IDENTIFICATION AND NUTRITIONAL CHARACTERIZATION OF EDIBLE WILD CACTUS VARIETIES FROM KENYA

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Abstract

Edible cactus is considered to have a promising commercial application in the food industry due to its nutritive composition and its drought resistant nature. However, knowledge on the nutritive composition of edible cactus varieties and their distribution in Kenya is still limited. This study sought to prospect for edible cactus varieties in Kenya and determine their physicochemical characteristics in order to unlock their industrial potential. Structured questionnaires based on Food and Agricultural Organization (FAO) cactus plant descriptors were used to identify and differentiate edible from non-edible cactus varieties from four Kenyan Arid and Semi-Arid lands (ASALs) counties (Machakos, Baringo, Makueni and Laikipia). The yields, morphological and physicochemical parameters of the fruits were determined. Three edible cactus varieties were identified namely: Opuntia ficus-indica (purple), Opuntia monacantha (green) and Opuntia megacantha (yellow). The purple variety had the highest yields (> 11kg/ m^2). At the mature ripe stage, the juice recovery rate for the purple and yellow varieties was above 50%. All the samples were a rich source of crude fiber (1.41-1.71g/ 100g), Calcium (295.56-342.42 g/100g), and Zinc (2.30-2.39g/100g). The sugar content was predominantly glucose (1.26- 4.59 g/100g) and fructose (1.45-2.66/100g). The fruits exhibited substantial amount of total phenolics (1.79-2.52g/100g G.A.E.) and high antioxidant activity (0.59-1.83 mg/ml). Generally, the yellow variety was most nutritious, had highest sugar and phytochemical content. This shows the potential of the fruits to be used either in isolation or with other food ingredients in the food industry.

Keywords: Cactus varieties, physico-chemical properties, juice extractability, phytochemical, yields

Submitted: 18.09.2015 Reviewed: 18.11.2015 Accepted: 02.12.2015

1.INTRODUCTION

Most indigenous communities especially the Indians have used the term 'Food for health' from ancient times for health treatments. The demand for functional foods is increasing due to the increased consumer awareness of the health benefits of foods (Hasler, 1998). Numerous bioactive compounds have been identified in many fruits such as apples, grapes and the prickly pear cactus amongst many others (Saenz, 2000). However, exploitation and utilization of wild fruits such as edible wild cactus is still limited (Kuti, 1992). The edible wild cactuses belong to cactaceae family and include the cactus pear (*Opuntia spp*.) varieties such as *O. ficus-indica, O.megacantha, O.monacantha, O.joconostle, O.Mutadae and O.Robusta* (Valadez-Moctezuma,*et al* 2015). The *opuntia spp.* is native to tropical and sub-tropical America, where it grows either wild or is cultivated in home gardens. As people continued to trade and settle, the plants were distributed to other parts of the world including Africa, Asia, Australia, and Europe (Kuti, 2004). In Kenya, most of the cactus species are found in ASALs, which covers over eighty per cent (80%) of the total land mass of Kenya (Cynthia, 2009). The *Opuntia* species is widely distributed in Laikipia plateau majorly west Doldol. This is attributed to shift in land use pattern and degradation of the arable and rangeland (Kunyanga *et al*, 2009).

The fruit is a berry with a thick peel enclosing a delicately flavoured seedy pulp (Kuti, 2004). The stems have been modified to succulent pads to retain as much moisture content as possible and the leaves have been reduced to spine to reduce the transpiration rate. Cacti withstand prolonged drought conditions and thus they can be considered as a potential alternative food crop for drier regions (DeFelice, 2004; Kang'ara and Gitari, 2009).

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2. MATERIALS AND METHODS

2.1. Sample collection and identification:

Sample collection was conducted in four counties in Kenya namely Makueni, Machakos, Baringo, and Laikipia. The geographic distribution of the samples collected is as indicated in **Table 1.** The identification of the samples was done using the FAO cactus plant descriptors by Chessa and Nieddu (1997).

