Impact of Senescence on the Nutritional Profiles of Some Fruits Consume in Makurdi, Nigeria

Peter Agorye Adie[1*], Peter Onyilo Ediga[1] and Raymond Ahule Wuana[2]

[1]*Department of Chemistry, Center for Food Technology and Research, Benue State University, Makurdi, Nigeria.*
[2]*Department of Chemistry, Federal University of Agriculture, Makurdi, Nigeria.*

Authors' contributions

This work was a collaborative effort of all authors. Author PAA designed the study, wrote the protocol, supervised the experimentals and wrote the manuscript. Author POE carried out sampling and bench work, provided literature review and performed statistical tests of the data. Author RAW co-designed and coordinated the research work, provided literature, managed data analysis and fine-tuned the manuscript. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Chemical and nutritional changes with senescence in some fruits commonly consumed in Makurdi, North Central Nigeria, were investigated using standard analytical methods. Four fruits: mango, pawpaw, orange and pineapple at three different stages of growth; pre-ripe, ripe, and post-ripe were screened for proximate composition, mineral elements, pH, titrable acidity, and vitamins A and C. Results indicated increase in moisture content as the fruit deteriorated in the climacteric fruits (mango and pawpaw), while in the non-climateric fruits (orange and pineapple) the parameter depreciated from ripe to over-ripe. Other proximate parameters showed a consistent rise at ripening and declining thereafter as the fruit deteriorated. In all cases, pH of the fruits showed steady rise with senescence, and this was inversely related to the titrable acidity. Beta-carotene (vitamin A) and ascorbic acid (vitamin C) showed similar trend of peaking at the ripening stages and declining as the fruits aged. Nitrogen recorded the highest concentration (45.28±0.04 mg/L)

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Corresponding author: Email: padie@bsum.edu.ng;

among the macronutrient elements at the ripe stage of pawpaw, while phosphorus recorded the least (1.39±0.01 mg/L) for over-ripe pineapple. The instrument failed to detect Ni in all samples analyzed in the micronutrient mineral elements category, while Ca recorded the highest (5.25±0.07 mg/L). Macronutrients showed consistency in appreciating at ripening and depreciating as the fruits aged. Only Zn showed presence in all samples among the micronutrients analyzed. Results showed that in most of the parameters investigated, nutritional and chemical contents of the fruits are at their optimum at the ripen stage of the fruits, and declined as the fruits deteriorates with age.

1. INTRODUCTION

Fruits are unarguably considered nature's gift to mankind as they are important sources of essential dietary nutrients. They are also recognized as rich sources of bioactive compounds such as antioxidants, natural sugars and organic acids [1]. Evidences gathered from many clinical studies support the fact that consumption of fruits and vegetables ameliorate age-related diseases such as cancers and heart diseases [2,3,4]. Thus, the popularity and acceptability of fruits among consumers is not only due to their high nutritive value and characteristic taste but also due to their known health promoting properties. Foods of plant origin are capable of contributing appreciable quantities of nutrients, including protein, needed by both children and adults if properly processed [5,6].

The characteristic flavour of fruits is usually attained as the fruit ripens. During fruit ripening, the biochemistry, physiology and structure are developmentally altered to influence the appearance, texture, flavour and aroma [3,7]. The changes in the composition of different chemical constituents and organic acids during fruit ripening play a key role in flavour development and can affect the chemical and sensory characteristics such as pH, total acidity, microbial stability and taste [8,9,10]. Chemical composition is one of the most important quality criteria for fruits and is measured while selecting them in the preparation for various fruit products. The sugar type and content, organic acids, pigments and many other essential constituents enable the ripe fruits to produce many value added products [11,12,13]. Different types of fruits contain different amounts of organic acids which act as intermediates in the metabolic processes and are directly involved in growth, maturation and senescence. The word *senescence* derives from two Latin words: *senex* and *senescere*. *Senex* means 'old'; this Latin root is shared by 'senile', 'senior', and even 'senate'. In ancient Rome the 'Senatus' was a 'council of elders' that was composed of the heads of

