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Physicochemical characteristics and levels of inorganic elements in off-vine ripened pineapple (*Ananas comosus L.*) fruits of Dar es Salaam, Tanzania

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ABSTRACT

Several physicochemical characteristics (ash, acidity, crude fat, crude fibre, sugars, moisture, ascorbic acid and soluble solids) and concentration of macro elements (Ca, Mg, Na, K) and trace elements (Al, Cd, Cr, Cu, Fe, Mn, Pb, Zn) were measured in harvested mature, green pineapple (Ananas comosus L.) fruits from Mbezi, Dar es Salaam during their off vine, open air, room temperature storage-ripening period of eight days. Pineapple fruits from early, middle and late fruit-season were studied. The results showed that the Mbezi pineapple fruits had high moisture content (68 – 89%), moderate titratable acidity (0.80 – 1.50% c.a.), low crude fat content (0.12%), low crude fibre amounts (0.40%), low ash content (0.20%), high reducing sugars (14.2 – 22.8%), high total sugars (15.2 – 30.0%), high total soluble solids (15.7 – 29.3%) and high ascorbic acid content (7.9 – 33.4%). Of the four macro elements potassium was highest in concentration. The heavy metals, copper, chromium, iron, manganese and zinc were detected at very low concentrations in the fruits indicating insignificant pollution in the fruits. Ascorbic acid, moisture, titratable acidity, sugars content and total soluble solids amounts varied within the season and with the days of storage-ripening.

KEYWORDS

Pineapple
Titratable acidity
Total sugars
Crude fibre
Macro element
Heavy metals

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INTRODUCTION

Mbezi in Dar es Salaam region, Tanzania, is well known for its pineapple fruit cultivation. Green, mature pineapples once harvested are usually allowed to ripen during storage before being marketed. The pineapples fruits are normally eaten fresh or as fresh pineapple juice. Pineapple fruits are an excellent source of vitamins and minerals and supply arrays of colour, flavour and texture to the pleasure of eating. One healthy, ripe, pineapple fruit can supply about 116.2% of the daily requirement for vitamin C. Because of the importance of fruits as valuable food resources many studies are being undertaken to establish the quality, physicochemical characteristics and seasonal variation in the properties of fruits. Physicochemical properties of fruits such as mango (*Mangifera indica*), papaya (*Carica papaya*), orange (*Citrus sinensis*), pineapple (*Ananas comosus*), medlar (*Mespilus germanica*), passion (*Passiflora edulis sims*), plum (*Vitex doniana*) and golden apple (*Spondias cytherea Sonnerat*) have been reported by Othman and Mbogo (2009), Othman (2009), Mbogo, et al. (2010), Shamsudin, et al. (2007), Aydin and Kadioglu (2001), Romero-Rodriguez, et al. (1994), Egbekun, et al. (1996) and Franquin, et al. (2005) respectively.

Analysis of food and food products (Robinson, et al., 1989) has revealed the presence of heavy metal in foods that may easily be taken up by persons from their diets. Heavy metals have been found in green leafy vegetables (e.g. Bahemuka and Mubofu, 1999; Raja, et al., 1997) and in some fruits (e.g. Saka, et al., 2007; Mamiro, et al., 2007). However information appears to be rather limited on many foods especially fruits of Tanzania. This study reports on the physicochemical properties and levels of inorganic elements in fresh pineapple fruits from Mbezi area, Dar es Salaam, Tanzania.

MATERIALS AND METHODS

Fruit sample collection

Samples of pineapple fruits were collected from Mbezi farms during the fruit season. Fully matured, green pineapple fruits were picked directly in batches of five for the appropriate laboratory determinations. Fruit samples were transported to the Chemistry Department laboratory, University of Dar es Salaam, for room temperature storage ripening and for further preparations and analysis.

Analysis

The determinations of the different parameters were done immediately on arrival and at intervals of two days from the day of harvesting of the fruits. These determinations were repeated for early, middle and late season pineapple fruits until they had fully ripened.

Moisture

The moisture contents of the fruits were determined according to standard methods (method 934.06 of AOAC, 1990).

