[a]	23.32[a]	5.76[b]	0.05[b]	0.44[a]	0.055[b]	36.15[b]	0.07[a]	0.08[a]
2	Ripe	101	4.38[b]	230.13[a]	24.21[a]	6.11[a]	0.06[a]	0.40[b]	0.065[a]	28.57[c]	0.04[b]	0.04[c]
3	Unripe	31	3.26[c]	209.27[b]	21.09[b]	4.84[c]	0.04[c]	0.46[a]	0.040[c]	40.67[a]	0.06[ab]	0.06[b]
	Heat											
1	25±3°C	107	4.08[m]	223.46[b]	23.27[m]	5.88[m]	0.05[m]	0.41[b]	0.05[b]	34.22[a]	0.059[a]	0.064[a]
2	35±5°C	73	4.16	228.17[a]	23.69	5.69	0.05	0.43[a]	0.06[a]	30.41[b]	0.035[b]	0.044[b]
	DAH											
1	0	30	3.62[c]	211.59[c]	20.02[d]	4.74[d]	0.036[c]	0.39[d]	0.037[c]	42.38[a]	0.09[a]	0.09[a]
2	2	30	3.87[bc]	221.09[b]	22.65[c]	5.46[c]	0.045[c]	0.44[bc]	0.050[d]	38.06[b]	0.07[ab]	0.08[b]
3	4	30	4.07[b]	231.85[a]	26.28[a]	6.36[b]	0.055[b]	0.49[a]	0.059[c]	33.83[c]	0.05[b]	0.07[c]
4	6	30	4.35[a]	236.42[a]	25.53[a]	6.65[a]	0.063[a]	0.46[b]	0.068[b]	30.48[d]	0.05[b]	0.05[d]
5	8	30	4.36[a]	231.94[a]	23.99[b]	6.28[b]	0.062[a]	0.42[c]	0.076[a]	27.19[e]	0.02[c]	0.03[e]
6	10	30	4.39[a]	219.33[b]	22.15[c]	5.31[c]	0.052[b]	0.35[e]	0.065[b]	24.13[f]	0.01[c]	0.02[e]

Increases level of Na suggests its reduced or zero used as a cofactor or by microbes. The present results support the findings that mangoes shell life varies from 4 to 14 days at ambient temperature (Herianus *et al.*, 2003) but not with only loss of sensory, flavour, texture, and macronutrient quality during lengthy storage days, of which Vit. C is a major marker (Baloch and Bibi, 2012; Escribano and Mitcham, 2014), in addition, minerals and vitamins such as Na, K, Ca, P, Fe, Cu, Mn, Vit B$_1$ and B$_2$, are also significantly lost and they could also serve as added markers for nutrient quality over storage dah in

mangoes. General linear model ANOVA statistics denotes if the level of the minerals and vitamins observed in Table 2 are significantly different or not among the various assessed harvest handling and postharvest conditions and the observed significant differences are visually signified on their means in Table 2.

There is a clear cut demarcation of means between the two harvests for Na, K, Ca, P, Cu and Fe, while Mn, Vits. C, B_1 and B_2 are not significantly different, translating to good nutrition on parent plant is significant. The differences in the level of minerals and vitamins observed among the various handling evaluated are highly significant as depicted in Table 2. Level of minerals and vitamins are also significant among the three ripening status while K and Ca are not significantly different between half-ripe and ripe. On a close observation at Table 2, K, Fe, Mn and vitamins are the only significantly different nutrients for heat, other differences observed in Table 2 are not significant. Conspicuously, levels of nutrients are highly significant for diverse assessed DAH with Vit. C presents distinct significant differences among the DAH. Related studies have reported significant differences of nutritional, organoleptic and functional properties in mangoes at diverse pre and post-harvest conditions but scantily on minerals and vitamins at harvest handling (Baloch and Bibi, 2012; Lee and Kader, 2000; Kong and Singh, 2013; Normand *et al.*, 2015; Shi *et al.*, 2015; Wafula, *et al.*, 2015). Therefore, the significant differences highlighted at present are useful for nutritious mango at both harvest handling and postharvest management and detailed descriptive ANOVA statistics is available on request. Before dropping, hand-plucked on parent plants; after dropping, hand-picked on the ground around parent plants; RMP, ripe mango on plant; R_2MP, half-ripen mango on plant; R_2MPHR, heat ripened- half-ripen mango on plant; UMP, unripe mango on plant; UMPHR, heat ripened- unripe mango on plant; RMG, ripe mango after dropping on ground; R_2MG, half-ripen mango on ground; R_2MGHR, heat ripened-half-ripen mango on ground; UMG, unripe mango on ground; UMGHR, heat ripened- unripe mango on ground. DAH, day after harvest.