patrician families. *Senescere* means 'to grow old'. The Merriam-Webster online dictionary defines *senescence* as 'the state of being old or the process of becoming old'. Ageing is also the process of getting older. Therefore, ageing and senescence are regarded as synonyms, and the two words have often been used interchangeably [14,15]. Senescence is the final stage of fruit growth and development. Fruit senescence as well brings about a plethora of deteriorative changes and disorders, all of which contribute to the weakening of the rind and leads to the final demise of the fruit. Most importantly however, senescence is promoted by plant hormones [16]. Plant hormones are chemicals produced by one part of the plant and transported to another part where they exert their action. Hormones are implicated in various plant phenomena such as cell division, differentiation, growth, seed germination, fruiting and senescence. Senescence has a tremendous effect on life as it manifests in leaf dropping. Leaves are the factory site of the plant for the synthesis of sugars, as they are the main plant organs which absorb and covert energy from the sun through the process of photosynthesis to forms of carbohydrate [17,18]. With senescence and leaf dropping, this vital plant function among others sharply declines. This research work was therefore designed to inquire into the effect of senescence on some chemical and nutritional indicators of commonly consumed fruits in the north central city of Makurdi, Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental Design, Sample Collection and Pre-treatment

The research aimed to investigate the effects of senescence on the nutritional profiles of some fruits consume in Makurdi metropolis, North – Central Nigeria. Four fruits; mangoes (*Magnifera indica*) (called Chugh kpev by the natives), oranges (*Citrus sinensis*) (Valencia), pawpaw (*Carica papaya*) (Red royale) and pineapples (*Ananas comosus*) (Queen pineapple) were

collected from a farm within the metropolis of Makurdi at various maturation stages and properly washed for analysis. The pre-ripe, ripe and over ripe (approaching spoilage) fruits (except for pineapple) were collected from the same plant for analysis. Pineapple was collected at different stages of maturation from within the same orchard. Fruits were collected in triplicates of three fruits per replicate. Fruits free from insect bites were selected and washed with deionized water to eliminate visible dirts and the water was removed quickly with a blotting paper. The fruits were peeled and the flesh blended into paste and homogenized.

2.2 Proximate and Physiochemical Analysis

Triplicate determinations of proximate composition were done using the procedure of [19]. All determinations were done in triplicates.

2.2.1 Determination of titrable acidity

About 1 g of the pre-treated sample was weighed out and macerated with 50 mL of distilled water. The mixture was filtered with Whatman's No 1 filter paper. The filtrate was collected into a 50 mL conical flask. About 1.0 mL of phenolphthalein indicator was added to it. The solution was titrated with 0.1 N sodium hydroxide to pink end point.

2.2.2 Determination of pH

About ten grams (10 g) of the sample was mixed with 25 mL of distilled water and stirred continuously to dissolve. The mixture was left to stand for 5 min. and 30 mL was pipetted out. The probe of the pH meter was dipped into the pipetted sample and the reading taken.

2.2.3 Determination of moisture

The crucible was properly washed and allowed to dry in an air oven at 110ºC for 10 minutes. The crucible was allowed to cool in a desiccator for 30 min. and then weighed (W_1). About 2.0 g of each of the sample was placed in the crucible and reweighed (W_2). The crucible with the sample was placed in an oven maintained at 103ºC for 5 hours, after which, it was removed and transferred to the desiccator to cool and finally weighed again (W_3). The percentage moisture content for the sample was calculated thus:

$$\text{Percentage moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \qquad (1)$$

Where: W_1 = initial weight of empty crucible, W_2 = weight of crucible plus sample before drying, W_3 = final weight of crucible plus sample after drying.

2.2.4 Determination of ash content

The porcelain crucible was washed and dried in an oven to a constant weight at 100ºC for 10 min. and cooled in a desiccator and weighed (W_1). About 2.0 g of the sample was weighed into the previously weighed porcelain crucible and reweighed (W_2). The crucible with the sample was transferred into the furnace at 550ºC for 5 hours to ensure proper ashing. It was removed and allowed to cool in the desiccator, and again weighed (W_3). The percentage ash content for each of the sample was calculated thus:

$$\% \text{ Ash} = \frac{\text{weight of ash}}{\text{weight of the original sample}} \times 100$$

$$= \frac{W_3 - W_1}{W_2 - W_1} \times 100 \qquad (2)$$

where: W_1 = weight of empty crucible, W_2 = weight of crucible and sample before ashing, W_3 = weight of crucible and sample after ashing.