Table 1: Geographic distribution of the samples collected for analysis

Sample No	Variety	Location of sampling			
		Machakos	Makueni	Laikipia	Baringo
1	*O.ficus-indica* (Purple)	x	✓	x	✓
2	*O.monacantha* (Green)	✓	✓	x	x
3	*O.megacantha*(Yellow)	x	x	✓	x

✓ = Sampled X = Not sampled

2.2. Yield Estimation:

The yield of the cultivars was determined by counting the average number of fruits per square meter at three different sample plots in each of the regions visited, which represented fruit density per square meter. The weight/m^2 was then determined.

2.3. Morphological characterization of the fruit:

The colour, shape, and recepticular scar position of the cactus fruit were determined by visual observation and compared to fruit descriptors described by Chessa and Nieddu (1997). The weight of 25 fruits from each location was then determined accurately using a weighing balance. Each fruit was at that point separated into three parts (skin, flesh and seeds) using a kitchen knife. The average weight of each part was accurately determined and expressed as proportionate composition of the whole fruit.

2.4. Sample Preparation and Juice extractability

Mature ripe fruits of the same size were harvested and transported to Jomo Kenyatta University of Agriculture and Technology for analysis. The fruits were stored in automated cold rooms at 7^0C±2 and relative humidity of 95% until the analysis day. Ripe cactus fruits were cleaned using scrubbing pad and the juice was extracted using a Ramtons juice extractor (RM/204-Ramtons, China) for physicochemical analyses. Juice extractability was determined by weighing approximately 200g of sample (about 5 cactus fruits) prior to juice extraction. The weight of the juice recovered after extraction was quantified as a percentage of the initial weight of the samples. The juice that was not used immediately was kept under cold storage at -18^{o}C for further analyses. All the physico-chemical analyses were done in triplicate.

2.5. Characterization of the juice

2.5.1 pH determination:

This was done by the method of Ofori and Hahn (1994) using a pH meter (TOA pH Meter HM–7B, Tokyo, Japan).

2.5.2. Total soluble solid (T.S.S.) determination

The total soluble solids were determined using hand refractometer (ATAGO model ATC-1, Tokyo, Japan) and expressed as % ^{0}brix.

2.5.3. Total Titratable Acidity (T.T.A) determination

The TTA was determined by titrating a specific volume of juice with 0.1N NaOH (sodium hydroxide) in the presence of phenolphthalein indicator as described using AOAC (2000) method. TTA results were expressed as % citric acid, which is the main organic acid in cactus fruit (Ueda *et al*., 2000).

2.6. Proximate composition

The moisture content, crude fat and ash were determined as per methods 925.09, 983.23 and 930.05 respectively of the Association of Official Analytical Chemists (AOAC, 2005). Nitrogen percentage was determined using Kjeldahl method and a factor of 6.25 was used to convert the nitrogen percentage into crude protein AOAC 2000(Method 950.48). For mineral composition, Calcium, Magnesium,

Iron, Zinc, Potassium, Sodium, and phosphorous composition were determined using Atomic Absorption Spectroscopy (AAS) as described in 968.08 AOAC, (2000) Method.

2.7. Analysis of sugars:

Quantification of the sugars present was determined using High Performance Liquid chromatography (HPLC) method as outlined in AOAC (2000). The standard solutions and the sample extracts were analysed using a HPLC auto sampler unit (HPLC Model SIL- 20A/C Shimadzu, Japan) fitted with a refractive index detector 10 A(Shimadzu,Japan). The conditions for analysis were; oven 35°C, flow rate: 1.0 ml/min, injection volume – 20 µl, and column-Ashipak NH2P-504E. Standard sugar solutions of fructose, glucose, and sucrose were used to identify and estimate the concentration of the specific sugars in the samples.

2.8. Determination of the phytochemicals:

The phytochemicals determined were Vitamin C, total carotenoids, total polyphenols, flavonoids, and free radical scavenging activity, which is attributed to the activity of the various phytochemicals.

2.8.1. Vitamin C determination:

Vitamin C content was determined using 2,6-dichlorophenol indophenol titrimetric method (AOAC, 1996).