Interaction effects and correlations among harvest, ripe, heat, and dah on Minerals and Vitamins in mango: Noticeably, there is high significant interactions of the harvest and postharvest conditions on the level of minerals and vitamins assessed and only interactions for harvest, ripe, heat and DAH are presented to avoid very large Table 3 (Detailed ANOVA statistics available on request). Table 3 also presents the direction of impact observed for heat, ripe and storage dah on the assessed minerals and vitamins (handling was omitted due to its cumbersome quantitation).

The only significant relationships among the assessed harvest and postharvest conditions is the positive correlation between ripe and dah, that is, ripening increases with dah. The macro minerals and Fe showed weak positive relationships with harvest while P and Cu showed reverse relationship but Mn and vitamins displayed no relationship. The minerals moderately increase with ripening while Fe and vitamins weakly decrease but Vit C shows a strong inverse relationship. Only level of K, Fe, Cu and Mn showed weak increase with increasing heat among the minerals while level of vitamins weakly declined with heat. Minerals increase with increasing dah except Fe that shows a weak inverse relationship and vitamins strongly decrease with increasing dah. The correlation relationships show the effect of the harvest handling and postharvest conditions do not possesses a tidy or regular direction with one another and for some minerals and vitamins. The minerals and vitamins show positive relationship with one another with strongest association among Na, K, and Ca; Mn and Vit C; Vit C and Vit B_1; and Vit B_1 and B_2. Interaction effects of heat, time and ripe on flavour, nutrient quality and taste have been previously reported and are usually useful for optimizing conditions necessary for postharvest management of mango. In sequel, optimal temperature*time combination has been emphasized as a key factor but more is on Vit C, sugar content, texture, phenolic compounds, organic acids and microorganism attack ((Lee and Kader, 2000; Baloch and Bibi, 2012**;** Herianus *et al.*, 2003; Joshi *et al.,* 2017) but scantly on minerals and vitamins, which is necessary considering mineral malnutrition ravaging underdeveloped countries. The present results highlight the importance of the co-effects of the present assessed harvest handling and postharvest conditions and their co-optimization that might be necessary for maximizing minerals and vitamins in mango for end use and consumer quality acceptance, though, require further researches. The present reported relationships are useful in breeding or fortifying mango for good nutrition and such useful relationships has been reported for antioxidants, minerals and orange colour in mango (Shi et al., 2015; Yusuf *et al.*, 2018). *Selection of optimal integrated harvest and postharvest condition for high level of minerals and vitamins in mango:* One tailed z test was carried out to assess best and worst integrated harvest condition for high level of minerals and vitamins that could be used to obtain a nutritious mango and Table 4 shows ρ values in green and blue colour as the highest and lowest nutrient content, respectively.

MOYIB, OK; OMOTOLA, OE; BANJOKO, OO, EZIKE, BU

Table 3: Analysis of variance and Pearson Correlations statistics for interaction effects among harvest, ripe, heat and time on minerals and vitamins content of mango fruit

