

Full Length Research Paper

Proximate, chemical compositions and sulphur concentrations on quality of selected dried mango (*Mangifera indica* L.)

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Preference for dried mango is on the increase as it provides a good source of nutrients, whilst evading consumption of fatty in some post-harvest processed fruits. However, data on proximate and chemical compositions of dried mango fruits is lacking. Hence this research was intended to determine effects of sulphur concentration (0, 10, 20, 50, 100, 150, 200, 250 and 300 ppm) on the nutritional value and the proximate composition of six selected mango cultivars (Tommy Atkins, Peach, Saber, Sunshine, Keitt and Vhavenda) grown in South Africa. The study shows that increasing sulphur concentration had a quadratic effect on mango pulp proximate concentration and chemical composition, reaching a maximum at 50 ppm regardless of cultivar. Significant differences ($p < 0.01$) in nutrient content were found in the mango cultivars. Keitt had significantly more protein than other cultivars, whilst Vhavenda had more fibre contents. Significant differences ($p < 0.01$) in secondary metabolites were also found in the mango cultivars with Saber having significantly more polyphenols (0.4 mg of Gallic acid/100 mg) and antioxidants (65.4 $\mu\text{mol/g}$).

Key words: Mango cultivars, nutritional value, proximate composition, sulphur.

INTRODUCTION

Fruit drying industry is becoming a thriving business in South Africa, presumably due to poor quality of subtropical fruits, smaller fruited size as well as poor colour development. Changes in health style or consumers behaviors are also contributing factors where consumers do not like fatty foods in exchange of preference dried fruits. This has influenced a major boost in fruit drying business which is being considered to have good return in investment in the industry. Mango is an important fruit, a good source of nutrients, particularly vitamin A and C and dietary fibre (Tiwari et al., 2013; Fowomola, 2010; Pal, 1998). The importance of optimal intakes of essential

mineral elements to maintain peak health is widely recognized. According to Rathore et al. (2007) mango plays an important role in balancing the diet of human being by providing 64-86 calories of energy.

Generally, tropical fruits are low to moderate in energy and macronutrient content, but can be rich in micronutrients. The proximate composition of any food will include its content of protein, carbohydrates, fat and oil, moisture and dietary fibre (Onimawo and Egbekun, 1998; Ihekoronye and Ngoddy, 1985).

The moisture, minerals and most vitamin contents increase with fruit maturity. Through processing such as

canning and drying, the vitamins are partially destroyed (Kendall and Sofos, 2012). It was reported that dried fruits have high energy values ranging from 1100 to 1450 kJ, due to concentrations of sugar. Proteins and fats contents of tropical fruits are very low; mostly less than 1 g. Gopalan et al. (2000), showed that nutritional value of foods is placed on the protein content and protein energy of the food. Although mango fruits are low in phosphorus, calcium and iron, they are also rich in vitamin A and C, as well as carbohydrates. Fruits of all varieties of mangoes are source of vitamin A than oranges and fair source of vitamin B (Panharwar, 2005). Different varieties vary greatly in vitamin C content (Fowomola, 2010).

Changes in carbohydrate contents are prominent chemical transformation occurring during the ripening of climacteric fruits such as mango with a decrease in starch and an increase in sugar content occurring during ripening of most fruits (Doreyappy-Gowda and Huddar, 2001). Mangoes have relatively high starch content at an unripe stage which is almost hydrolyzed during ripening to sugars such as fructose, glucose and sucrose (Kudachikar et al., 2001).

Depending on the cultivar (Othman and Mbogo, 2009; Mercandate and Rodriguez-Amaya, 1998), cultivation practice (Hofman et al., 1995), climatic conditions (Léchaudel and Joas, 2006), ripeness at harvest (Lalel et al., 2003; Jacobi et al., 1995), and postharvest storage and treatment of the fruit (Nunes et al., 2007; Hofman et al., 1997), the proximate composition of mango flesh varies considerably. The nature variability of the nutrient content and of fruits can be due to edaphic factors, climatic conditions, state of maturity, cultivar differences and fruit positioning.