Titratable acidity

Minced fresh fruit samples (10 g) were mixed with 200 cm^3 distilled water, boiled for 1 hour, cooled and the mixture was then filtered. The filtrate (10 cm^3) was titrated with 0.1M NaOH up to pH 8.1 measured with a pH meter. The results were expressed as % citric acid (g-citric acid/100 g-fw (gram-fresh weight)) (Ranganna, 1997).

Ash

The sample (5 g) was kept in a muffle furnace and ashed at a temperature not exceeding 525 °C for 6 hours. The ash was then cooled in a desiccator and weighed. The ash content was recorded as g per 100 g-fresh weight (g/100 g-fw) (method 940.26 of AOAC, 1990).

Crude fat

The weighed dried fruit sample was put into a thimble, covered with fat free cotton and then put into the soxhlet apparatus. The flask was filled with 150 cm^3 petroleum ether and extraction was done for 16 hours or longer on a water bath. The sample was dried at 100°C in the oven for 1 hour, cooled and re-weighed. The difference in the weights gave the fat-soluble material present in the sample. The determination was done in triplicate and the average value was recorded (Ranganna, 1997).

Crude fibre

Crude fibre was determined from the residue after the crude fat determination. The procedure of Mbogo, et al. (2010) and Ranganna (1997) was followed.

Sugars and soluble solids

Total sugars, reducing sugars and total soluble solids content in the pineapple fruits were determined following the procedures of method 932.12 of AOAC (1990).

Ascorbic acid

Ascorbic acid content was obtained by using the titration method involving 2,6-dichlophenol-Indophenol, that is, method 967.21 of AOAC (1990).

Determination of metals

Sample preparation

Concentrated hydrochloric acid (10 cm3) was added to the fresh fruit juice (20 cm3) and the solution made up to a volume of 100 cm3 with distilled water. After thorough mixing the solution was then centrifuged and used for aspiration into the atomic absorption spectrophotometer (AAS). Appropriate dilution was done for elements present at high concentrations (McHard, et al., 1976).

Atomic absorption spectrophotometric determination

The above sample solution was aspirated into the instrument after all necessary set up and standardization procedures. All determinations of metals were performed on a Perkin Elmer Model AAnalyst 300 AAS (Perkin-Elmer, 1994) at the Chemistry Department, University of Dar es Salaam.

Table 1. Initial physicochemical characteristics of the pineapple (*Ananas comosus L.*) fruit from Mbezi area, Dar es Salaam (based on 100 g of fresh fruit)

Physicochemical parameter	Value
Ascorbic acid content (mg/100g-fw)	27.4
Ash (g/100 g-fw)	0.22
Crude fat (g/100g-fw)	0.13
Crude fibre (g/100g-fw)	0.41
Moisture content (%)	79.3
Reducing sugars (%)	14.2
Titratable acidity (%)	1.50
Total soluble solids (%)	15.7
Total sugars (%)	15.2

RESULTS AND DISCUSSION

The initial physicochemical characteristics for the pineapple (*Ananas comosus L.*) fruits of Mbezi, Dar es Salaam are summarized in Table 1. These are the measured characteristics of the first fruits collected for the study that is early season mature fruits.

The average ascorbic acid content of 27.4 mg/100 g-fresh-fruit measured in the harvested Mbezi pineapples (Table 1) is comparable to values of 27.0-165.2 mg/100 g-fw reported for pineapples from Central America by Mortin (1987). Achinewhu and Hart (1994) have reported ascorbic acid values of 22.5-33.5 mg/100 g-fw for pineapples from Nigeria. The average ash content of the Mbezi pineapples was 0.22 g/100 g-fw (Table 1). Mortin (1987) reported comparable ash values of 0.21-0.49 mg/100 g-fw in pineapples from Central America. Asare-Bediako, et al. (2007) reported a higher ash content of 0.5 mg/100 g-fw for pineapples from Ghana. The measured crude fat value for Mbezi pineapples (0.13 g/100 g-fw) was lower than the crude fat content of 0.4 mg/100 g-fw reported for pineapples from Ghana by Asare-Bediako, et al. (2007). The average crude fibre content of 0.41 g/100 g-fw (Table 1) for Mbezi pineapples was similar to that measured in Nigerian pineapples i.e. 0.39 g/100 g-fw (Achinewhu and Hart, 1994). Pineapples from Ghana have been reported with a crude fibre content of 1.2 g/100 g-fw by Asare-Bediako, et al. (2007).