Nutrient	Harvest Interactions								Ripe heat*Dah interactions					
	Model statistics		Harvest*Ripe	Harvest*Heat	Harvest*Dah	Harvest*Ripe*Heat	Harvest*Heat*Dah	Harvest*Ripe*heat*Dah	Model statistics		Ripe*Heat	Ripe*dah	Heat*dah	Ripe*Heat*dah
	R^2	CV	$Pr>F^\beta$	$Pr>F^\beta$	$Pr>F$	$Pr>F^\beta$	$Pr>F^\beta$	$Pr>F$	R^2	CV	$Pr>F^\beta$	$Pr>F^\beta$	$Pr>F$	$Pr>F$
Na	0.86	5.35	***	***	***	***	***	***	0.63	8.97	***	***	***	***
K	0.84	2.5	***	***	***	***	***	***	0.79	2.86	***	***	***	***
Ca	0.91	3,5	***	***	***	***	***	***	0.85	4.73	***	***	***	***
P	0.89	5.2	***	***	***	***	***	***	0.81	6.97	***	***	***	***
Cu	0.78	12.9	***	***	***	***	***	***	0.64	16.8	***	***	***	***
Fe	0.89	5.02	***	***	***	***	***	***	0.72	8.2	***	***	***	***
Mn	0.80	13.0	***	***	***	***	***	***	0.79	13.4	***	***	***	***
Vit. C	0.94	5.51	***	***	***	***	***	***	0.94	5.54	***	***	***	***
Vit B$_1$	0.46	25.2	*	***	***	***	***	***	0.88	25.4	***	***	***	***
Vit B$_2$	0.86	23.4	***	***	***	***	***	***	0.84	26.4	***	***	***	***

Pearson Correlation among assessed harvest and postharvest conditions, and nutrients														
	Ripe	Heat	Dah	Na	K	Ca	P	Cu	Fe	Mn	Vit. C	Vit. B$_1$	Vit B$_2$
Harvest[†]	NS	NS	NS	-0.5***	-0.33***	-0.25***	0.32***	0.42***	-0.43***	NS	NS	NS	NS
Ripe[‡]		NS	0.64***	0.69***	0.54**	0.43*	0.52*	0.60***	-0.42***	0.57***	0.70*	-0.2*	-0.26***
Heat[□]			NS	NS	0.18*	0.15*	NS	NS	0.19*	0.28****	-0.26***	-0.25**	0.29***
Dah[δ]				0.49***	0.29***	0.27***	0.32***	0.51***	-0.23**	0.72***	-0.90***	-0.55***	-0.80***
Na					0.75***	0.56***	0.36***	0.31***	ns	0.59***	-0.52***	ns	-0.19*
K						0.81***	0.59***	0.49***	0.34***	0.60***	-0.45***	ns	ns
Ca							0.66***	0.51***	0.47***	0.53*	0.41***	ns	ns
P								0.81***	0.19*	0.50***	-0.39***	ns	-0.16*
Cu									NS	0.59***	-0.60***	-0.24**	-0.30***
Fe										NS	NS	NS	NS
Mn											-0.79***	-0.42***	-0.55***
Vit. C												0.52***	0.72***
Vit. B$_1$													0.64***

† Harvest- Before dropping → After dropping from parent plant; ‡ Ripe - unripe → half ripe→ ripe mango; □ Heat - 25±3 ºC→ 35±5 ºC; δDah - 0→10 days; *, significant at ρ ; 0.05; **, ρ ≤ 0.005; ***, ρ ≤ 0,0005;NS= not significant at ρ = 0

Sixty-eight integrated harvest handling and postharvest conditions are generated but only best and worst 20 are presented and listed in the order of decreasing mean p values which is a representation of nutrient quality (full Table is available on request). Table 4 shows no single integrated harvest and postharvest condition has a complete p score of either 1.00 or 0.00 for all the minerals and vitamins assessed, signifying integrated harvest condition used could be nutrient specific as indicated for harvest handling and those showing high nutrient values among the best 20 listed are more desirable. The general linear model showed very high significant variation of mean ρ scores among the integrated harvest condition (r = 0.73, CV = 18.15, RMSE = 0.069, and mean = 0.11, SS3 = 0.66, MS = 0.02, ρ<0.0001). Figure 1 is a Duncan grouping for visual separation of means and shows naturally ripened half-ripe mango on parent plant at 6 dah, R$_2$MPRHn6[a]; ripe mango on parent plant at 4 dah, RMPHn4[ab] and half-ripe mango on parent plant at 4 dah, R$_2$MPHn4[ab] as best three optimal integrated harvest conditions with no significant difference between RMPHn4 and R$_2$MPHn4.