However, data that describe the nutritional efficacy and proximate analysis among the provenances of mango as well as chemical compositions of mangoes is lacking. The standard industry norm is to dip mango slices to sulphur concentrations (Verma and Joshi, 2000). This generally causes bitter taste as well as non-appealing colours (Padda et al., 2011) which deter consumers from buying dried mangoes in retail stores or supermarkets. Therefore, the objective of this study was to check the nutritional value and proximate composition on selected mango cultivars as a function of different concentrations of sulphur to meet the demands of the consumer market, such as taste and colour on dried mango fruits.

MATERIALS AND METHODS

Location

The ripe fruits samples of six mango cultivars, namely Tommy Atkins, Peach, Saber, Sunshine, Keitt and Vhavenda were collected from a commercial orchard in Hoedspruit, Limpopo Province. The standard agronomical practices of mangoes were employed based on Sutrops industry norms. Vhavenda cultivar was collected from another commercial orchard in Vhembe District (23 °N 50' E, 30 °S 17' E); alt 610 m; subtropical-type climate (that is summer rainfall and cold, dry winter) of Limpopo Province, South Africa. This culti-

var is usually not grafted from any rootstock and there is a serious loss due sudden decay during ripening however standard agronomic practices employed were the same as for other cultivars.

Plant materials

Fresh, healthy and disease free fruits of the six mango cultivars were washed and manually peeled, seed was removed and pulp sliced using a stainless steel knife. The thickness of the mango slices was 5 to 10 mm. Slices were soaked in a sodium metabisulfite solution (BASF chemical company, Germany). Nine different concentrations of SO₂ (in 3 L of water) were used. Treatment concentrations were 0, 10, 20, 50, 100, 150, 200, 250 and 300 ppm, respectively. Mango slices were soaked for 5 min in the solution, and then dried in a hot air oven at 58°C for 28 h. Dried fruit samples were stored at -30°C until their analysis. Mango peels were immediately dried like the slices without being immersed in the SO₂ solution.

Solvents and reagents

All the chemicals used in this study were of analytical grade, and water used here refers to distilled water. Nitric acid (HNO₃) was from Riedel-de-Haen (Seelze, Germany) and hydrogen peroxide (H₂O₂) from Mallinckrodt Baker B.V. (Deventer, Holland). Hydrochloric acid (HCL) and LaCl₃ were obtained from Fluka Chemie AG (Buchs, Switzerland). Petroleum ether (B.P 40-60°C), sodium hydroxide, boric acid and sulphuric acid were from Merck (Darmstadt, Germany). Acetone was purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Copper sulphate catalyst, potassium hydroxide and iso-octanol was obtained from the Promark chemicals (Robertsham, South Africa). The 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), Sodium carbonate, Gallic acid monohydrate puriss, and Methanol, were all purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Folin-Ciocalteu phenol reagent was from Merck, Darmstadt, Germany; Potassium persulphate and Sodium chloride from Brummeria, Pretoria, South Africa; Sodium di-hydrogen (Monobasic) and di-Sodium hydrogen (Dibasic) were from Promark chemicals, Robertsham, South Africa) and Sodium metabisulfite (SO₂) was from BASF chemical company Germany).

Sample preparations (extraction)

Flesh samples

For the analysis, 10 g dried fruit samples were weighed and transferred to a warring commercial blender (Instrulab, Johannesburg, South Africa) containing 100 ml of methanol, and then blended at a high speed for 2 min (stopping occasionally to avoid accumulation of fumes). The mixture was removed and let to stand in the beaker to achieve separation. After 6 to 8 min, the supernatant was collected, centrifuged at 12 000 x g for 10 min and stored. The residues were blended again with 50 ml methanol, supernatant collected as above, combined with the first one, filtered with MN-615 (240 mm) filter papers (Bethlehem, USA) and stored at -4°C until analysis.

Proximate composition analysis

Moisture content

The moisture content of the mango fruit samples was determined using the Infrared (IR-30) moisture analyser method as described in AOAC (1998). IR drying involves penetration of heat in to the sam-

ple being dried, as compared to heat conduction and convection with convectional ovens. Dried mango samples were finally ground using a mortar and pestle to pass through a 1-mm screen and transferred into the disposable sample dish which was placed on the dish retainer of the IR-30. IR drying ovens are equipped with forced ventilation to remove moisture, and analytical balance to read the moisture content directly. During the operation, the instrument was automatically weighing and calculating the percentage moisture.

