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Influence of Source Area and Solar Drying on The Quality Characteristics of Pineapples Varieties Grown in Central Uganda

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ABSTRACT

In Uganda, pineapples form the most developed and widely grown commodities among the fruit's subsector. The fruit is highly produced in central Uganda from the districts of Kayunga, Luwero and Masaka concentrating largely on three varieties of smooth Cayenne, Queen and Red Spanish with smooth cayenne taking the largest share of pineapple farmers. This study targeted analyzing the effect of source area and drying on the quality of pineapple varieties produced in Uganda. Two varieties were collected from three large scale pineapple growing districts in Central Uganda and they were prepared and coded for quality analysis. Physical properties of the varieties were investigated. The results indicated a significant differences in weight, diameter, circumference and height of the pineapple varieties as compared to source areas at $p<0.05$. Findings showed no significant differences ($p<0.05$) between varieties and between source areas with respect to proximate composition across all parameters tested with the exception of dietary fiber. Mineral content varied significantly between different varieties grown in selected areas of Uganda ($p<0.05$). Potassium was the most abundant mineral found in both pineapple varieties while both varieties exhibited low iron levels. Similarly, Solar drying had varied significant effects on some quality parameters of dried fruits and vegetables but retained substantial amounts. Findings revealed significant differences ($p<0.05$) for all tested variables with the exception of titratable acidity with respect to biochemical composition of solar dried pineapple. The mineral content of solar dried pineapple among different cultivars and among production areas ($p<0.05$). Findings revealed that Potassium was the most abundant mineral retained after solar drying. Pineapple quality as observed in this study is affected by many factors, such as genotype, environment, climate, soil characteristics and agricultural practices among many others which in turn affects quality of the final products. Solar drying improved the shelf life of pineapples and therefore can be used to improve the marketability of pineapples in the value chain.

Keywords: pineapple; source area; solar drying; quality

INTRODUCTION

Pineapples (Ananas comosus) are by far the most developed and widely grown commodity in the fruit crop range and value chain in Uganda (FIT, 2007; Magala et al., 2010). The fruits are largely produced from Kayunga, Luwero, Mukono and Masaka districts located in central Uganda. Other sources of pineapples include Iganga, Kamuli, Tororo, Mbale, Bushenyi, Ntungamo and Kabale (Bua et al., 2013; FIT, 2007). According to NAADS (2014), the main cultivars grown in Uganda include Smooth Cayenne, Queen and Red Spanish. The smooth cayenne remains dominant in most pineapple growing regions because of its favorable characteristics such as ratoon cropping, large size, high juice levels, uniformity in shape as well as its acid-sugar balance. The Queen cultivar is known for producing a small fruit (0.5 to 1.0kg) and it grows with spiny leaves that are difficult to work (Kwikiriza et al., 2016; Magala et al., 2010). According to Asare (2012), pineapple composition varies depending on geography, season, process, and stage of fruit ripeness, variety, agronomic and environmental factors and time of harvest (Akhtar et al., 2015; Asare, 2012). The chemical and physical properties of different pineapple cultivars have been extensively studied and reported globally by several authors (Akhtar et al., 2015; Asare, 2012; Bartolome, Ruperez, & Fuster, 1995; Fournier, Dubois, & Soler, 2007; Lu et al., 2014; Mongi, 2013; Shamsudin, 2007; Steiner-Aseidu, Wardy, Saalia, Budu, & Sefa-Dedeh, 2009). Solar drying remains the most employed method of pineapple preservation in Uganda. However, solar drying has varied significant effects on some quality parameters of dried fruits and vegetables but retains substantial amounts with potential to extend shelf life of fruits (Mongi, 2013). Regardless, only limited empirical data exists on the physicochemical properties of pineapple varieties cultivated in Uganda. There is limited data regarding nutritional, sensory and shelf stability of solar dried pineapples processed in Uganda. This study therefore targeted analysis of the effect of pineapple varieties and solar drying on quality of the fruits from selected areas of Uganda.

MATERIALS AND METHODS

Sample collection and preparation

Fresh pineapple fruits were obtained from three pineapple production areas; Kangulumira in Kayunga district, Buyaga in Masaka district and Kabanyi in Luwero district respectively all in central Uganda. Two varieties (large sized spineless smooth cayenne and the square shouldered spiny queen) were harvested at full maturity (ripe) based on standard indices. The fruits were washed with potable water, manually peeled and cored using a stainless-steel knife to separate the flesh, core and peels. To analyse fresh fruits, the fresh was cut into 50g pieces and homogenization was performed using a laboratory blender (Waring model). The dried fruits were obtained by cutting the peeled pineapple into quarter slices and these were dried in a tunnel solar drier (Hohenheim) available at the Makerere University Agricultural Research Institute Kampala, Uganda (MUARIK) for 15 sunshine hours. Dried pineapples were then milled in a vertical mill to obtain a homogenous sample for further analyses

Experimental site and design

The experiment was conducted at the School of Food Technology, Nutrition and Bioengineering (SFTNB), Makerere University, Kampala. A 2 ×3 factorial Completely Randomized Design with three replications was used. The pineapple varieties at two levels and the production areas at three levels served as factor treatments (Table 1). Each replicate consisted of five randomly selected fruits from different production areas.