2.2.5 Determination of fat content

The pre-treated sample (5.0 g) was Soxhlet-extracted with petroleum ether for 6 hours. The solvent was recovered and the oil was dried in the oven at 70ºC for 1 hour. The fat content was calculated thus:

$$\% \text{ Fat} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100 \qquad (3)$$

2.2.6 Determination of crude protein and nitrogen

The micro Kjeldahl method was used. 0.5 g of the sample was weighed and placed on the nitrogen free filter paper, then folded and dropped into a Kjeldahl digestion tube. 3.0 g of digestion mixed catalyst ($CuSO_4$ + Na_2SO_4) and 25 mL of Conc. Na_2SO_4 was added to the sample in the digestion tube. The mixture in the digestion tubes was transferred to the Kjeldahl digestion apparatus; the heater was regulated at a temperature below the boiling point of the acid until frothing ceased. The mixture boiled vigorously as temperature increases, until clear (light) green colour was obtained. The digest was allowed to cool, then transferred into 100 mL volumetric flask and diluted with distilled water

and made up 100 mL. 10 mL aliquot of digest was introduced into the distillation jacket of the micro steam distillation apparatus that was connected to the main, as the water in the distiller flask boils. Exactly 20 mL of 40% NaOH was added to each digest in the distillation jacket. About 50 mL of 40% boric acid was measured into 250 mL conical flask, and four (4) drops of methyl red indicator was added. The conical flask containing the mixture was placed onto the distillation apparatus with the outlet tubes inserted into each conical flask and NH_3 was collected through the condenser. The distillation continued until 25 mL of the distillate was trapped into the boric acid solution and colour changed from red to yellow. The distillate was then titrated with 0.02 M HCl. Percentage nitrogen and crude protein of the sample were calculated thus:

$$\% \ N_2 = \left(\frac{100}{W} \times \frac{N \times 14}{1000} \times \frac{V_t}{V_a}\right) T. B \qquad (4)$$

% Protein = % N_2 x 6.25 (conversion factor)   (5)

where W = weight of sample, N = normality of titrant (0.02 H_2SO_4), Vt = total digest volume (100 mL), Va = volume of digest analyzed (10 mL), T = titre value of sample, B = titre value of blank.

2.2.7 Determination of crude fiber

A weighed sample (2.0 g) free of moisture and ether extracted was digested with 0.25 M H_2SO_4 and neutralized with 0.3 M KOH. The residue was made alkaline-free by washing with warm water and dried in an oven at 100°C for two hours, cooled in a desiccator and weighed. The weighed sample was then incinerated in a muffle furnace and reweighed (w_3). Percentage crude fibre content for the sample was calculated thus:

$$\% \text{ crude fibre} \quad = \frac{100(W_2 - W_3)}{W_1} \qquad (6)$$

where: W_1= weight of the sample used
W_2 = weight of crucible + sample after boiling, washing and drying
W_3 = weight of crucible + sample as ash

2.2.8 Determination of carbohydrate content

Carbohydrate was determined by difference. Carbohydrate was calculated by subtraction of the sums of the weights of crude protein, total fat, moisture, and ash.

Total Carbohydrate(%) =100 - {Moisture (%) + Protein (%) + Fat (%) + Ash (%)}   (7)

2.3 Determination of Beta-carotene (Vitamin A) Content

The spectrophotometric method described by Onwuka [20] was used. About 5 g of wet sample was dispersed in 30 mL of absolute alcohol [ethanol], and 3 mL of 5% potassium hydroxide was added to it. The mixture was boiled under reflux for 30 min. and was cooled rapidly with running water and filtered. 30 mL of distilled water was added and the mixture was transferred into a separating funnel. The mixture was washed with three portions of 50 mL of ether and the lower layer was discarded and the upper layer was further washed with 50 mL of distilled water. The extract was evaporated to dryness and dissolved in 10 mL of isopropyl alcohol and its absorbance was measured at 325 nm. The absorbance of the standard solution of vitamin A was measured. Vitamin A content [mg/100 g] was calculated from the expression:

$$\text{Vit.A [mg/100 g]} = \frac{100}{W} \times \frac{A_U}{A_S} \times C \qquad (8)$$

where Au = absorbance of test sample, As = absorbance of standard solution, C = concentration of the test sample, W = weight of sample.