The moisture content (79.3%) of pineapple fruits from Mbezi, Dar es Salaam, (Table 1), was comparable to that reported for Guatemala pineapples (Mortin, 1987) and Josapine pineapples of Malaysia (Shamsudin, et al., 2007). The reducing sugars content in Mbezi pineapples was 14.2% similar to that reported for Nigerian sweet Cayenne pineapples (13.8%) by Achinewhu and Hart (1994) but was higher than the value of 2.9% reported for pineapples from Ghana by Asare-Bediako, et al. (2007).

The titratable acidity value of 1.50% (Table 1) for the Mbezi pineapple fruits was higher than that reported for Mauritius pineapples (0.7%)

and Kew pineapples (0.6%) by Weerahewa and Adikaram (2005) and Smooth Cayenne pineapples (0.51%) by Antunes, et al. (2008).

The Total Soluble Solids (TSS) value of 15.7% (Table 1) was similar to the TSS value of 15.2% reported for Mauritius pineapples by Weerahewa and Adikaram (2005). Malaysian Josapine pineapples had a TSS content of 12.8% (Shamsudin, et al., 2007) and Brazilian Cayenne pineapples had a TSS value of 13.5% (Antunes, et al., 2008). The total sugars content of Mbezi pineapples was 15.2% (Table 1) while the Malaysian Josapine pineapples were reported with 13.6% (Shamsudin, et al., 2007). Antunes, et al. (2008) reported that the Cayenne pineapples of Brazil had a total sugars content of 13.2% and the Pearl pineapples also of Brazil had a total sugars value of 14.5%.

Moisture content (Mo)

The percent moisture content varied significantly with time of season and during the ripening period. The pineapple fruits of Tanzania had moisture content higher than 69.2% throughout the season, the highest being 89.2% in late season fruits (Table 2). Late season fruits had the highest moisture content while early season fruits had the lowest content. Moisture content decreased during the room temperature storage ripening period. The decrease is due to the evaporation of moisture from the surface of the fruit during the storage ripening period (Inyang and Agbo, 1995). The juiciest pineapple fruits, the late season ripened fruits of 2 to 4 days storage, were ideal for fresh fruit consumption. High moisture content pineapples have also been reported for Nigerian pineapples (Fasoyiro, et al., 2005) and Indian pineapples (Ramulu and Rao, 2003). The high moisture contents suggests a low energy value for the fruits thus suggesting usefulness in the treatment of obesity as observed by Muller and Tobin (1980). The moisture in fruits gives them a natural laxative property which is also important for human body nutrition.

Titratable acidity (TA) in pineapple

The titratable acidity for the pineapple fruits ranged from 0.80 to 1.50% c.a. (Table 2). The TA values were lower than the TA amounts reported for Nigerian pineapples by Fasoyiro, et al., (2005). During the storage-ripening period a noticeable decrease in titratable acidity of pineapples was observed similar to that reported by Dhar, et al., (2008) for Indian pineapples. The acidity in (early season) pineapples decreased from 1.50% c.a. to 0.95% c.a. during eight days of storage-ripening and decreased from 1.50% c.a. (early season fruit) to 1.20% c.a. (late season fruit) during the season. In citrus fruits, the predominant acid is citric acid (Echeverria and Ismail, 1987). The loss in the dominant citric acid might be the cause for the decrease in acidity during the ripening of pineapples as a direct relationship exists between the acidity of citrus fruit juices and the concentration of combined citric and malic acids (Yamaki, 1989). The reduction of titratable acidity might also be due to the utilization of these constituent acids in the fruit respiratory process (Nagar, 1994).