TABLE 1: Experimental Design

Treatments	Production Area		
Variety	K	L	M
SC	SCK	SCL	SCM
Q	QK	QL	QM

SC = smooth cayenne, Q = Queen, K = Kayunga, L = Luwero, M = Masaka

Determination of physical characteristics

Fruit length was measured using a measuring tape from the crown end to the base. The fruit diameter was determined using a standard Vernier caliper by measuring the distance across three sections of the pineapple and obtaining the mean. Fruit circumference was determined using a measuring tape by measuring from the largest part of the fruit (mid-section). Pulp to peel ratio were determined using a method described by Kamol et al., (2014).

Determination of physicochemical properties of selected pineapple varieties

Total Soluble Solids (TSS) was determined using standard AOAC methods as described by Lu et al., 2014. About 2-3 drops were dispensed onto the refractometer prism plate, and TSS directly read off and recorded in °Brix. pH of the samples was determined using a digital pH meter using a method described by Shittu (2013). Titratable acidity (TA) was determined by using AOAC, 2004 methods.

Determination of Vitamin composition of the samples

Ascorbic acid content was evaluated using the 2,6-dichloroindophenol titrimetric method (AOAC Method 967.21) as described by Nielsen, (2017). Beta carotene was determined using a method described by Rodriguez-Amaya & Kimura, 2004.

Determination of Total Antioxidant Activity

The total antioxidant activity was determined using DPPH assay as described by Ahmed, Khan and Saeed, (2015)

Determination of proximate composition

The moisture content was determined by using the draft oven method (Nielsen, 2017) by drying overnight at 105°C. Total ash was determined by oxidizing the samples according to methods described by Nielsen, (2017) at 550-600°C for 8 hrs. The dietary fiber content was determined using the acid detergent fiber assay (Nielsen, 2017) using the FOSS Fiber Tec 2010 equipment. Protein composition was determined from total nitrogen using Kjeldahl method as described by Nielsen, 2017. Crude fat was quantified according to the soxhlet method (Nielsen, 2017) using a Soxhlet extracting machine (Soxtec System HT 1043) using petroleum ether (40-60 bps). Carbohydrates composition was determined according to Phenol-Sulfuric method. Dry matter content was determined using a method of Karakashova et al., 2016.

Mineral Analysis

Sodium, Potassium, Iron, Magnesium, Calcium and Phosphorous of fresh pineapple samples were determined using dry ashing and Atomic Absorption Spectroscopy methods (Nielsen, 2017). 5g of pineapple samples were weighed and placed in a crucible and ignited at 550°C overnight. The muffle furnace was turned off and crucibles transferred to desiccators for cooling. The ash was then dissolved in 20mls of 1:1 68% Nitric acid to water solution and the solution was warmed so as to dissolve any un-dissolved particles. The solution was then filtered through an acid washed filter paper to a 100 mL volumetric flask. The solution was then diluted to volume with potassium chloride solution and transferred the solution to the sample Vials. Standard solutions of different minerals earlier prepared in the concentrations of 0.1, 0.5, 1.00, 2.00 and 5.00 ppm were used in the calibration. The samples were then analyzed with an Atomic Absorption Spectrophotometer (Analysit-400, PerkinElmer).

Data Analysis

The physicochemical data was collated, coded and analyzed using SPSS version 23.0 software using One-way and two-way Analysis of Variance (ANOVA) at a confidence interval of 95% and significance deduced at $p \leq 0.05$. Two-way ANOVA was conducted to determine the main and interaction effects between pineapple variety and the Source area for each parameter. One-way ANOVA was conducted to evaluate the effects of the different varieties and production areas on the physicochemical properties of pineapples.

RESULTS AND DISCUSSION

Physical characteristics of Pineapples grown in Uganda

Physical characteristics of pineapple varieties grown in Uganda is presented in Table 2 below. The results from the study revealed that the overall weight of the pineapples ranged from 1.278 to 2.013 kg. Significant differences were observed between different cultivars obtained from different source areas (Table 3). Variety, source area and their interaction all had a significant effect with consideration to weight (Table 4). The diameter of the pineapples in this study ranged from 11.63 to 13.75cm. Both the variety type, Source area and their interaction had a significant effect on the diameter (Table 3). The circumference of pineapples varied between 37.5 and 43.72cm. The variety type, Source area and their interaction significantly influenced the pineapple circumference at $p \leq 0.05$. Pineapple height was measured before and after removing the crowns. The height of the pineapples with crown varied from 30.06 to 36.04cm. The source area had a significant effect on height of pineapples with crowns at $p \leq 0.05$. Both Source area and the interaction had a significant influence on height of pineapples without the crown. Pulp to peel ratio was determined as the ratio of the pulp weight to waste weight. In this study, the pulp to peel ratio varied from 0.45 to 2.02. Pulp to peel ratio was significantly affected by the variety type, source area and their interaction at $p \leq 0.05$.