2.8.2. Total carotenoids:

The analysis of total carotenoid was done using the method of Rodriguez-Amaya and Kimura (2004). This involved extraction with cold acetone using a mortar and pestle, partitioned to petroleum ether, and taking the absorbance at 450 nm in a UV-Vis spectrophotometer (UV 1800, Shimadzu, Japan). The readings were converted β-carotene equivalent. The total carotenoid content was calculated using the formula:

$$Total\ Carotenoid\ Content\ (\mu g/g) = = \frac{A*Volume(ml)*104}{A^{1\%}{}_{1cm}*sample\ wt(g)}$$

2.8.3. Determination of total polyphenols:

Qualitative determination of total polyphenol was done using Ferric chloride test as described by Singleton et al (1999) in which the methanolic extract of the cactus samples was diluted to 5 ml with distilled water. To that, a few drops of neutral 5% Ferric chloride solution were added. A dark green or a blue-black color indicated the presence of phenolic compounds.

For quantitative determination of total phenols, Folin-Ci ocalteu reagent was used as per method described by Singleton et al (1999). The amount of total phenolics was calculated from standard curve of catechin hydrate (20-100 µg) and the results were expressed as g/100g Gallic Acid Equivalent (G.A.E.)

2.8.4. Extraction and determination of flavonoids:

Sample extraction for analysis of flavonoids and antioxidant activity was done as described by Harbone (1973 & 1998). About 5 g of dried and crushed samples were weighed into a 250 ml conical flask and about 100 ml methanol added. The flask was closed securely using parafilm and covered with aluminium foil. The samples were put in a shaker and shaken for about 3 hours. They were then kept in the dark and left to extract for 72 hours. After 72 hours, the samples were filtered through whatman No. 4 filter paper, and then the filtrate concentrated in a vacuum evaporator to a volume of 20 ml. The extract was transferred into vial bottles and securely stoppered. The extract was used for analysis of flavonoids and anti-oxidative activity.

Firstly, qualitative determination of flavonoids was determined. Approximately 5 ml of dilute ammonia solution was added to a portion of aqueous filtrate of extracted sample followed by addition of concentrated H_2SO_4. If a yellow coloration was observed, it indicated the presence of flavonoids. The yellow coloration disappeared on standing for 3-5 minutes.

For quantitative determination of flavonoids, the Aluminium chloride colorimetric method as described by Jagadish *et al, (*2009) was used. The results were expressed as mg/100g Quercetin Equivalent (Q.E.).

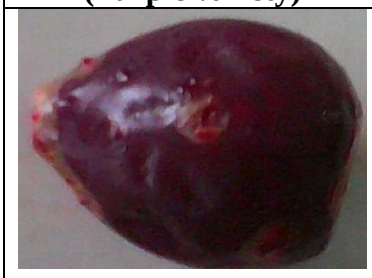
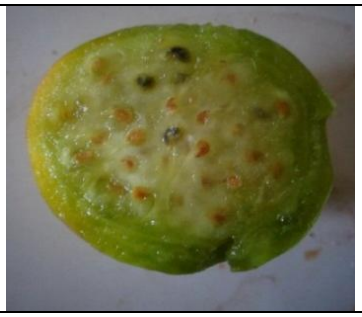
O. ficus- indica (Purple variety)	*O.monacantha* (Green variety)	*O.megacantha* (Yellow variety)
		
		

Plate 1: The three edible cactus varieties found in Kenya and their cross-sectional views

2.8.5. Determination of the Free Radical Scavenging Activity:

The radical scavenging activities of the plant extracts against 2, 2-Diphenyl-1-picryl hydrazyl (DPPH) radical (Sigma-Aldrich) were determined by UV spectrophotometer at 517 nm as described by Molyneux (2003).

A. 2.9. Statistical analysis:

All the analyses were performed in triplicates and the results presented as mean values ± standard error. The data was statistically analysed with the Statistical Analysis Software (SAS) Genstat, 14th edition and the means separated using Least Significance Difference (LSD) at $p \leq 0.05$. Mean comparisons for treatments were made using Duncan's Multiple Range Tests (Steel et al, 1997).