Ash content

The ash content was determined by drying of the fruit samples in a hot air oven at 58°C for 28 h. 5 g of dry mango samples were ground using a mortar and pestle to pass through a 1-mm screen and transferred into the porcelain crucibles and spread as a thin layer. The porcelain crucibles containing dry fruit sample were placed in a muffle furnace at a temperature of 550°C overnight until the fruit sample was completely ashed.

Fat content

The fat of the sample was determined according to AOAC (1998) methods by solvent extraction using the Soxtec system. 5 g of the sample was accurately weighed into the fat-free cellulose thimbles, and they were placed beneath the Soxtec condensers using the thimble support clamps. 50 ml of petroleum ether (B.P 40 to 60°C) was refluxed over the sample for 30 min after which it was drained and removed by evaporation, and then samples were rinsed for 10 min. The residual mass in the aluminium reflux cups was designated crude fat.

Fibre content

Determination of fibre was done using the Fibretec semi-automated system. Dry samples were milled using laboratory mill to pass through a 1-mm screen, and then 2 g was weighed into the crucible. Sulphuric acid was pre-heated to approximately 95°C, and then 150 ml of it was poured into the reflux columns and few drops of iso-octanol (anti-foaming agent) were added using a dropper. Samples were boiled for 30 min and rinsed 3 times with hot water and filtered. Pre-heated potassium hydroxide (150 ml) was poured together with few drops of iso-octanol into the reflux columns, and then samples were rinsed again for 30 min and filtered. Subsequently, 25 ml of acetone was used to rinse the samples. Crucibles were cooled in desiccators and accurately weighed such that loss in weight represented the crude fibre amount (Ranganna, 1977).

Protein content

The protein content was determined by using the Kjeldhal method of nitrogen determination. In this method, a kjeltec semi-automated system was used. 1 g of the sample was weighed and transferred to digestion tubes. 7 g of copper sulphate catalyst and 12 ml nitrogen-free Sulphuric acid were added to the samples in the digestion tubes and swirled. 5 ml of H₂O₂ was carefully added and the tubes were placed on heating mantle, with digester temperature of 420°C. Samples were digested until they turned to clear green or colourless, and then allowed to cool and then 75 ml of water was added.

In a receiving flask, 25 ml of 4% boric acid was added thereafter both the receiving flask and digestion tubes were placed in a distillation unit. Subsequently, 50 ml of sodium hydroxide was dispensed into the digestion tubes, distillation was initiated and 100 ml of distillate was collected in the receiving flask. Colour changed from pink to green in samples which had nitrogen. The contents of the receiving flask were titrated against the standard acid (0.1 M HCL) and titre obtained was recorded when a neutral grey colour was reached. The carbohydrate content of the samples was deter-

mined by the colorimetry method as reported by James (1995).

Quantitative determination of vitamins

Vitamin C was determined by titration against 2, 6-dichlorophenol indophenols dye following AOAC method 967.21 (AOAC, 1998). The ascorbic acid of the samples was extracted by grinding with small amount sand and 6% metaphosphoric acid (v/v). The extract was centrifuged at 3000 x g for 15 min at room temperature (24°C). 5 ml of the supernatant was titrated against a 0.02% standard solution of ascorbic acid in 6% of metaphosphoric acid.

Total phenolic determination in the plant extracts

Total polyphenol content (TPC) for both mango flesh and peel samples, was determined using Waterman and Mole method (1994). In this method, 50 ml volumetric flasks were used, each containing 10 ml of water. To this, 10 ml of water, and 0.5 ml of the sample extracts was added; 2.5 ml of the Folin-Ciocalteu's reagent was added. Within 2 to 8 min, 7.5 ml of sodium carbonate was added and the flasks were filled with water to the mark. The flasks were swirled and allowed to stand for 2 h in the dark. The absorbance was measured at 760 nm using Genesis 20 Spectrophotometer (Thermo Electron Corporation, Madison, USA). Data were calculated using a pre-prepared Gallic acid calibration curve. A stock solution was prepared by dissolving 0.1 g Gallic acid in 100 ml methanol. Results were expressed as milligrams of Gallic acid per 100 ml of sample extracts.