The effect of variety and source area on the physical characteristics of fresh pineapple is presented in Table 4. Both variety and Source area had significant effects on the morphological characteristics of fresh pineapple. Masaka grown pineapples had the maximum weight, diameter, circumference and height of 1.90kg, 13.20cm, 42.11cm, 35.44cm, 17.40cm respectively. Kayunga grown pineapples had the highest pulp to peel ratio of 1.47. Smooth cayenne variety had the highest mean weight, diameter, circumference and height of 1.90kg, 13.40cm, 42.93cm, 16.95cm respectively. The Queen Pineapple variety however had the highest pulp to peel ratio of 1.43 and maximum height with crown of 33.89cm. Luwero pineapples scored the least on all attributes having the least weight, diameter, circumference, height and pulp to peel ratio with mean values of 1.57kg, 12.4cm, 40.1cm, 31.55cm, 15.84cm and 0.70 respectively. The weight of sooth cayenne pineapples was within the range stated by Asare (2012) of 1.8 to 4.5 kg. Queen pineapple weight values were approximately in the range of 1 to 1.5 kg reported for this variety by Hossain and Bepary (2015). Diameter values for smooth cayenne were consistent with values reported by Bartolome, Ruperez, and Fuster (1995). Height values for smooth cayenne were in agreement with values reported by Bartolome et al., (1995) found to be on average 17.9cm

TABLE 2: Physical characteristics of Fresh Pineapple Varieties

Variety	Source area	Weight (kg)	Diameter (cm)	Circumference (cm)	HWC (cm)	HWoC (cm)	PPR
Queen	Luwero	1.28±0.22^{a}	11.63±0.68^{a}	37.50± 2.73^{a}	33.04± 2.93^{ab}	14.66±1.48^{a}	0.58± 0.81^{a}
	Kayunga	1.54±0.28^{b}	11.93± 1.11^{a}	36.64± 3.85^{a}	33.79± 5.08^{ab}	15.34±2.29^{a}	2.01± 0.56^{b}
	Masaka	2.00±0.12^{c}	13.10± 0.72^{b}	41.84± 0.85^{b}	34.84±1.70^{ab}	18.58±0.97^{c}	1.70± 0.13^{b}
Smooth Cayenne	Luwero	1.86±0.13^{c}	13.17±0.65^{b}	42.70± 1.10^{b}	30.05± 3.54^{a}	17.03±1.14^{b}	0.80± 0.07^{a}
	Masaka	1.84±0.19^{c}	13.29± 0.51^{b}	42.38± 1.50^{b}	36.04± 3.58^{b}	16.20±1.34^{bc}	0.45± 0.47^{a}
	Kayunga	2.01±0.10^{c}	13.75±0.63^{b}	43.72± 1.38^{b}	33.0± 1.20^{ab}	17.63±1.14^{c}	0.93± 0.54^{a}

Means of parameters in the same column followed by different superscripts are significantly different at p<0.05

TABLE 3: ANOVA Summary Table for Morphological Characteristics of Fresh Pineapple

Source of variation	Weight (kg)	Diameter (cm)	Circumference (cm)	HWC (cm)	HWoC (cm)	PPR
Variety	33.58±0.00	36.58±0.00	49.90±0.00	0.77±0.38	3.44±0.07	20.68±0.00
Production Area	15.76±0.00	6.53±0.00	4.81±0.01	6.42±0.00	5.53±0.01	8.90±0.00
Variety × Production Area	17.36±0.00	6.29±0.00	9.40±0.00	1.88±0.16	14.83±0.00	10.66±0.00

Values represent F-ratios ± p-values, HWC=Height with Crown, HWoC=Height Without Crown

TABLE 4: Effect of Variety and Source area on the Morphological Characteristics of Fresh Pineapple (Mean ± SE)