3. RESULTS AND DISCUSSION

3.1. Morphological Characteristics:

The morphological characteristics and colour of the three edible varieties identified are shown in **Plate 1**. The purple and green fruits were ovoid is shape whereas the yellow cactus fruit was oblong. The recepticular scar position for the green and purple fruit was flattened while for the green and yellow fruit was sunken. The color varied from purple to yellow. The size of the fruit varied depending on the variety with yellow variety being the largest. The fruit are a berry type with juicy pulp that contains many hard-coated seeds.

The purple variety exhibited the highest yields (11.07 kg and 11.38 kg /m^2) (**Table 2**). The proportionate composition of each variety is presented in **Table 2**. The heaviest variety was the yellow type while the lightest was the purple variety. Additionally, the yellow variety had the highest percentage flesh content while the purple variety was the least fleshy. The skin density was in the range of 27 -34%, with the purple variety having the lowest skin density and the yellow type having the highest skin density. Interestingly, the purple variety had the highest seed density per fruit while the yellow type had the lowest. The green variety was intermediate in most aspects. Agro-ecological difference did not result in any significant difference ($p<0.05$) in fruit characteristics and yield among the green variety samples. Juice extraction rate was over 50% in the yellow and purple varieties, while the juice recovery in the green types was low (< 40%). The juice extractability is an important quality aspect to consumers and processors.

Table 2: Physical and morphological characteristics of edible cactus varieties

Fruit Type	Eco-geographical zone	Average number of fruits/m^2	Average Fruit Weight(g)	Fruit Yield Kg/m^2	Flesh (%)	Skin (%)	Seeds (%)	Juice Extractability (%)
O.ficus-indica (Purple Variety)	Baringo (Marigat)	342.00 ±2.31^{b}	32.38 ±0.05^{a}	11.07 ±0.09^{c}	51.38 ±0.41^{a}	27.23 ±0.72^{a}	21.55 ±1.09^{c}	50.89 ± 0.02^{d}
	Makueni (Sultan Hamud)	353.30 ±5.78^{c}	32.22 ±0.09^{b}	11.38 ±0.17^{c}	51.41 ±0.64^{a}	28.22 ±0.30^{a}	20.53 ±0.64^{c}	52.14 ± 0.26^{d}
O.monacantha (Green Variety)	Machakos (Kangundo)	104.00 ± 3.06^{a}	58.39 ±0.98^{b}	6.07 ±0.09^{a}	57.66 ±0.63^{b}	32.58 ±0.66^{c}	9.75 ±0.05^{b}	32.79 ±0.34^{a}
	Makueni (Nziu)	104.70 ± 1.20^{a}	61.37 ±1.76^{b}	6.43 ± 0.11^{a}	57.79 ±0.36^{b}	30.82 ±0.04^{b}	11.61 ±0.43^{b}	38.16 ±1.10^{b}
Opuntia megacantha (Yellow Variety)	Laikipia (Matunda)	99.3 0 ±2.40^{a}	78.74 ±3.68^{c}	7.82 ±0.38^{b}	59.07 ±0.31^{b}	33.51 ±0.05^{c}	7.50 ±0.31^{a}	50.37 ±0.34^{c}

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p< 0.05$)

3.2. Pulp characteristics

The results for pulp characteristics are presented in **Table 3.** The fruits were moderately acidic with pH ranges from (4.01-4.86). There was a significant difference in the fruit pH for the purple variety. These differences may due to the variation in the altitude, cultivar/genotype, and environmental conditions (Hardisson *et al*., 2001).

The Total Titratable Acidity (TTA) increased from the green to purple variety. Agro-ecological differences did not result in significant differences at ($p<0.05$) for TTA for the green and purple varieties respectively. At the same maturity level, the yellow variety exhibited the highest Total Soluble Solids (TSS) while the green had the least.