2.4 Determination of Vitamin C Content by Titration with 2,6-dichlorophenol indophenol

Vitamin C content was determined by the method of AOAC [19], with slight modification.

Exactly 5 mL of standard solution of ascorbic acid was pipetted into 100 mL conical flask and 10 mL of 0.5% oxalic acid was added and the solution titrated against 2,6-dichlorophenol indophenol (V_1 mL) until a pink colour persisted for 15 seconds. The dye consumed is equivalent to the amount of ascorbic acid. Also, 2.0 g of the sample W, was extracted by maceration using 100 mL of 4% oxalic acid. The solution was filtered. 10 mL of oxalic acid was added to 5 mL of the filtrate above. The solution was then titrated against the dye solution (2, 6 – dichlorophenol indophenol). The volume of dye used was recorded as (V_2 mL).

Ascorbic acid (mg/100 g) $= \frac{0.5mg \times V2 \times 100mL}{V1 \times 5mL \times W} \times 100$ (9)

where W = sample weight.

2.5 Determination of Mineral Elements

Mineral content of the fruits was determined by atomic absorption spectrophotometry preceded by wet digestion, according to the method of AOAC [19]. For wet digestion of sample, exactly (1.0000 g) of the sample was taken in digestion glass tube. Twelve milliliters (12 mL) of HNO_3 was added to the sample and mixture was kept overnight at room temperature. Then 4.0 mL perchloric acid ($HClO_4$) was added to this mixture and was digested in a fume cupboard. The temperature was increased gradually, starting from 50ºC up to 250-300ºC. The digestion was completed in about 75 min as indicated by the appearance of white fumes. The mixture was left to cool and the content of the tube was transferred to 100 mL volumetric flask and the volume was made up to 100 mL with distilled water. The wet digested solution was transferred to plastic bottle and labeled accurately. The digest was stored and used for mineral elements determination [17,21].

2.6 Nitrogen and Phosphorus

The method of AOAC [19] was adopted. About 1.0 g of the sample was digested with 20 mL of concentrated acid mixture (HNO_3: $HClO_4$: H_2SO_4; 1: 1: 1) and aliquots of the diluted clear digest analyzed using Jenway PFP7 digital flame photometer. Nitrogen and phosphorus concentrations were obtained from the calibration curves obtained from the standards.

3. RESULTS AND DISCUSSION

3.1 Proximate Parameters, pH and Titrable Acidity

Variation in proximate composition in the climateric (mango and pawpaw) and non-climateric (orange and pineapple) fruits as well as pH and titrable acidity are presented in Table 1. Moisture content varies linearly with maturity in mango and pawpaw, and non-linearly in orange and pineapple. This indicates that in the climateric fruits, physiological change of ripening leads to release of moisture within the fruits, that is, moisture content increases with maturity. In the non-climateric fruits physiological changes requiring moisture tend to cease, and the fruits begin to lose moisture through transpiration and shrink in size hence, low moisture content in the transition from ripe to over ripe. Other proximate parameters; ash,

crude protein, crude fat, fibre and carbohydrate show a consistent regular pattern of peaking at the ripening stage and declining thereafter at the over-ripe stage. This variation is as a result of incomplete physiological transformations in the unripe fruits, nutrients depletion in the over ripe fruits as the fruits aged as well as inefficient nutrients remobilization. However, orange and pineapple show a characteristic marked increase in carbohydrate at the over ripe stage. This could indicate that at the post ripening stage photosynthetic processes are favoured. The general trend observed here agrees with the report of Assaf, et al. [18] and Bello, et al. [22] that once senescence has been initiated, it leads to a massive remobilization of nutrients from the senescing plant parts to the developing sinks such as seeds. In all the samples analysed, there is a steady increase in pH, indicating increase alkalinity with senescence, whereas the titrable acidity decreases. The pH of a food sample is an important indicator to assess the ability of a microorganism to grow in a specific food, hence, the steady increase at the over ripe stage of the fruits indicate the tendency of the fruits to spoilage. The decline in titrable acidity indicates decline in fruits flavour with senescence. As the fruits progress toward spoilage, their flavour decline.