	Weight (kg)	Diameter (cm)	Circumference (cm)	HWC (cm)	HWoC (cm)	PPR
Kayunga	1.78±0.05^{b}	12.84±0.19^{ab}	40.18±0.59^{a}	33.41±0.94^{ab}	16.49±0.40^{b}	1.47±0.15^{c}
Luwero	1.57±0.04^{a}	12.40±0.14^{a}	40.10±0.43^{a}	31.55±0.68^{a}	15.84±0.29^{a}	0.69±0.11^{a}
Masaka	1.90±0.05^{b}	13.19±0.17^{b}	42.11±0.54^{b}	35.44±0.85^{b}	17.39±0.36^{c}	1.07±0.14^{b}
SC	1.90±0.04^{b}	13.40±0.13^{b}	42.93±0.397^{b}	33.04±0.63^{a}	16.95±0.269^{b}	0.73±0.10^{a}
Queen	1.59±0.04^{a}	12.22±0.15^{a}	38.66±0.456^{a}	33.89±0.73^{b}	16.19±0.309^{a}	1.43±0.12^{b}

Mean values of the same superscript in column are not significant at 0.05 level SC= Smooth Cayene, HWC=Height with Crown, HWoC=Height without Crown

Bio-Chemical Characteristics of the Fresh and Solar Dried Pineapple

Findings revealed significant differences for all tested variables with the exception of titratable acidity (Table 5). The pH values ranged from 3.47 to 4.32. Significant differences in pH were observed between different pineapple cultivars and between varieties obtained from different areas at p≤0.05. There was a statistically significant interaction between the effects of variety and Source area on the pH of pineapple at p≤0.05 (Table 6). Asare, (2012), states that pH of pineapple should range from 3.2 to 4.00 which is consistent with values obtained from this study. Solar dried pineapples had a pH within the range of 3.33 to 4.13 and were more acidic than the fresh samples. The titratable acidity values of fresh samples ranged from 0.11 to 0.18 % citric acid g/100g while that of dried samples ranged from 3.58 to 4.52 thus there was an observed increase in total acids during the drying process. Total acids were found to vary significantly between the two varieties, between varieties from different production areas (Table 6) at p≤0.05. There was a statistically significant interaction of Source area and variety on the total acids content of pineapple. Total acidity did not differ from cultivar to cultivar and between areas of production (p≤0.05). pH of solar dried pineapple was significantly affected by variety, source area as well as interaction. Titratable acidity was significantly affected by variety (p=0.02) and source area (p = 0.04) respectively (Table 6). This is so because during the drying process there is a concentration of organic acids as water is driven off explaining the variation (Mongi, 2013). The average moisture content of the fresh samples in this study ranged from 80.64 to 86.92% while moisture content of solar died pineapple varied between 7.45 and 14.2%. (Table 5). Moisture content values showed a significant variation between varieties sourced from different regions and the interaction effect between Source area and variety on moisture content at P<0.05 (Table 6). However, there was no significant difference in moisture content of the different varieties since p>0.05 (Table 6).

Moisture content of solar died pineapple varied between cultivars and between areas of production. Pineapples are known to consist of water contents in the range of about 81.2-87% of fresh weight (Asare, 2012) which is consistent with values from this study. Findings also were consistent with values reported by Mongi (2013), stated to be about 80.6% moisture content in fresh pineapple. Solar dried pineapple had lower moisture contents compared to the fresh samples because of the loss of water during the drying process.

The average dry matter content of fresh samples ranged from 13.08 to 19.36% while for solar dried pineapple it ranged from 85.81 to 92.41% (Table 5). Pineapple varieties sourced from different regions showed a significant variation in dry matter content at $p \leq 0.05$. A highly significant interaction between Source area and variety on dry matter content at $p \leq 0.05$ was observed (Table 6). However, there was no significant difference in dry matter content between the varieties ($p = 0.973$) i.e. $p > 0.05$. In the drying process, water is driven off and there is a concentration of total solids as a resulting effect which can explain why solar dried samples have a significantly higher dry matter content than the fresh samples.

The total antioxidants in this study ranged from 10.87 to 17.84% antioxidant activity (Table 5). According to Table 3.6, results showed a significant difference in the total antioxidant content of different varieties cultivated in different areas at $p \leq 0.05$. However, no significant interaction was observed between Source area and variety with respect to total antioxidant content and between different varieties i.e. $p > 0.05$ (Table 6). Dietary fiber ranged from 3.38 to 11.73 mg/100 g of fresh samples while the dietary fiber of the solar dried pineapple varieties ranged from 6.35 – 10.07 % (Table 5). Table 6 shows a significant difference in dietary fiber between varieties; between varieties from different areas and a significant interaction between Source area and variety on dietary fiber at $p \leq 0.05$. Findings reported no significant differences among varieties and production areas with respect to dietary fiber (Table 6). In this study, beta carotene content of fresh samples ranged from 20.76 to 36.85 mg/100g of fresh weight while that of solar dried samples ranged from 0.08 to 0.23 RAE mg/100g (Table 5). Significant variations were observed in the beta carotene levels of different varieties, between varieties cultivated in different areas in Uganda at $P < 0.05$. A significant interaction effect of source area and variety on the beta carotene content was observed (Table 6). Main effects of the differences in Source area were not significant with respect to beta carotene (Table 7). There was a significant interaction effect of variety and Source area vitamin A of solar dried pineapple. There was a significant reduction in beta carotene levels during the drying process as can be observed in this study that fresh samples had higher values as compared to the solar dried samples. This is because beta carotene is thermo labile and can easily be destroyed in the presence of heat, light, oxygen, enzymes, moisture and metal ions. The UV radiation from the sun enhances the photo catalytic oxidation of beta carotene during the drying process (Ndawula, Kabasa, & Byaruhanga, 2004). Vitamin C content in this study ranged from 6.22 to 12.81mg/100g of fresh weight while that of solar dried pineapple was significantly different from cultivar to cultivar and between areas of production and was found to be in the range of 3.97 to 16.25 mg per 100g dry matter (Table 5).