Table 3: Pulp characteristics of the different cactus varieties found in Kenya

Fruit Type	Eco-geographical zone	pH	TTA (%)	TSS (^{o}Brix)
O.ficus-indica (Purple Variety)	Baringo (Marigat)	4.82 ± 0.01^{d}	0.38±0.00^{c}	8.47±0.07^{b}
	Makueni (Sultan-Hamud)	4.01 ± 0.01^{a}	0.37±0.00^{c}	7.47±0.07^{a}
O.monacantha (Green Variety)	Machakos (Kangundo)	4.47± 01^{c}	0.16 ± 0.00^{a}	7.30±0.21^{a}
	Makueni (Nziu)	4.24 ± 0.00^{b}	0.15 ± 0.01^{a}	7.26±0.07^{a}
O.megacantha (Yellow Variety)	Laikipia (Matunda)	4.85± 0.01^{e}	0.32± 0.00^{b}	10.13±0.07^{c}

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p< 0.05$)

Fruits with pH values greater than 4.5 pose greater challenges for storage attributed to bacterial growth (Saenz, 2000; Mulas and D'hallewin, 1997). Acidity plays a good role in determination of the product quality, which renders the fruit suitable for juice production. The moderately high TSS value in yellow variety is attributed to the hydrolysis of sucrose, which is the most common form of carbohydrate in the fruit.

3.3. Proximate analysis

The proximate composition of cactus varieties in Kenya is given in **Table 4.** The fruits had high moisture content (87.68% -92.82%).

Table 4: Proximate composition (%) of cactus pulp

Fruit Type	Eco-geographical zone	Moisture Content	Crude protein	Crude fat	Crude ash	Crude fiber	Carbohy-drates
O.ficus-indica(Purple Variety)	Baringo (Marigat)	91.56 ±0.01^{b}	1.41 ±0.01^{a}	0.41 ±0.01^{a}	1.61 ±0.01^{a}	1.43 ±0.01^{c}	3.56 ±0.01^{b}
	Makueni (Sultan Hamud)	92.82 ±0.01^{e}	1.40 ±0.01^{a}	0.42 ±0.00^{a}	1.61 ±0.01^{a}	1.39 ±0.01^{a}	2.35 ±0.01^{b}
O.monacantha (Green Variety)	Makueni (Nziu)	91.89 ±0.01^{c}	1.52 ±0.00^{c}	0.48 ±0.00^{b}	1.71 ±0.01^{b}	1.63 ±0.01^{d}	2.77 ±0.01^{c}
	Machakos (Kangundo)	87.68 ±0.05^{a}	1.47 ±0.01^{b}	0.42 ±0.00 ^{a}	1.71 ±0.01^{b}	1.71 ±0.01^{e}	6.98 ±0.01^{e}
O.megacantha (Yellow Variety)	Laikipia (Matunda)	92.60 ±0.02^{d}	1.53 ±0.01^{c}	0.41 ±0.00^{a}	1.77 ±0.01^{c}	1.41 ±0.01^{b}	2.27±0.01^{a}

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p< 0.05$)

Table 5: Mineral content (Mg/100g) of cactus pulp

Fruit Type	Eco-geographical zone	Ca	Mg	Fe	Zn	K	Na	P
O.ficus-indica (Purple Variety)	Baringo (Marigat)	324.42 ±0.15^{e}	62.19 ±0.12^{a}	2.55 ±0.02^{a}	2.39 ±0.01^{c}	197.11 ±0.51^{c}	16.58 ±0.16^{a}	0.06 ±0.01^{c}
	Makueni (Sultan Hamud)	322.83 ±0.64^{d}	63.44 ±0.12^{b}	2.28 ±0.22^{ab}	2.39 ±0.01^{c}	199.83 ±0.38^{d}	14.95 ±0.28^{a}	0.09 ±0.01^{c}
O.monacantha (Green Variety)	Makueni (Nziu)	304.35 ±0.08^{c}	117.04 ±0.12^{d}	2.18 ±0.03^{a}	2.30 ±0.01^{a}	108.69 ±0.25^{b}	19.02 ±0.16^{a}	Trace
	Machakos (Kangundo)	295.56 ±0.08^{a}	123.85 ±0.21^{e}	2.07 ±0.02^{a}	2.32 ±0.01^{ab}	106.21 ±0.14^{a}	16.86 ±3.25^{a}	Trace
O.megacantha (Yellow Variety)	Laikipia (Matunda)	296.88 ±0.13^{b}	109.60 ±0.21^{c}	2.11 ±0.02^{a}	2.34 ±0.01^{b}	203.71 ±0.28^{e}	14.95 ±0.28^{a}	0.09 ±0.01^{c}