Table 2 Percent moisture content and percent titratable acidity values (% c.a.) during storage ripening for Mbezi pineapple fruits

Days	Percent Titratable Acidity (% c.a.)			Percent Moisture content		
	SEASONS			SEASONS		
	Early	Middle	Late	Early	Middle	Late
0	1.50 ± 0.13	1.40 ± 0.25	1.20 ± 0.19	79.3 ± 3.4	84.7 ± 1.9	86.4 ± 3.6
2	1.45 ± 0.06	1.35 ± 0.06	1.20 ± 0.25	81.5 ± 2.2	86.0 ± 1.8	88.3 ± 3.3
4	1.30 ± 0.13	1.20 ± 0.12	1.00 ± 0.13	76.2 ± 2.7	87.1 ± 2.7	89.2 ± 2.1
6	1.10 ± 0.19	0.95 ± 0.06	0.90 ± 0.22	73.1 ± 1.3	84.5 ± 3.5	87.2 ± 1.7
8	0.95 ± 0.06	0.90 ± 0.13	0.80 ± 0.06	69.3 ± 2.4	82.8 ± 1.4	85.7 ± 2.5

All data are the mean of measurements for three samples ± average deviation

Ascorbic acid (AA) content

The ascorbic acid content of freshly harvested fruits was 27.4 mg/100 g in early season fruits and 33.4 mg/100 g in late season fruits (Table 3). Fasoyiro, et al. (2005) reported a high AA content of 41.82 g/100 g for Nigerian pineapples. Late season pineapple fruits had highest content of AA whereas middle-season fruits had the lowest values during the season. The AA content in the fruits decreased significantly during the storage-ripening period similar to observations on Indian pineapple fruits (Dhar, et al., 2008). The usual adult dose of AA as dietary supplement is between 30 – 200 mg/day. Thus only 200 g of Mbezi fresh pineapples can be an adequate adult daily dietary supplement dose of AA. Mbezi fresh pineapples can be considered as a good source of AA for purposes of human nutrition.

Total soluble solids (TSS)

The soluble solids content of the Mbezi pineapple fruits increased during the ripening process (Table 3) similar to observations by Dhar, et al. (2008) and Botrel, et al. (1993). The pineapple fruit also exhibited a seasonal variation in TSS content. Higher TSS amounts were observed in late season fruits while the lowest TSS amounts were in early season fruits. Fasoyiro, et al. (2005) reported a low soluble solids content of 8.72 °Brix (~8.70 %w/w) for Nigerian pineapples. High TSS content is a desirable fruit characteristic for processed fruit (Ercisli, 2007) so Mbezi pineapples are suitable for such processing.

Sugars content

The reducing sugars (RS) and total sugars (TS) content of the pineapple fruits increased during the eight days ripening period and also during the season. The highest RS and TS content were found in late season pineapple fruits and the lowest contents in early season fruits (Table 4). Such increase has been attributed to a concurrent increase in the sucrose contents which is then hydrolysed to simple sugars (Echeverria and Ismail, 1987). Increase in the concentration of juices as a result of dehydration might be another factor (Nagar, 1994). These results are

Table 3 Ascorbic acid and total soluble solids content of Mbezi pineapple fruits during storage ripening

	Ascorbic Acid (AA) content (mg/100 g-fw ± 2.9 [pooled Std. Dev.])			**Total Soluble Solids (TSS)** (% solids ± 1.4 [pooled Std. Dev.])		
Storage days	SEASONS			SEASONS		
	Early	Middle	Late	Early	Middle	Late
0	27.4	19.4	33.4	15.7	17.8	19.3
2	25.3	14.4	31.2	18.5	19.6	20.7
4	21.8	10.7	24.9	20.4	21.0	23.4
6	16.8	8.6	21.3	22.1	23.5	26.5
8	12.5	7.9	18.5	24.5	26.3	29.3

Each data is the mean of measurements for three samples

Table 4 Reducing sugars and total sugars content of Mbezi pineapple fruits of Dar es Salaam, Tanzania