Table 4: Z test probability values for Integrated handling conditions for minerals and vitamins retention in mango fruits

Obs	Integrated Harvest	Freq	Na	K	Ca	p	Cu	Fe	Mn	Vit C	VitB$_1$	VitB$_2$	Mean p
1	R2MPHn6	1	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.71	0.85	1.00	0.95
2	RMPHn4	3	1.00	1.00	1.00	1.00	1.00	1.00	0.31	0.74	1.00	1.00	0.90
3	R2MPHn4	3	1.00	1.00	1.00	1.00	0.00	1.00	0.95	1.00	1.00	1.00	0.90
4	R2MGHRR4	2	0.71	1.00	1.00	1.00	1.00	1.00	0.93	0.07	0.78	0.99	0.85
5	RMGHn4	3	0.82	1.00	1.00	1.00	1.00	0.00	0.31	0.90	1.00	1.00	0.80
6	RMPHn6	3	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.00	0.71	0.33	0.80
7	R2MPHR2	3	1.00	0.99	1.00	0.00	0.00	1.00	0.93	1.00	1.00	1.00	0.79
8	R2MGHR4	1	0.88	1.00	1.00	1.00	1.00	1.00	0.93	0.08	0.01	0.98	0.79
9	RMPHn2	3	1.00	1.00	1.00	1.00	0.00	0.78	0.00	1.00	1.00	1.00	0.78
10	R2MPHRR6	3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.66	0.77
11	UMPRHn8	2	1.00	0.99	1.00	1.00	1.00	1.00	0.46	0.96	0.00	0.00	0.74
12	R2MPRHn8	3	1.00	1.00	1.00	1.00	1.00	0.79	1.00	0.00	0.57	0.01	0.74
13	UMPHR8	3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.70
14	R2MPHR4	3	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00	0.67	0.67
15	R2MPHn2	3	1.00	1.00	0.00	0.00	0.00	1.00	0.62	1.00	1.00	1.00	0.66
16	RMGHn2	3	0.04	0.91	0.67	1.00	1.00	0.00	0.00	1.00	1.00	1.00	0.66
17	R2MGHn4	3	0.00	0.43	0.30	1.00	1.00	1.00	0.00	1.00	0.85	1.00	0.66
18	RMGHn6	3	0.53	1.00	1.00	1.00	1.00	0.00	0.98	0.00	0.38	0.66	0.65
19	R2MGHRR6	3	0.99	1.00	1.00	1.00	1.00	0.38	1.00	0.00	0.00	0.00	0.64
20	UMGHR/6	2	0.24	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.62
21	RMGHn8	3	0.00	0.00	0.67	1.00	1.00	0.00	0.95	0.00	0.00	0.00	0.36
22	UMPURHn2	3	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.85	0.66	0.35
23	UMPURHn0	3	0.00	0.00	0.00	0.00	0.00	0.79	0.00	1.00	0.71	0.99	0.35
24	UMPRHn10	2	1.00	0.00	0.00	0.24	1.00	0.00	0.96	0.09	0.00	0.00	0.33
25	R2MPHR10	3	1.00	1.00	0.32	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.33
26	UMGRHn8	3	0.43	0.02	0.00	1.00	0.00	0.78	1.00	0.01	0.00	0.00	0.32
27	RMGHn0	3	0.00	0.00	0.00	0.20	0.00	0.00	0.00	1.00	1.00	1.00	0.32
28	UMGHRUR2	3	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.85	0.33	0.32
29	UMPR10	1	1.00	0.00	0.00	0.17	1.00	0.01	0.93	0.05	0.00	0.00	0.32
30	R2MGHR0	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	0.30
31	R2MGHn0	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	0.30
32	UMGHRUR0	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.98	0.30
33	UMGURHn0	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.98	0.30
34	R2MGRHn10	3	0.25	0.00	0.00	0.50	1.00	0.00	0.98	0.00	0.00	0.00	0.27
35	UMGHR10	3	1.00	0.04	0.00	0.15	0.33	0.00	1.00	0.00	0.00	0.00	0.25
36	UMPHRUR2	3	0.00	0.00	0.04	0.00	0.00	1.00	0.00	1.00	0.01	0.00	0.20
37	R2MPRHn10	3	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.20
38	UMGRHn10	3	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
39	RMGHn10	3	0.00	0.00	0.00	0.00	1.00	0.00	0.31	0.00	0.00	0.00	0.13
40	RMPHn10	3	1.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.13