Significant differences at $p<0.05$ were observed in the ascorbic acid content levels of different varieties, between varieties sourced from different areas respectively (Table 6). A statistically significant interaction effect was observed on the ascorbic acid content. However, results from this study were much lower than values reported by Asare (2012); Wardy, Saalia, Asiedu, & Budu (2009) reported to be in the range of 20 to 34.44 mg/100 g (Asare, 2012). The vitamin C content of fruits varies widely based on a number of factors ranging from species, variety, stage of maturity, storage conditions, part of fruit, place of growth, harvesting period, storage, processing methods among many others (Asare, 2012). Vitamin C of solar dried samples was relatively higher than that of fresh samples. This can be explained by the fact that the tunnel dryer creates an inert atmosphere by reducing the presence of oxygen which enhances vitamin C retention as can be observed in this study (Mongi, 2013). Pineapple TSS in the study ranged from 7.9 to 13.3°Brix (Table 5). The TSS of queen pineapple ranged from 7.9 to 13.3°Brix while that for smooth cayenne ranged from 11.84 to 12.28 °Brix. Significant differences were observed in the TSS values of different varieties obtained from different areas in Uganda. Only Source area was found to have a significant influence on the sweetness levels of the pineapple varieties at $p \leq 0.05$. An international index for establishing pineapple maturity is total soluble solids with a value set at 12ºBrix established by CODEX and FAO/WHO in international trade to guarantee consumer acceptance (Australian Government Office of the Gene Technology Regulator, 2008). For pineapples, TSS ranges between 10.8 - 17.5% with very little variations between varieties (Asare, 2012; Steiner-Aseidu et al., 2009). However, results from this study revealed even much lower values of up to 7.9°Brix. During the development of the flesh of a fruit, in many species, nutrients are deposited as starch, which during the ripening process is transformed into sugars. Values as low as 7.9°Brix may suggest that pineapple samples used for the analysis were still immature. TSS values for queen pineapple have been reported to be within 14-19 ºBrix (Hossain & Bepary, 2015) which is slightly higher than values obtained in this study of 7.9 to 13.3 ºBrix. TSS values for smooth cayenne pineapple in this study were slightly higher than values reported for this variety by Wardy et al., (2009) found to be about 11.59 ºBrix. The effect of variety and source area on the physicochemical composition of fresh pineapple varieties is shown in Table 7. Findings showed significant differences across all evaluated parameters for all production areas ($p<0.05$). pH, titratable acidity, moisture content and vitamin A were highest in Queen pineapple with mean values of 3.79, 0.14%, 83.31% and 30.82mg/100g respectively. On the other hand, dry matter content, total antioxidants, vitamin C and total soluble solids were highest in smooth cayenne pineapple with mean values of 16.71%, 14.05%, 10.74 mg/100g and 12.13°Brix respectively. Masaka grown pineapples were the most acidic with a mean pH of 3.57 while Luwero grown pineapples were the least acidic with a pH of 3.96. Moisture content was highest in Masaka grown pineapples with a mean value of 85.91% while the least moisture content was found in Luwero grown pineapples. However, Luwero pineapples had a significantly higher dry matter content (18.33%) as compared to pineapples grown in the other areas. Kayunga pineapples recorded the highest total antioxidants (16.78%) and Total Soluble Solids (12.77 °Brix) respectively. Beta carotene was highest in Luwero pineapples (34.31) while Vitamin C was highest in Masaka grown pineapples (9.89)

TABLE 5: Physico-Chemical Properties of Fresh and Solar Dried Pineapple from Varieties Grown in Different Parts of Uganda