ABTS free radical scavenging activities

The ABTS assay was used to measure the total antioxidant activity (TAC) of the mango extracts. 8 mM ABTS and 3 mM potassium persulfate (K₂S₂O₈) were dissolved in 25 ml distilled water each, and then the equal volumes of the two were mixed. The reaction mixture was left to stand at room temperature overnight (12-16 h) in the dark before usage. The resultant intensely coloured ABTS (mother solution) was diluted with phosphate buffered (pH 7.4) solution to make a working solution. The assay was first carried out on Trolox, the water-soluble α -tocopherol (vitamin E) analogue, which served as standard. 2900 μ l of the working solution was added to 100 μ l serial Trolox dilutions, swirled and left to react for 15 min.

For sample analysis, dilutions were made by adding 1 ml of the sample extract to 4 ml of the solvent (methanol), and then 2900 μ l of the working solution was added to 100 μ l sample extracts, swirled and left to react for 30 min. Absorbance was measured at 734 nm using Genesis 20 Spectrophotometer (Thermo Electron Corporation, Madison, USA). The assay was performed in triplicates and data were calculated using a Trolox calibration/standard curve. Fresh ABTS solution was prepared everyday due to self-degradation of the radical. The results were expressed as μ mol Trolox equivalents (TEAC).

Statistical analysis

Analyses of variance (ANOVA) were performed on data using the General linear model (GLM) procedure of SAS version 8.0 (SAS Institute Inc., 1999). In sulphur trial, the treatment sum of squares were partitioned into linear and quadratic polynomial contrasts in all variables. Hence in varietal trials, the comparisons between the mean values were tested using Duncan's Multiple Range Test (DMRT).

RESULTS

Effect of sulphur on mango pulp proximate composition

Table 1 shows proximate composition of dried mango

Table 1. Nutritional contents mango pulp at different sulphur concentrations

Sulphur Concentrations (ppm)	Moisture (%)	Proteins (%)	Fats (%)	Ash (%)	Fibre (%)	Carbohydrates (%)	Energy (kJ/100 g)	Vitamin C (mg/100 g)	Sulphur content (%)
0	7.9	2.6	0.1	1.8	1.9	84.0	1406.6	98.0	0.1
10	8.9	2.2	0.1	1.5	1.7	85.3	1419.8	122.5	1.2
20	8.9	2.3	0.1	1.3	2.0	86.0	1437.2	144.7	1.3
50	10.5	2.1	0.1	1.6	2.5	90.7	1450.8	149.1	1.4
100	10.3	2.3	0.1	1.7	1.5	89.1	1435.4	131.5	1.4
150	10.3	2.1	0.1	1.8	1.8	85.0	1436.6	136.1	1.3
200	10.2	2.9	0.2	2.2	1.9	85.5	1433.4	137.2	1.3
250	8.6	2.6	0.2	2.1	1.4	85.1	1434.9	132.9	1.3
300	8.3	2.3	0.1	2.1	1.5	85.4	1435.2	98.3	1.3
	Q	ns	ns	ns	ns	Q	Q	Q	Q

Linear (L) or polynomial quadratic (Q) polynomial at $P < 0.01$ and ns denotes non significance at $P < 0.05$.

Table 2. Nutritional contents of dried mango pulp on selected cultivars.

Cultivar	Moisture (%)	Proteins (%)	Fats (%)	Ash (%)	Fibre (%)	Carbohydrates (%)	Energy (kJ/100 g)	Vitamin C (mg/100 g)
Saber	8.9 ^c	2.3 ^b	0.2 ^a	2.0 ^a	2.0 ^b	85.0 ^a	1441.2 ^a	198.3 ^a
Peach	9.3 ^a	2.0 ^b	0.2 ^a	2.0 ^a	1.6 ^b	85.1 ^a	1411.7 ^c	27.7 ^e
Keitt	7.8 ^d	2.8 ^a	0.2 ^a	2.0 ^a	1.8 ^b	85.7 ^a	1419.7 ^b	177.5 ^b
Tommy Atkins	9.1 ^b	2.4 ^b	0.2 ^a	2.0 ^a	1.7 ^b	85.2 ^a	1419.6 ^b	67.1 ^d
Vhavenda	7.8 ^d	1.9 ^b	0.2 ^a	2.0 ^a	2.6 ^a	85.1 ^a	1411.5 ^c	29.8 ^e
Sunshine	8.8 ^c	2.2 ^b	0.2 ^a	2.0 ^a	1.8 ^b	84.4 ^b	1412.9 ^c	140.8 ^c