δ integrated harvest acronyms for names are such that harvest and postharvest conditions are merged,, examples, 2MPHn6 is for half ripe mango on plant no heat at 6 DAH; RMGHn4, ripe mango on ground no heat at 4 DAH; UMPHR8, unripe mango on plant heat ripened at 8 DAH; R2MGRHn10, half ripe mango ripe with no heat at 10 DAH;.Values in green and blue colors are best and worst scores, respectively. P mean is the mean score of one tailed z test probability scores. When sample value is greater than population mean, z test returns probability score greater than 0.5. x >x, then p >0.5.

The worst three integrated harvest are ripe mango on ground 10 dah, RMGHn10; ripe mango on parent plant at 10 dah, RMPHn10 and heat ripened mango on ground at 10 dah, UMGRHn10, with no significant difference between RMGHn10 and RMPHn10.

Close observations at Table 4 and Figure 1 reveal harvesting healthy mango as full ripen either plucked on parent tree or picked on ground and stored at 2 to 4 dah without heat, half ripened mango plucked on parent tree and stored to ripe between 4 to 6 dah without heat have highest mineral and vitamins content with few exceptions while harvesting mango irrespective of harvest handling and stored with or without heat at lengthy 8 to 10 dah and unripe mangos at 0 to 2 dah present worst minerals and vitamins content with few exceptions. This further confirms loss of nutrient quality with lengthy dah and also unripe mango is inferior in nutrient quality to ripe mangoes (Baloch and Bibi, 2012; Joshi *et al*., 2017; Herianus *et al*., 2003; Lee and Kader, 2000). The Correlation, Duncan grouping, GLM, and z-test analyses approach used at present enables selection of optimal harvest and postharvest conditions for high level of minerals and vitamins for a nutritious mango and have been previously used in mango for discriminating maturity, ripening, color and genotypes (Shi *et al*., 2015; Yusuf *et al*., 2018).

Same have been applied in beans, cassava, mushroom for crop improvement (Moyib *et al*., 2015a; *Moyib et al*., 2015b; Moyib *et al.,* 2019).

P_Mean Duncan Grouping for Means of Integrated_Harvest (Alpha = 0.05)
Means covered by the same bar are not significantly different.