	Reducing Sugars content (% sugar ± 1.1 [pooled Std. Dev.])			**Total Sugars content** (% sugar ± 1.8 [pooled Std. Dev.])		
Storage days	SEASONS			SEASONS		
	Early	Middle	Late	Early	Middle	Late
0	14.2	16.5	17.4	15.2	18.5	20.7
2	15.7	17.5	18.1	18.7	20.8	22.2
4	17.1	18.4	19.3	21.6	23.1	24.8
6	17.9	19.8	21.3	24.5	25.7	27.6
8	19.3	21.7	22.8	27.0	28.5	30.0

Each data is the mean of measurements for three samples

similar to observations on Indian pineapple fruits by Dhar, et al. (2008) and Mauritius pineapples (Wijesinghe and Sarananda, 2002).

Ash

The average ash content of the pineapple fruits during the season was 0.20 ± 0.01 g/100 g-fw (Table 5), which was lower than that reported for Nigerian pineapple fruits by Fasoyiro, et al. (2005). The ash content of the Mbezi pineapple fruits is not high implying low quantities of inorganic compounds in the fruits. Thus, to get higher quantities of such compounds in the body, repeated intake of the fruits is recommendable. No significant variation in ash content was observed for early, middle and late season pineapple fruits.

Crude fat (CFa)

The average crude fat content in the pineapple fruits was 0.12 ± 0.01 g/100 g-fw (Table 5). Fasoyiro, et al. (2005) reported a high CFa content of 1.18 g/100 g-fw for Nigerian pineapples. Low values of fat contents imply that the Mbezi pineapple fruits are not good sources of fat and hence, for proper body nutrition, there is a necessity for supplementing these fruits with other sources of fat.

Crude fibre (CFi)

Pineapples had average crude fibre content of 0.40 ± 0.03 g/100 g-fw (Table 5). Fasoyiro, et al. (2005) reported a CFi content of 0.94 g/100 g-fw for Nigerian pineapples and Ramulu and Rao (2003) reported CFi content of 0.5 g/100 g-fw for Indian pineapples. Fibre helps to maintain the health of the gastrointestinal tract, but in excess it may bind trace elements, leading to deficiencies of iron and zinc in the body (Siddhuraju, et al., 1996).

Macro element contents

The content of mineral elements and other metals in the fruits are summarized in Table 5. Potassium was the predominant element of the mineral elements in the pineapple fruits. The average amount of potassium in the fruits was 411.25 mg/100 g-fw-pineapple. The potassium content of the pineapple fruits measured was higher than the potassium contents for East Africa fruits reported by West, et al. (1988) i.e. 150.0 – 280.0 mg/100 g-fw.

The average magnesium content in the pineapple fruits was 92.75 ± 2.36 mg/100g-fw (Table 5). This level in magnesium was much higher than the range (6 – 14 mg/100 g-fw) reported by Hunt, et al. (1991) for Galician fruits.

The average calcium levels observed in the pineapples was 37.34 mg/100g fw (Table 5). This value was higher than that reported by West, et al. (1988) (16.0 – 28.0 mg/100 g-fw) for fruits in East Africa but was lower than that reported for Nigerian pineapples by Fasoyiro, et al. (2005).

Among the four mineral elements studied sodium showed the lowest content of 4.24 mg/100 g-fw in the fruits. The sodium content of fruits herein reported was comparable to the sodium content (2.0 – 4.0 mg/100 g-fw) reported for fruits of East Africa by West, et al. (1988) but was low when compared to reports on the sodium content (0.82 g/100g) in Nigerian pineapple fruits (Fasoyiro, et al., 2005).

Heavy metal contents

The heavy metals levels measured in the pineapples are summarized in Table 5. The pineapples had a manganese content of 5.70 mg/100 g-fw, a level much higher than the values (0.02 – 0.39 mg/100 g-fw) reported for fruits by

Table 5 Ash, crude fat, crude fibre and metal element contents in Mbezi pineapple (*Ananas comosus L.*) fruits from Dar es Salaam, Tanzania

Average fruit attributes (g/100 g-fw)	
Ash	0.20 ± 0.01
Crude fat	0.12 ± 0.01
Crude fibre	0.40 ± 0.03