Source	PH	TA (%)	MC (%)	DM (%)	TAO (%)	β-Carotene	AA	TSS (°Brix)
Kayunga ^{FR,SC}	3.78±0.00^{dc}	0.17±0.01^{c}	80.64±1.57^{a}	19.36±1.57^{c}	17.84±2.16^{c}	27.60±0.57^{b}	8.90±0.36^{b}	12.26±0.83^{ab}
Kayunga ^{SD,SC}	4.13±0.04^{c}	3.69±0.30^{a}	9.45±3.79^{ab}	90.55±3.79^{bc}		0.23±0.04^{ab}	3.97±0.73^{a}	
Luwero ^{FR,SC}	3.60±0.03^{b}	0.13±0.01^{b}	82.32±0.19^{a}	17.68±0.19^{c}	12.62±2.52^{ab}	31.77 ±0.64^{c}	12.81±2.4^{d}	11.84±1.72^{ab}
Luwero ^{SD,SC}	3.65±0.060^{b}	4.51±1.30^{a}	14.20±0.71^{c}	85.81±0.71^{a}		0.14±0.08^{ab}	16.25±2.1^{d}	
Masaka ^{FR,SC}	3.67±0.01^{c}	0.11±0.01^{a}	86.92±0.45^{c}	13.08±0.45^{a}	11.70 ±1.57^{a}	20.76±0.73^{a}	10.49±0.3^{c}	12.28±1.45^{ab}
Masaka ^{SD,SC}	3.33±0.05^{a}	4.14±0.14^{a}	13.12±1.10^{bc}	86.88±1.10^{ab}		0.08±0.03^{a}	15.55±2.0^{d}	
Kayunga ^{FR,Q}	3.59±0.01 ^{b}	0.18 ±0.01^{c}	84.01±2.33^{b}	15.99±2.33^{b}	15.72±2.43^{bc}	25.80±1.59^{b}	8.43±0.63^{b}	13.3±1.02^{b}
Kayunga ^{SD,Q}	4.11±0.02^{c}	3.67±0.12^{a}	7.59±0.68^{a}	92.41±0.68^{c}		0.41±0.40^{b}	8.21±0.88^{b}	
Luwero ^{FR,Q}	4.32±0.00^{e}	0.12±0.01^{b}	81.02±0.21^{a}	18.98±0.21^{c}	13.97±1.88^{ab}	36.85±0.46^{d}	6.22±0.42^{a}	7.9±5.43^{a}
Luwero ^{SD,Q}	3.43±0.05^{a}	3.58±0.23^{a}	12.60±0.25^{bc}	87.40±0.25^{ab}		0.11±0.04^{a}	16.01±1.5^{d}	
Masaka ^{FR,Q}	3.47±0.01^{a}	0.13±0.01^{b}	84.91±1.18^{bc}	15.09±1.18^{ab}	10.87±1.35^{a}	29.80±2.75^{c}	9.29±0.32^{bc}	10.8±0.87^{ab}
Masaka ^{SD,Q}	3.60±0.08^{b}	4.52±0.59^{a}	13.42±0.36^{bc}	86.58±0.36^{ab}		0.21±0.05^{ab}	12.2±2.13^{c}	

**Values are presented as means ± standard deviations of triplicate determinations,*
**Means of parameters in the same column followed by different superscripts are significantly different at p<0.05*

TABLE 6: ANOVA Summary Table for Physico-Chemical Analyses of Fresh and Solar Dried Pineapple

Source of variation	*PH*	*TA*	*MC*	*DM*	*TAO*	*DF*	*β-Carotene*	*AA*	*TSS*
Variety ^{FR}	*416.67±0.00*	*10.73±0.00*	*0.00±0.97*	*0.00±0.97*	*0.70±0.4*	*16.19±0*	*103.89±0.00*	*88.87±0.0*	*2.79±0.10*
Variety ^{SD}	*7.64±0.04*	*10.31±0.02*	*2.70±0.16*	*2.70±0.16*			*1.11±0.34*	*4.82±0.08*	
Source area^{FR}	*1811.17±0.00*	*317.84±0.0*	*28.15±0.00*	*28.15±0.00*	*22.38±0*	*67.06±0.0*	*198.26±0.00*	*6.16±0.00*	*3.96±0.03*
Source area^{SD}	*127.84±0.00*	*6.94±0.04*	*94.39±0.00*	*94.39±0.00*			*1.64±0.28*	*12.42±0.0*	
Variety × Source area^{FR}	*3128.17±0.00*	*12.29±0.00*	*11.04±0.00*	*11.04±0.00*	*2.5±0.1*	*41.68±0.0*	*61.09±0.00*	*43.54±0.0*	*2.76±0.07*
Variety × Source area^{SD}	*47.77±0.00*	*4.46±0.09*	*15.48±0.01*	*15.48±0.01*			*31.67±0.00*	*0.22±0.66*	

Values represent F-ratios ± p-values TA = Titratable Acidity, MC = Moisture Content, DM = Dry Matter, TAO = Total Antioxidants, DF = Dietary Fiber, VIT.A = Vitamin A, AA = Ascorbic Acid, TSS = Total Soluble Solids, FR = Fresh, SD = Solar Dried, SC=Smooth Cayene and Q=Queen,