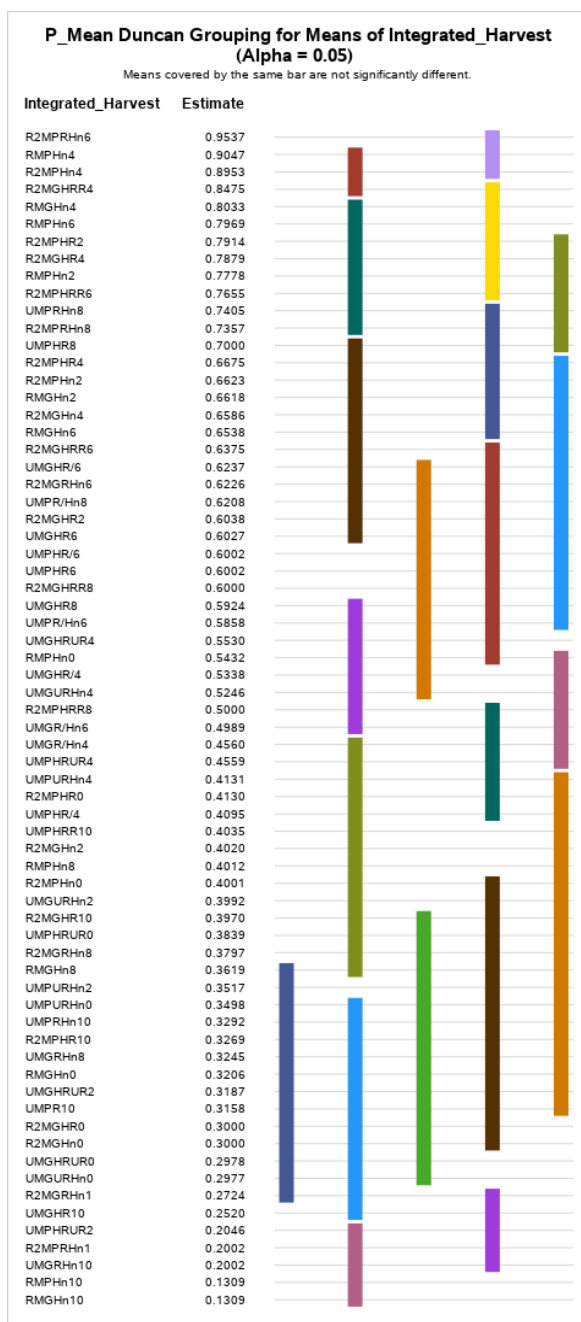| Integrated_Harvest	Estimate
R2MPRHn6	0.9537
RMPHn4	0.9047
R2MPHn4	0.8953
R2MGHRR4	0.8475
RMGHn4	0.8033
RMPHn6	0.7969
R2MPHR2	0.7914
R2MGHR4	0.7879
RMPHn2	0.7778
R2MPHRR6	0.7655
UMPRHn8	0.7405
R2MPRHn8	0.7357
UMPHR8	0.7000
R2MPHR4	0.6675
R2MPHn2	0.6623
RMGHn2	0.6618
R2MGHn4	0.6586
RMGHn6	0.6538
R2MGHRR6	0.6375
UMGHR/6	0.6237
R2MGRHn6	0.6226
UMPR/Hn8	0.6208
R2MGHR2	0.6038
UMGHR6	0.6027
UMPHR/6	0.6002
UMPHR6	0.6002
R2MGHRR8	0.6000
UMGHR8	0.5924
UMPR/Hn6	0.5858
UMGHRUR4	0.5530
RMPHn0	0.5432
UMGHR/4	0.5338
UMGURHn4	0.5246
R2MPHRR8	0.5000
UMGR/Hn6	0.4989
UMGR/Hn4	0.4560
UMPHRUR4	0.4559
UMPURHn4	0.4131
R2MPHR0	0.4130
UMPHR/4	0.4095
UMPHRR10	0.4035
R2MGHn2	0.4020
RMPHn8	0.4012
R2MPHn0	0.4001
UMGURHn2	0.3992
R2MGRH10	0.3970
UMPHRUR0	0.3839
R2MGRHn8	0.3797
RMGHn8	0.3619
UMPURHn2	0.3517
UMPURHn0	0.3498
UMPRHn10	0.3292
R2MPHR10	0.3269
UMGRHn8	0.3245
RMGHn0	0.3206
UMGHRUR2	0.3187
UMPR10	0.3158
R2MGHR0	0.3000
R2MGHn0	0.3000
UMGHRUR0	0.2978
UMGURHn0	0.2977
R2MGRHn1	0.2724
UMGHR10	0.2520
UMPHRUR2	0.2046
R2MPRHn1	0.2002
UMGRHn10	0.2002
RMPHn10	0.1309
RMGHn10	0.1309

Fig 1. *Duncan multiple grouping of combo pre and post-harvest handling conditions of mango fruits for retention of minerals and vitamins*. Means that are not significantly different at P = 0.05 are covered by same colored bar. P_mean is the means of one tailed- z test probability score returns, mean p. Integrated Harvest name acronyms are a combinatory of harvest handling and postharvest conditions acronyms.

Conclusion: Harvesting ripe mango on parent plant is nutritious while lengthy dah is adverse on its mineral and vitamin content. Unripe mangoes are poor nutrient and therefore, are not suitable when nutritious mango with high minerals and vitamins is the main focus.

There is high interaction effect of various assessed harvest handling and postharvest condition on mineral and vitamin content of mango which might necessitates their co-optimization to maximize high nutrient level.

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