3.2 Vitamin Content of the Samples

Vitamins A and C contents of the fruits are presented in Table 2. Results indicate increase in both vitamin C and beta carotene from the unripe fruits to the ripe and declining thereafter. It is implied here that physiological processes that produce these essential vitamins are favoured up to the ripening of the fruits. This is in agreement with earlier studies that β-carotene content of ripe tomatoes varied directly with the ripeness of the fruit at harvest [16]. It is significant to observe the high increase in vitamin C as the fruits transform from unripe to ripe stage. Of note is the geometric increase in vitamin C content in mango (24.48±0.91 to 51.08±1.57 mg/mL), pawpaw (29.21±2.53 to 72.86±0.85 mg/mL) and orange (24.02±1.69 to 67.37±1.69 mg/L). This rapid increase in vitamin C content and the decline thereafter could form the basis of the nutritionist's advice to consumers of fruits on nutritional and health grounds. Similarly, beta carotene of the fruits varies linearly with senescence. Mango (18.10±0.69 to 78.83±4.49 mg/100 mL) x 10^{-4}, pawpaw (21.87±0.35 to 66.09±0.21 mg/100 mL) x 10^{-4} and pineapple (12.62±0.57 to 40.30±0.03 mg/100 mL) x 10^{-4}.

Table 1. Proximate composition, pH and titrable acidity of mango, paw-paw, orange and pineapple

Fruit	Stage	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	pH	T.A. (%)	CHO (%)
Mango	Unripe	76.80 ± 0.65^c	0.88 ± 0.009^{ab}	0.51 ± 0.11^e	1.15 ± 0.07^c	0.67 ± 0.05^a	3.33 ± 0.12^a	21.54 ± 0.12^e	21.68 ± 0.95^e
	Ripe	80.21 ± 0.31^d	1.34 ± 0.19^e	0.69 ± 0.03^f	2.05 ± 0.07^g	1.17 ± 0.07^{cd}	3.76 ± 0.06^b	20.06 ± 0.62^d	15.81 ± 0.16^{cd}
	Over ripe	82.99 ± 0.60^{ef}	1.09 ± 0.15^{cd}	0.36 ± 0.07^{cd}	0.68 ± 0.04^b	1.10 ± 0.02^c	5.02 ± 0.03^e	14.22 ± 1.58^b	15.08 ± 0.30^c
Pawpaw	Unripe	84.98 ± 1.38^{fg}	0.91 ± 0.01^{abc}	0.45 ± 0.02^{de}	1.56 ± 0.05^{de}	0.66 ± 0.06^a	4.42 ± 0.13^c	38.15 ± 0.39^h	11.49 ± 0.55^b
	Ripe	86.16 ± 1.03^g	1.16 ± 0.07^{de}	1.07 ± 0.06^g	2.27 ± 0.07^h	1.69 ± 0.02^f	5.22 ± 0.15^e	34.86 ± 0.08^g	8.98 ± 0.52^a
	Over ripe	88.55 ± 0.09^h	0.93 ± .058^{abc}	0.65 ± 0.018^f	1.83 ± 0.04^f	1.52 ± 0.13^e	5.71 ± 0.04^f	27.46 ± 0.90^f	8.01 ± 0.04^a
Orange	Unripe	79.62 ± 0.98^d	1.69 ± 0.05^f	0.31 ± 0.02^c	1.49 ± 0.07^d	1.18 ± 0.05^{cd}	4.19 ± 0.13^c	34.06 ± 0.65^g	16.54 ± 0.49^d
	Ripe	84.05 ± 0.10^f	1.99 ± 0.11^g	0.31 ± 0.02^c	1.66 ± 0.007^e	1.31 ± 0.12^d	4.68 ± 0.07^d	16.79 ± 0.01^c	12.02 ± 0.052^b
	Over ripe	68.56 ± 1.29^a	1.79 ± 0.02^f	0.27 ± 0.04^{bc}	0.80 ± 0.03^b	1.29 ± 0.03^d	5.19 ± 0.13^e	10.54 ± 0.08^a	29.04 ± 0.65^h
Pineapple	Unripe	75.90 ± 0.68^c	0.78 ± 0.04^a	0.14 ± 0.004^a	0.47 ± 0.07^a	0.92 ± 0.03^b	5.12 ± 0.16^e	19.11 ± 0.44^d	22.94 ± 0.34^f
	Ripe	81.10 ± 0.95^{de}	0.99 ± 0.04^{bcd}	0.19 ± 0.03^{ab}	1.23 ± 0.11^c	1.21 ± 0.02^{cd}	5.70 ± 0.03^f	15.26 ± 0.52^b	16.82 ± 0.48^d
	Over ripe	71.42 ± 1.51^b	0.91 ± 0.02^{abc}	0.18 ± 0.04^{ab}	0.80 ± 0.03^b	1.08 ± 0.05^c	5.97 ± 0.07^g	9.31 ± 0.73^a	27.22 ± 0.76^g