Means with different superscripts along the same column are significantly different at ($P < 0.01$)

pulp after soaking in varying concentrations of SO_2 (0, 10, 20, 50, 100, 150, 200, 250 and 300 ppm). The analysis showed that sulphur concentration had a quadratic effect ($P < 0.01$) of mango pulp proximate composition reaching a maximum at 50 ppm in all cultivars evaluated.

Observation of significant quadratic effect ($P < 0.01$) were on carbohydrates, energy and vitamin contents reaching maximum at 50 ppm sulphur concentrations. The difference between the highest and lowest carbohydrates contents was 6.7%, for energy, it was 44.2 kJ/100 g, vitamins was 51.1 mg/100 g and sulphur was 1.3%. Moisture content reached maximum at 10.5% with different between the highest and the lowest being 2.6%. However, protein, fat, ash and fibre contents did not significantly (at $P \leq 0.05$) change when mango pulp were preserved with varying ranges of sulphur.

Proximate composition of selected mango cultivars

Results in Table 2 shows that the proximate composition varied from cultivar to cultivar. Keitt had highest protein content (2.8%) compared to other selected cultivars whilst Vhavenda cultivar had highest fibre content 2.6%. Sunshine had significantly lowest carbohydrates content compared to all cultivars (Table 2). Saber had significantly highest energy content (1441.2 kJ/100 g) followed

by Keitt (1419.7 kJ/100 g) and Tommy Atkins (1419.6 kJ/100 g). Peach, Vhavenda and Sunshine had lowest energy content ranging from 1411 to 1413 kJ/100 g. The different between the highest and the lowest was 39.7 kJ/100 g. Saber also had significantly highest vitamin content (198.3 mg/100 g) (Table 2). The lowest vitamin contents were observed in Peach and Vhavenda ranging from 27.7 to 29.8 mg/100 g. The difference between the lowest and highest was 170.6 mg/100 g. Results in Table 2 also show that Peach had highest moisture content (%) of 9.3% with the lowest moisture content observed in Keitt (7.8%) and Vhavenda (7.8%). The difference between the highest and the lowest was 1.5%. However, all selected cultivars had no significant difference in ash and fat content (Table 2).

Total phenolic and antioxidant content of dried mango pulp

The total phenolic content of six mango cultivars was measured (Table 3): Saber had significantly highest total polyphenol content (0.41 mg of Gallic acid/100 mg of pulp sample), compared to all selected cultivars. The different between the different between the highest and the lowest was 0.2 mg of Gallic acid/100 mg of pulp sample. Saber had highest total antioxidants of 65.4 μmol of Trolox

Table 3. Chemical compositions of dried mango pulp on selected cultivars.

Cultivar	Total polyphenols (mg of gallic acid/100 mg)	Total antioxidant ($\mu\text{mol/g}$)
Saber	0.4 ^a	65.4 ^a
Peach	0.2 ^b	24.2 ^d
Keitt	0.2 ^b	35.6 ^c
Tommy Atkins	0.2 ^b	34.9 ^c
Vhavenda	0.2 ^b	56.7 ^b
Sunshine	0.3 ^b	56.3 ^b

Means with different superscripts along the same column are significantly different ($P < 0.01$) using Duncan Multiple Range Test (DMRT).

equivalents/g of the sample followed by Vhavenda (56.7 $\mu\text{mol/g}$) and Sunshine (56.3 $\mu\text{mol/g}$) respectively (Table 3). The flesh of the Peach, Keitt and Tommy Atkins had total antioxidant activities of 24.2, 35.6 and 34.9 $\mu\text{mol/g}$ of the sample, respectively. The dried pulp value of antioxidant activity of Peach was significantly lower than that of the other mango cultivars. The total antioxidant content ranged from 24.2 to 65.4 $\mu\text{mol/g}$.