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p< 0.05$)

The fruits are a good source of minerals as exemplified by the ash content (1.61%-1.77 %). Like in many fruits, cactus pulp contains a low amount of proteins (Sáenz, C. &

Sepúlveda, 1999). The percentage content of crude fibre (1.39%- 1.71%) is substantial, which could be of benefit to human health. The green variety from Kangundo had the highest carbohydrate content (7%).

3.4. Mineral composition

Cactus varieties were found to be a rich source of calcium (295.56-324.42 mg/100g) and iron (2.07-2.55 mg/100g), the purple variety exhibiting the highest calcium and iron content (**Table 5**).

The fruits are good source of potassium (106.21-203.71mg/100g) and are low in Sodium (14.95-19.02 mg/100g), which is favourable for people with kidney problems and hypertension (Sepúlveda and Sáenz, 1990). Phosphorous was in trace amounts in the green variety that may be attributed to its deficiency in the soil. The results were similar to those reported by, Saénz and Sepúlveda (2001), Tegegne (2001) and Feugang *et al*, (2006) for green, purple, and orange cactus fruits.

3.5. Soluble sugar content of cactus pulp

Most of the sugars present in the cactus fruit were of reducing type. Glucose, which is used as energy metabolite for brain and nerve cells, was highest in all varieties (**Table 6**). The yellow variety was predominantly richer in the profile and content of sugar. The fructose and glucose content of the yellow variety was approximately 1.5-2 folds higher than in the other varieties. This indicates that the yellow variety is sweeter than the other varieties. Besides, sugar content is an important criterion for fruit quality since consumers prefers sweet fruit.

Table 6: Sugar characteristics of cactus pulp

Fruit Type	Eco-geographical zone	Fructose(g/100g)	Glucose(g/100g)	Sucrose(g/100g)
O.ficus-indica (Purple Variety)	Baringo (Marigat)	1.16±0.01 ^{a}	1.26±0.04 ^{a}	0.11±0.06 ^{a}
	Makueni (Sultan Hamud)	2.37±0.03 ^{d}	2.58±0.15 ^{c}	0.85±0.00 ^{c}
O.monacantha (Green Variety)	Machakos (Kangundo)	1.45±0.01 ^{c}	2.03±0.02 ^{b}	0.65±0.03 ^{b}
	Makueni (Nziu)	1.54± 0.00 ^{b}	1.71±0.13 ^{b}	0.64 ±0.05 ^{b}
O.megacantha (Yellow Variety)	Laikipia (Matunda)	2.66±0.02 ^{e}	4.59±0.11 ^{d}	1.04±0.03 ^{d}

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p< 0.05$)

3.6. Phytochemical composition of cactus

Fruits contain non-nutritive compounds of health benefit to the consumer (Jana, 2012). The profile and content of these phytochemical compounds depend largely on the fruit type. Cactus varieties showed a large variation in phytochemical composition (**Table 7**). The Vitamin C content was highest in the green and yellow type. β-Carotene was exhibited in highest amount in the yellow variety with purple varieties exhibiting the least. This may be attributed to masking of the β-Carotene pigments by betalains pigments in the purple variety and higher biosynthesis in the yellow variety (Elshamey *et al*, 2006; Saenz and Sepulveda (2001a).

Cactus' varieties were rich in total phenolics (1.79 -2.52 g/100g GAE) and total flavonoids (0.16-0.23 g/100g Q.E.), which help the fruits to survive harsh climatic conditions and remain intact in the plant for long time without deterioration (Chang *et al*, 2008). The methanol extracts of the cactus varieties showed potential of free radical scavenging activity against DPPH (0.59-1.83 mg/ml), with the highest antioxidant activity being observed in the purple variety(*O. ficus-indica*).