T.A. = Titrable acidity, CHO = Carbohydrate. Values are % mean ± SD of triplicate determinations; values in the same column and having the same superscript letters are not statistically significantly different at 95% confidence level (P < 0.05)

Table 2. Vitamin C and beta carotene contents of unripe, ripe and over ripe mango, paw-paw, orange and pineapple

Fruits	Development	Vitamin C (mg/mL)	Beta Carotene (mg/100mL)×10^{-4}
Mango	Unripe	24.48 ± 0.91^b	18.10 ± 0.69^c
	Ripe	51.08 ± 1.57e^f	78.83 ± 4.49^h
	Over ripe	49.90 ± 0.85^e	39.31 ± 1.16^e
Pawpaw	Unripe	29.21 ± 2.53^c	21.87 ± 0.35^d
	Ripe	72.86 ± 0.85^h	66.09 ± 0.21^g
	Over ripe	43.62 ± 1.13^d	45.33 ± 0.26^f
Orange	Unripe	24.02 ± 1.69^b	11.67 ± 0.05^a
	Ripe	67.37 ± 1.69^g	15.83 ± 0.10^{bc}
	Over ripe	54.04 ± 2.5^f	15.21 ± 0.05^{bc}
Pineapple	Unripe	9.59 ± 0.54^a	12.62 ± 0.37^{ab}
	Ripe	10.97 ± 0.07^a	40.30 ± 0.03^e
	Over ripe	10.23 ± 0.85^a	14.22 ± 0.60^{ab}

Values are % mean ± SD of triplicate determinations. Values in the same column and having the same superscript letters are not statistically significantly different at 95% confidence level (P < 0.05)

Table 3. Mineral elements contents of mango, paw-paw, orange and pineapple in mg/L