Mineral elements content (mg/100 g-fw)	
Calcium	37.34 ± 1.56
Magnesium	92.75 ± 2.36
Sodium	4.24 ± 0.40

Heavy metals content (mg/100 g-fw)	
Chromium	0.036 ± 0.005
Copper	0.23 ± 0.03
Iron	3.12 ± 0.01
Manganese	5.70 ± 0.89
Zinc	0.32 ± 0.04
Aluminium	BD
Cadmium	BD
Lead	BD

Ellen, et al. (1990) and values (0.08 – 0.2 mg/100 g-fw) reported for Galician fruits by Romero-Rodriguez, et al. (1994) The observed levels in Tanzania pineapples were equivalent to the Recommended Daily Intake (RDI) of manganese of 2-5 mg per day (Ellen, et al., 1990) indicating that 100 grams of Mbezi pineapple juice was sufficient to provide the RDI of manganes

The average amount of copper in the pineapple fruits was 0.23 mg/100 g-fw, a level much below the Recommended Dietary Intake (RDI) of 2 mg per day. The copper content was similar to levels reported for Galician passion fruits by Romero-Rodriguez, et al. (1994) and for some Netherlands fruits by Ellen, et al. (1990). To obtain the RDI for copper from Mbezi pineapple juice would therefore require eating up to 1 kg of the fruit.

The average amount of iron in the Tanzania pineapples was 3.12 mg/100 g-fw. The iron content was similar to the level found in Nigerian pineapples by Abulude, et al. (2007). The iron level was higher than the iron level (0.07 – 0.37 mg/100 g-fw) reported by Hunt, et al. (1991) and the level (0.3 – 0.6 mg/100 g-fw) reported by Romero-Rodriguez, et al. (1994) for Galician fruits.

The zinc level in the Tanzania pineapple fruits was 0.32 mg/100 g-fw which was much lower than the level found in Nigerian pineapples by Abulude, et al. (2007). The Tanzania pineapples had zinc content well below the RDI of zinc in foods i.e. 15 mg per day. However the levels of zinc in the Tanzania pineapples were generally higher than those reported by Hunt, et al. (1991) i.e. 0.002 – 0.06 mg/100 g-fw and were within the range, 0.035 – 0.41 mg/100 g-fw, reported by Ellen, et al. (1990) for some fruits of Netherlands. We can conclude that the RDI for Zn cannot be achieved by eating only pineapples as this would require eating more the 4 kilograms of the fresh fruit.

The Mbezi pineapples had an average concentration of 0.036 mg/100 g-fw of chromium (Table 5). Aluminium, cadmium and lead were not detected in the pineapple fruits. Ellen, et al. (1990) has reported lead and cadmium contents of 10 – 29 µg and 2 – 9 µg per kg-fruit respectively for some fruits from the Netherlands while Abulude, et al. (2007) has reported lead and arsenic contents of 1.7 mg and 20.0 mg per litre respectively for pineapple juice of Nigeria. We clearly note that the Mbezi pineapples did not have significant levels of trace elements and were therefore relatively free of heavy metal pollution.

CONCLUSION

Before storage the pineapple fruits exhibit moderate acidity, high moisture, high sugars and soluble solids content and low crude fibre and fat. With storage as the pineapple ripened the moisture content decreases, the titrable acidity decreases, the ascorbic acid content, reducing sugars and soluble solids levels all increase. The K and Ca contents are also high while the heavy metal content is very low. Since the 500 grams of fresh Mbezi pineapple fruits can supply up to 150 mg of ascorbic acid to the consumer, such fruits can be used as supplements for good personal health.

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REFERENCES

Abulude, F.O., Oyenene, O.O., Elemide, A., Okunola, O.O. and Alaja, B.F. (2007) Physico-chemical properties, metal contents and organoleptic characteristics of juice samples, J. Food Technology, 5 (1), pp. 1–4.

Achinewhu, S.C. and Hart, A.D. (1994) Effect of processing and storage on the ascorbic acid (vitamin C) content of some pineapple varieties grown in the Rivers State of Nigeria, Plant Foods For Human Nutrition (Formerly Qualitas Plantarum) 46(4), 335–337.