DISCUSSION

The proximate composition of mango fruit pulp was 106 mg/100 g Vitamin C, 0.2% fats, 2.3% protein, 0.4% minerals, 1.9% fibre and 85% carbohydrates which were close to those reported by Gopalan et al. (2000). According to Lechaudel and Joas (2007), the amount of carbohydrates supplied to the tree fruit depends on the amount produced by leaf photosynthesis, on sink demand and on the availability of the reserve pool.

The high moisture content results in early processing of the fruits to avoid microbial spoilage (Abulude et al., 2006) unless when the fruits can be preserved under cold storage. The fibre in mango fruits aids in facilitating muscular action within the alimentary canal preventing constipation (Abulude et al., 2006).

Mango is regarded as a valuable source of phytochemical compounds (Johnson, 2013; Kim et al., 2007); among these compounds, polyphenolics are widely distributed secondary metabolites that serve as the predominant antioxidants present. Several studies have reported phenolic compounds in mango flesh and peels, including various flavonoids, xanones, phenolic acids and gallo-tannins (Tiwari et al., 2013; Berardini et al., 2005; Schieber et al., 2000).

Antioxidants are substances that can prevent or delay the oxidative damage of lipids, proteins and nucleic acids by reactive oxygen species (ROS), which include free radicals such as hydroxyl, peroxy and non-radicals such as hydrogen peroxides (Lim et al., 2006). In this study, the antioxidant ability of mango cultivars was shown to be significantly different ranging from 24.2 to 65.4 $\mu\text{mol/g}$. These results corroborated previous information that mangoes are a good source of phytochemicals (Johnson et al., 2013; Barreto et al., 2008; Gouado et al., 2007;

Rocha Ribeiro et al., 2007; Mahattanatawee et al., 2006 and Singh et al., 2004). Phytochemicals are compounds that act as free radical scavengers to help eliminate the highly charged oxygen molecules that are byproducts of metabolized oxygen (Jarvis and Neville, 2000), and are believed to offer various health benefits (Van Duyn and Pivonka, 2000). According to Pietta (2000), phenolic antioxidants are thought to neutralize ROS before they can cause damage and lead to diseases.

Lim et al. (2006), reported that most of the abundant antioxidants in the fruits are the polyphenols, vitamin C, A and E and carotenoids to a lesser extent in some fruits. According to Fleuriet and Macheix (2003), most of these polyphenols are flavonoids and are present in the form of ester and glycoside in fruits. Flavonoids commonly found in fruits and vegetables have been linked to reduced risk of mortality from the coronary heart diseases (Hertog et al., 1993).

Phenolic compounds are plant secondary metabolites that are biosynthesized through the shikimic acid pathway (Tiwari et al., 2013; Tomas-Baraeran and Espin, 2001). Phenolic compounds are associated with the health benefits deriving from consuming high levels of fruits (Hertog et al., 1993; Parr and Bolwell, 2000). Fruits such as mango contain many compounds including carotenoids, tocopherols; phenolics and glucosinolates that may exert chemo-protective effects through variety of mechanisms (Dragsted et al., 1993).

Schieber et al. (2000) stated that in terms of nutritional value, mango is a rich source of carotenoids, with β -carotene accounting for more than half of the total carotenoids content in most cultivars. β -carotene has been shown to possess high amount of vitamin A, activity and antioxidative capacity (Mercandate and Rodriguez-Amaya, 1998; Miller et al., 1996). Barreto et al. (2008) and Chen et al. (2004) also declared that mango contain high amounts of carotenoids.

Conclusion

Mango fruits are valuable sources of essential minerals and other nutrients which can be beneficial to the human health. The study concludes that different cultivars of mango contain variable quantities of proximate composition

and mineral content. Cultivar Saber constitutes significantly highest polyphenols, antioxidants, energy and vitamin C content than the other cultivars. The study also shows that regardless of cultivar, 50 ppm of SO₂ can effectively preserve dried mango with maximum proximate composition attained at this concentration. Further studies are important to determine the effect of preservative (SO₂) residual in human's health; and to give clarity on the amount of preservative needed for fruit and juice preservation.

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