Fruit	Growth stage	Macronutrients					Micronutrients			
		N	P	K	Mg	Fe	Ca	Ni	Zn	Cu
Mango	Unripe	27.42 ± 0.05^g	$3.06 \pm .07^c$	9.10 ± 0.00^a	3.25 ± 0.00^a	ND	3.25 ± 0.07^b	ND	$.09 \pm 0.00^c$	0.01 ± 0.00^a
	Ripe	43.78 ± 0.18^k	3.93 ± 0.00^e	25.30 ± 0.00^f	9.65 ± 0.00^j	0.20 ± 0.00^a	3.70 ± 0.00^e	ND	0.12 ± 0.00^d	ND
	Over ripe	$39.34 \pm 0.06i$	3.51 ± 0.01^d	19.30 ± 0.00^e	3.45 ± 0.00^b	0.10 ± 0.00^a	3.40 ± 0.00^c	ND	0.11 ± 0.00^d	0.04 ± 0.00^a
Pawpaw	Unripe	34.91 ± 0.09^h	11.60 ± 0.08^i	25.30 ± 0.00^f	3.95 ± 0.00^c	ND	3.20 ± 0.00^b	ND	0.03 ± 0.00^a	0.02 ± 0.00^a
	Ripe	45.28 ± 0.04^l	12.04 ± 0.08^j	42.30 ± 0.00^j	12.45 ± 0.00^l	0.10 ± 0.00^a	5.25 ± 0.07^j	ND	0.20 ± 0.00^h	0.04 ± 0.00^a
	Over ripe	40.29 ± 0.01^j	8.89 ± 0.02^h	26.10 ± 0.00^g	10.25 ± 0.00^k	0.10 ± 0.00^a	4.10 ± 0.00^g	ND	0.19 ± 0.00^h	ND
Orange	Unripe	22.80 ± 0.01^d	4.65 ± 0.006^f	12.30 ± 0.00^b	4.20 ± 0.07^d	ND	3.40 ± 0.00^c	ND	0.07 ± 0.00^b	0.02 ± 0.00^a
	Ripe	24.18 ± 0.04^f	5.03 ± 0.09^g	30.30 ± 0.00^h	6.45 ± 0.00^h	0.10 ± 0.00^a	3.80 ± 0.00^f	ND	0.13 ± 0.00^g	0.01 ± 0.00^a
	Over ripe	23.38 ± 0.00^e	3.53 ± 0.06^d	15.30 ± 0.00^d	5.65 ± 0.00^g	ND	$3.50 \pm 0 .00^d$	ND	0.13 ± 0.00^{fg}	ND
Pineapple	Unripe	13.99 ± 0.07^a	1.36 ± 0.02^a	13.30 ± 0.00^c	4.55 ± 0.00^f	ND	3.10 ± 0.00^a	ND	0.07 ± 0.00^b	ND
	Ripe	15.01 ± 0.03^c	1.52 ± 0.01^b	34.80 ± 0.71^f	6.55 ± 0.00^c	ND	4.40 ± 0.00^l	ND	0.12 ± 0.00^{ef}	ND
	Over ripe	14.15 ± 0.08^b	1.39 ± 0.01^a	15.30 ± 0.00^d	4.45 ± 0.00^e	ND	4.20 ± 0.00	ND	$.09 \pm 0.00^c$	ND

Values are % mean ± SD of triplicate determinations. Values in the same column and having the same superscript letters are not statistically significantly different at 95% confidence level (P < 0.05). Key: ND = Not detected

Like vitamin A, beta carotene profile indicates that senescence has a significant impact on its content. Beta carotene indicates 4-fold increase from the unripe to ripe mango, and 3-fold increase from the unripe to ripe pawpaw and pineapple fruits.

3.3 Mineral Elements Content of the Samples

Mineral elements concentrations are discussed in accordance with the classification as, macro- and micro-nutrients, with nitrogen and potassium having the highest levels among the macronutrients while nickel was not detected among the micronutrient elements studied. The macronutrients show a general increase in concentration from the unripe to ripe, and declining thereafter, Table 3, which is consistent with the proximate composition in this report. This result agrees with the report by Smith and Reuther [23] that nitrogen showed non-accumulative tendencies in the months of October and November; while other elements showed unabated accumulative tendencies. They also observed only small differences in the concentration of the mineral elements in relation to availability and uptake of N and P. It was observed that manifold increase in the rate of applied N (ammonium nitrate) stimulated yield but did not affect the amount of N in the fruits with age.

4. CONCLUSION

Information gathered from this research work indicates trend variability in the proximate composition of the fruits studied. Whereas other proximate parameters peaked at ripen stage and declined as the fruit ages, carbohydrate content shows inconsistent variation with fruit age. In general, data indicates that the proximate composition of the studied fruits is statistically significant at 95% confidence level ($p < 0.05$). The pH of the fruits varies linearly with age, while the titrable acidity declines steadily with fruit age. In conclusion, the pH and titrable acidity show inverse relationship. Senescence therefore is a significant factor in the nutritional composition of fruits in Makurdi, North Central Nigeria.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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