TABLE 7: Effect of Variety and Source area on the Physicochemical Content of Fresh Pineapple (Mean ± SE)

Source area, Variety	pH	Titratable Acidity	Moisture Content (%)	Dry Matter Content (%)	Total Anti-Oxidants (%)	β-Carotene (mg/100g)	Vitamin C (mg/100g)	TSS (°Brix)
Kayunga	3.68±0.01^{b}	0.17±0.00^{c}	82.33±0.45^{a}	17.67±0.45^{b}	16.78±0.67^{c}	26.70±0.34^{a}	8.66±0.25^{a}	12.77±0.86^{c}
Luwero	3.96±0.01^{c}	0.13±0.00^{b}	81.67±0.45^{a}	18.33±0.45^{b}	13.30±0.49^{b}	34.31±0.34^{b}	9.52±0.25^{b}	9.92±0.61^{a}
Masaka	3.57±0.01^{a}	0.12±0.00^{a}	85.91±0.42^{b}	14.09±0.42^{a}	11.29±0.48^{a}	25.28±0.38^{a}	9.89±0.25^{b}	11.54±0.74^{b}
SC	3.68±0.00^{a}	0.14±0.00^{a}	83.30±0.36^{a}	16.71±0.36^{a}	14.05±0.50^{b}	26.71±0.30^{a}	10.73±0.21^{b}	12.13±0.58^{b}
Queen	3.79±0.00^{b}	0.14±0.00^{b}	83.31±0.35^{a}	16.69±0.35^{a}	13.52±0.40^{a}	30.82±0.27^{b}	7.98±0.21^{a}	10.69±0.63^{a}

Mean values with the same superscript in column are not significant at 0.05 level, SC = Smooth Cayenn

Proximate composition of fresh and solar dried pineapple

The proximate composition of fresh and solar dried pineapple is presented in Table 8. For fresh pineapple findings showed no significant differences (p<0.05) between varieties and between production areas across all parameters tested with the exception of dietary fiber which showed significant differences. The crude protein content of fresh pineapple ranged from 1.41 to 2.43%, Crude fat ranged from 0.36 to 1.44%, Carbohydrates ranged from 10.56 to 12.97%, Ash content ranged from 2.18 to 2.77% while Dietary fiber ranged from 3.38 to 11.73%. Main effects and interaction effects on the tested parameters are shown in the Table 9. Main effects related to differences in variety and production areas had no significant effect (p>0.05) on parameters related to crude protein, crude fat, carbohydrates, ash. Crude protein was however significantly affected by Source area differences (p=0.016) while crude fat was significantly influenced by the interaction effect of variety and Source area (p=0.036). Differences in variety, Source area and their interaction all had a significant effect on the dietary fiber composition of fresh pineapple (see Table 9). The effect of variety and Source area on the proximate composition of fresh pineapple varieties is presented in Table 10. The findings revealed significant differences (p<0.05) across evaluated parameters. The variation in proximate composition of fresh pineapple across different production areas was significant for all measured parameters with the exception of ash content only i.e. (p>0.05). Similarly, significant variations were observed across different varieties for all measured attributes with the exception of fat content which did not vary significantly (p>0.05). The Queen variety had significantly higher protein (1.99) and carbohydrate (12.08) contents while Smooth cayenne had significantly higher fat (1.07), ash (2.65) and dietary fiber (6.98) contents. Protein (2.40), Ash (2.58) and dietary fiber (8.92) were highest in Masaka grown pineapples while fat and carbohydrate content were highest in Luwero grown pineapples with values of 1.32 and 11.90 respectively.

Ash content, dietary fiber was significantly higher than values obtained from earlier studies by Mongi, (2013) which were 1.6±0.2, 2.1±1.1 respectively. However, crude protein and fat content were found to be consistent for tunnel-dried samples and these were 2.1±1.1 and 0.9±0.1 respectively. Ash results from this study were consistent with those from earlier studies by Morais and others (2017) which showed proximate content of pineapple pulp to be in the range of 2.7±0.3%. Table 8 shows the proximate composition of solar dried pineapple. The crude protein, fat, and ash were in the range of 1.38–2.63%, 0.37–1.76% and 0.63–2.73% respectively. The dietary fiber of the pineapple varieties was 6.35–10.07% dry matter, Carbohydrate content ranged from 3.95-12.19% and was found to be significantly different ($p<0.05$) among the varieties and production areas. The amount of protein, fat and ash varied significantly among the two pineapple varieties and three source areas (Table 8). Findings reported no significant differences among varieties and production areas with respect to total ash and dietary fiber respectively (Table 9).