Table 7: Phytochemical properties of cactus pulp

Fruit Type	Eco-geographical zone	Vitamin C (mg/100g)	β-Carotene (mg/100g)	Total phenolics (g/100g G.A.E.)	Total flavonoids (g/100g Q.E.)	Antioxidant ic:50 (mg/ml)
O.ficus-indica (Purple Variety)	Baringo (Marigat)	21.53 ±0.01 [b]	0.01 ±0.00 [a]	1.87 ±0.01 [c]	0.16 ±0.00 [a]	1.58 ±0.08 [d]
	Makueni (Sultan Hamud)	20.85 ±0.19 [a]	0.07 ± 0.01 [a]	2.52 ±0.18 [d]	0.22 ±0.02 [d]	1.83 ±0.08 [e]
O.monacantha (Green Variety)	Machakos (Kangundo)	23.64 ±0.06 [c]	0.55 ±0.02 [b]	1.79 ± 0.00 [a]	0.18 ±0.00 [c]	0.59 ±0.01 [a]
	Makueni (Nziu)	28.85 ± 0.28 [d]	0.59 ±0.55 [c]	1.79 ± 0.02 [a]	0.16 ±0.02 [b]	0.63 ±0.05 [b]
O.megacantha (Yellow Variety)	Laikipia (Matunda)	24.82 ± 1.14 [e]	2.47 ± 0.68 [d]	1.84 ± 0.20 [b]	0.23 ±0.00 [e]	0.79 ±0.30 [c]

The results are presented as mean± standard error of three separate determinations (n=3). Means within the same column with different superscripts are significantly different at ($p < 0.05$)

High % inhibition of DPPH was an indication of high free radical scavenging activity (FRSA) of the extract. The results were not different from those obtained by Sáenz, & Sepúlveda, (2001) and Súpulveda and Moreno (1995a), Súpulveda and Sáenz (1990) for green, purple and orange cactus varieties.

4. Conclusions

The purple variety (*O.ficus-indica*) exhibited the highest yields and high juice extraction rates, which are important quality aspects to consumers and processors. The green variety (*O.monacantha*) had the lowest yields, was low in sugars and phytochemical content. The yellow variety (*O. megacantha*) was most nutritious, richest in the phytochemical content, and had the largest and sweetest fruits that rendered it friendlier to processors and consumers. This study unlocks the industrial potential of edible wild cactus for use either in isolation or with other food ingredients to develop a variety of value added products.

5. Acknowledgements

Sincere thanks to Jomo Kenyatta University of Agriculture and Technology (JKUAT) through the Research, Production, and Extension (RPE) division and JICA through the Africa ai Japan Initiative for funding this project.

6. References

[1.] AOAC. Association of Official Analytical Chemists. *Official Methods of Analysis*, 17th edition. Washington DC, USA, 1996.

[2.] AOAC. Association of Official Analytical Chemists. *Official Methods of Analysis*,17th edition. Washington DC, USA, 2000.

[3.] AOAC. Association of Official Analytical Chemists. *Official Methods of Analysis*,17th edition. Washington DC, USA, 2005.

[4.] Chessa, I. and Nieddu G. Descriptors for Cactus pear (*Opuntia* spp) CACTUSNET-FAO Newsletter Special Issue, 1997.

[5.] Cynthia, A. Increasing drought in Kenya. In Understanding Climate Change Adaptation: Lessons from community-based approaches. In e. J. Ensor and R. Berger, Practical Action, 2009;101-114.

[6.] DeFelice, M. Prickly pear cactus, Opuntia spp. A spine-tingling tale. Weed Technology, 2004; 18, 870-879.

[7.] El-Samahy, S.K, Abd El-Hady E.A, Habiba R.A, Moussa T.E. Chemical and rheological characteristics of orange-yellow cactus pear pulp from Egypt. Journal of the Professional Association for Cactus Development, 2006; 8, 39-51.

[8.] Ernestina Valadez-Moctezuma,Samir Samah& Arturo Luna-Paez. Genetic diversity of Opuntia spp varieties assessed by classical marker tools (RAPD and ISSR). Plant system evolution, 2015;301, 737–747.