Antunes A.M., Ono E.O., Sampaio A.C. and Rodrigues J.D. (2008) Physico-chemical and harvest time alterations in pineapple fruits 'smooth cayenne' caused by paclobutrazol, Braz. arch. biol. technol. 51(1), 19–26.

AOAC Association of Official Analytical Chemists (1990) Official Methods of Analysis of the Association of Official Analytical Chemists. 15th ed., Arlington, VA.

Asare-Bediako, E., Showemimom, F.A., Buah, J.N. and Ntow-Manu, A.O. (2007) Quality of pineapple fruits as influenced by floral induction in Ghana, American Journal of Food Technology, 2, 100–103.

Aydin, N. and Kadioglu, A. (2001) Changes in the chemical composition, polyphenol oxidase and peroxidase activities during development and

ripening of medlar fruits (Mespilus germanica L.) Bulg. J. Plant Physiol., 27 (3-4), pp. 85–92.
Bahemuka, T.E. and Mubofu, E.B. (1999) Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi rivers in Dar es Salaam, Tanzania, Food Chemistry, 66 (1), pp. 63–66.
Botrel, N., de-Carvalho V.D. and de-Capriade V.D. (1993) Effect of fruit Weight on internal browning and quality in pineapple Smooth Cayenne. III. Internal browning, total soluble solids, total titratable acidity, pH and sugars. Pesquisa Agropequaria Brasiliera, 28 (9), pp. 1055–1064 [Cited from Postharvest News and Information (1995), 9 (2), pp. 329]
Dhar, M., Rahman, S.M. and Sayem, S.M. (2008) Maturity and post harvest study of pineapple with quality and shelf life under red soil. Int. J. Sustain. Crop Prod. 3 (2), pp. 69–75.
Echeverria, E. and Ismail, M. (1987) Changes in sugars and acids of citrus fruits during storage. Proc. Fla. State Hort. Soc., 100, pp. 50–52.
Egbekun, M.K., Akowe, J.I. and Ede, R.J. (1996) Physicochemical and sensory properties of formulated syrup from lack plum (*Vitex doniana*) fruit, Plant Foods Hum Nutr. 49 (4), pp. 301–306.
Ellen, G., Van Loon, J.W. and Tolsma, K. (1990) Heavy metals in vegetables grown in Netherlands and in domestic and imported fruits, Z. Lebensm Unters Forsch., 190, pp. 34–39.
Ercisli S. (2007) Chemical composition of fruits in some rose (Rosa spp.) species, Food Chem. 104, pp.1379 – 1384.
Fasoyiro, S.B., Babalola, S.O. and Owosibo, T. (2005) Chemical composition and sensory quality of fruit-flavoured roselle (*Hibiscus sabdariffa*) drinks, World Journal of Agricultural Sciences 1 (2), pp. 161–164.
Franquin, S., Marcelin, O., Aurore, G., Reynes, M. and Brillouet, J.M. (2005) Physicochemical characterisation of the mature-green Golden apple (Spondias cytherea Sonnerat). Fruits 60 (3), pp. 203–210.
Hunt, C.D., Shuller, T.R. and Mullen, M.L. (1991) Concentration of boron and other elements in human foods and personal-care products. J. Am. Diet. Assoc., 91, pp. 558–568.
Inyang, U.E. and Agbo, A.U. (1995) Effect of hot ash treatment of mango fruits on the physicochemical changes during ripening. Trop. Sci. 35, pp. 259–262.
McHard, J.A., Winefordner, J.D. and Attaway, J.A. (1976) A new hydrolysis procedure for preparation of orange juice for trace element analysis by Atomic Absorption Spectroscopy. J. Agric. Food Chem., 24, pp. 41.
Mamiro, P., Fweja, L., Chove, B., Kinabo, J., George, V. and Mtebe, K. (2007) Physical and chemical characteristics of off vine ripened mango (Mangifera indica L.) fruit (Dodo). Afri. J. Biotech. 6 (21), pp. 2477–2483.