[9.] Harbone, J. Phytochemical Methods London. Chapman and Hall Ltd, 1973.

[10.]Harbone, J. B. Phytochemical Methods. A guide to modern techniques of plant analysis. 3rd edition. Springer (India) Private Limited, New Delhi, 1998.

[11.]Hardisson A., Rubio C., Martin M., Alvarez R., Diaz E. Mineral composition of the banana (*Musa acuminata*) from the island of Tenerife. Food Chemisty,2001; 73 , 153-161

[12.]Jana, S. Nutraceutical and functional properties of cactus pear (Opuntia spp.) and its utilization for Food Applications. Journal of the Entomological Research Society,2012; 3(2),60-66.

[13.]Kunyanga, C.N, Strum, S.,Graham, S., Sipitiek and Imungi, J.K. Confrence proceedings. African Crop Science , 2009; 9, 333-337.

[14.]Kuti, J.O. Growth and compositional changes during the development of prickly pear fruit. Journal of Horticultural Science, 1992; 67, 861–868.

[15.]Kuti, J.O. and Galloway, C.M. Sugar composition and invertase activity in prickly pear. Journal of Food Science, 1994,;59 (2),387–393.

[16.]Kuti, J.O. Antioxidant compounds from four Opuntia cactus pear fruit varieties. *Journal of Food Chemistry*, 2004; 85(4),527-533.

[17.]Molyneux, P. The use of free radical diphenylpicrilhydrazyl (DPPH) for estimating antioxidant activity, 2003.

[18.]Mulas, M. and D'hallewin, G. Fruit quality of four cactus pear (*Opuntia ficus indica* Mill.) cultivars as influenced by irrigation. Acta Hort,1997,438,115–121.

[19.]Ofori, F. and Hahn, S.K. Tropical Root Crops. A developing economy. Proceedings of the 9th symposium of the international Society for Tropical root Crops. Accra, Ghana,1994, 20–26.

[20.]Rodríguez-Félix**,** A. Postharvest physiology and technology of cactus pear fruits and cactus leaves. Acta Hort. 2002; 581: 191–199.

[21.]Sáenz, C. Nopal and cactus pear processing alternatives. In C. Saenz, ed. Proceedings of the International Symposium on Cactus Pear and Nopalitos: Processing and Uses. Universidad de Chile, 1998.

[22.]Saenz, C. Processing technologies: an alternative for cactus pear (Opuntia spp.) fruits and cladodes. Journal of Arid Environments,2000;46, 209-225.

[23.]Sáenz, C., and Sepúlveda, E. Physical, chemical, and sensory characteristics of juices from pomegranate and purple cactus pear fruit. In Annals of the 22nd IFU Symposium, Paris, 1999; 91–100.

[24.]Sepúlveda, E., Sáenz, C. and Moreno, M., Obtención y caracterización de harina de nopal *(Opuntiaficus-indica (L.) Miller)*. In VI Congreso Nacional IV Congreso Internacional sobre Conocimiento y Aprove chamiento del Nopal. Jalisco, Mexico, 1995;28–31.

[25.]Singleton VL, Orthofer R and RM Lamuela-Raventos, Analysis of total Phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Met Enzy. ,1999; 299,152–178.

[26.]Steel, R., Torrie, J. and Dicky, D. Principles procedures of statistics, McGraw Hill Book Company, 1997,633.

[27.]Tegegne, F., Nutritional value of *Opuntia ficus-indica* as a ruminant feed in Ethiopia. In: Cactus (*Opuntia* spp.) as forage. Eds Mondragón-Jacobo, C. & Pérez-González, S., FAO Plant Production and Protection Paper 169. Food and Agriculture Organization of the United Nations, Rome, 2001,91-99.

[28.]Ueda, M., Sasaki, K., Utsunomiya, N., Inaba, K. and Shimbashi, Y. Change in physical and chemical properties during maturation of mango fruit (Mangifera indica L. *twin*') cultured in plastics green houses. Food Science and Technology Resource, 2000;6,299.