Mbogo G.P., Mubofu E.B. and Othman O.C. (2010) "Post harvest changes in physical chemical properties and levels of some inorganic elements in off vine ripened oranges (Citrus sinensis) fruits cv Navel and Valencia of Tanzania" Afr. J. Biotechnol. 9(12): 1809–1815.
Morton, J. (1987) Pineapple. In: Fruits of warm climates, p. 18–28, Julia F. Morton, Miami, FL., USA.
Muller, H.G. and Tobin, G. (1980) Nutritional and food processing, 5th edition, Croom Helm applied biology series, 302 pages, Croom Helm, London.
Nagar, P.K. (1994) Effect of some ripening retardants on fruit softening enzymes of Kinnow mandarin fruits, Indian Journal of Plant Physiology, 37, pp. 122.
Othman O.C. (2009) "Physical and chemical composition of off vine, storage ripened papaya (Carica papaya L.) fruit of eastern Tanzania" Tanz. J. Sci. 35: 47–56.
Othman O.C. and Mbogo G.P. (2009) "Physico-chemical characteristics of off vine, storage-ripened mango (Mangifera indica L.) fruits, Dodo and Viringe varieties, of eastern Tanzania" Tanz. J. Sci. 35: 57–66.
Perkin-Elmer, (1994) Analytical Methods for Atomic Absorption Spectrophotometry, Perkin-Elmer Corporation, Norwalk.
Raja, T.K., Othman, O.C. and Bahemuka, T.E. (1997) Levels of crude protein and some inorganic elements in selected green vegetables of Dar es Salaam, J. Food Sci. Technol. 34: pp. 419–422.
Ramulu, P. and Rao, P.U. (2003) Total, insoluble and soluble dietary fiber contents of Indian fruits, J. Food Comp. Anal. 16, pp. 677–685.
Ranganna, S. (1997) Manual of Analysis of Fruit and Vegetable Products, MacGraw Hill Company Ltd, New Delhi.
Robinson, A.R., Maclean, K. and MacConnell, H.M. (1989) Sugars and sugar products: Heavy metal, pH, and total solid content of maple sap and syrup produced in Eastern Canada. J. Assoc. Off. Anal. Chem., 72 (4), pp. 674–676.
Romero-Rodriguez, M.A., Vazquez-Oderiz, M.L., Lopez-Hernandez, J. and Simal-Lozano, J. (1994) Composition of babaco, feijoa, passion fruit and tamarillo produced in Galicia (north-west Spain), Food Chem., 49, pp. 23–27.
Saka, J., Rapp, I., Akinnifesi, F., Ndolo, V. and Mhango, J., (2007) Physicochemical and organoleptic characteristics of *Uapaca kirkiana*, *Strychnos cocculoides, Adansonia digitata* and *Mangifera indica* fruit products, Int. J. Food Sci. Techno., 42, pp. 836–841.
Shamsudin, R., Daud, W.R.W., Takriff, M.S., and Hassan, O. (2007) Physicochemical properties of the josapine variety of pineapple fruit, International Journal of Food Engineering: Vol. 3 (5): Article 9.
Siddhuraju, P., Vijayakumari, K. and Janardhanan, K. (1996) Chemical composition and nutritional evaluation of an underexploited legume, *Acacia nilotica* (L.) Del. Food Chem., 57 (3), pp. 385–391.
Weerahewa, D. and Adikaram, N.K.B. (2005) Some biochemical factors underlying the differential susceptibility of two pineapple cultivars to internal browning disorder Cey. J. Sci. (Bio.Sci.) 34, 7–20.
West, C.E., Pepping, F. and Temalilwa, C.R. (1988) The composition of foods commonly eaten in East Africa. Wageningen Agricultural University, Wageningen, Netherlands.
Wijesinghe, W.A.J.P. and Sarananda, K.H. (2002) Post harvest quality of 'Mauritius' pineapples and reasons for reduced quality Tropical agricultural research and extension 5 (1&2), pp. 53–56.
Yamaki, Y.T. (1989). Organic acids in the juice of citrus fruits. J. Japanese Soc. Hortic. Sci. 58, pp. 587–594.