Crude protein was significantly affected by differences in source area. Crude fat was significantly affected by the interaction effect between variety and Source area and the main effects of Source area differences. Findings from this study imply that the solar drying process has minimal effects on the proximate properties of solar dried pineapple as these are much similar to values of fresh pineapple. A report by Mongi, (2013) suggests that during drying there is loss of both proteins and lipids (fat) due to a number of complex reactions such as oxidation and hydrolysis etc. which is contrary to the study findings as these were enhanced in the current study. Dietary fiber is however less affected because it is less sensitive to thermal degradation. Regardless there were minimal changes to the proximate composition of pineapple during solar drying (Table 8). Mongi, (2013) also suggests that retention of proximate properties during solar drying varies based on plant composition which in turn influences different reactions and behavior during drying resulting into different recovery values between the varieties within the fruits

TABLE 8: Proximate Composition of Fresh and Solar Dried Pineapple

Cultivar	Source area	Proximate content (%)				
		Crude protein	Crude fat	Carbohydrates	Ash	Dietary fiber
Smooth Cayenne	Kayunga ^{FR}	1.41 ± 0.47 ^{a}	1.24 ± 0.98 ^{a}	10.56 ± 0.56 ^{a}	2.77 ± 0.04 ^{a}	4.82 ± 0.83^{a,b}
	Kayunga ^{SD}	1.38±0.41^{a}	1.57±0.42 ^{b}	3.945±0.59 ^{a}	2.73±0.06 ^{a}	6.35±0.71 ^{a}
	Luwero ^{FR}	1.75 ± 0.56 ^{a}	1.29 ± 0.13 ^{a}	10.83 ± 1.14 ^{a}	2.53 ± 0.33 ^{a}	4.38 ± 0.12^{a,b}
	Luwero ^{SD}	1.79±0.58 $^{a, b}$	1.34±0.12 ^{b}	11.768±4.12 ^{b}	0.82±1.27 ^{a}	8.91±0.96 ^{a}
	Masaka ^{FR}	2.37 ± 0.46 ^{a}	0.67 ± 0.19 ^{a}	11.76 ± 1.95 ^{a}	2.64 ± 0.26 ^{a}	11.73 ± 1.32 ^{d}
	Masaka ^{SD}	2.43±0.49^{a,b}	1.00±0.45^{a,b}	12.186±3.12 ^{b}	0.63±0.99 ^{a}	9.28±2.33 ^{a}
Queen	Kayunga ^{FR}	1.87 ± 0.23 ^{a}	0.36 ± 0.18 ^{a}	11.42 ± 1.27 ^{a}	2.18 ± 0.04 ^{a}	7.14 ± 0.84 ^{c}
	Kayunga ^{SD}	1.89±0.27 $^{a, b}$	0.37±0.17 ^{a}	4.258±0.93 ^{a}	2.13±0.06 ^{a}	8.98±3.83 ^{a}
	Luwero ^{FR}	1.68 ± 0.045 ^{a}	1.35 ± 0.18 ^{a}	12.97 ± 0.61 ^{a}	2.49 ± 0.42 ^{a}	3.38 ± 0.29 ^{a}
	Luwero ^{SD}	1.68±0.05 $^{a, b}$	1.44±0.32 ^{b}	9.118±1.44 ^{b}	0.63±0.98 ^{a}	10.07±2.03 ^{a}
	Masaka ^{FR}	2.43 ± 0.48 ^{a}	1.44 ± 0.55 ^{a}	11.85 ± 0.87 ^{a}	2.52 ± 0.27 ^{a}	6.11 ± 0.47$^{b, c}$
	Masaka ^{SD}	2.63±0.45 ^{b}	1.76±0.11 ^{b}	7.645±3.67 $^{a, b}$	1.2±1.64 ^{a}	9.64±2.06 ^{a}

Values are presented as means and standard deviations (in parentheses) of triplicate determinations.
Means of parameters in the same column followed by different superscripts are significantly different at $p<0.05$

TABLE 9: ANOVA Summary for Proximate Composition of Fresh Pineapple Varieties

Source of Variation	*Proximate Composition*				
	Crude Protein	Crude Fat	Carbohydrates	Ash	Dietary Fiber
Variety ^{FR}	*0.54 ± 0.48*	*0.01±0.93*	*3.50±0.09*	*4.15±0.06*	*16.19±0.00*
Variety ^{SD}	*1.02±0.33*	*0.65±0.43*	*3.78±0.08*	*4.21±0.06*	*2.80±0.12*
Source area^{FR}	*5.96 ± 0.02*	*1.79±0.21*	*1.10±0.36*	*0.24±0.79*	*67.06±0.00*
Source area^{SD}	*8.48±0.01*	*3.92±0.05*	*1.18±0.34*	*0.22±0.81*	*0.77±0.49*
Variety × Source area^{FR}	*0.64±0.55*	*4.43±0.04*	*1.20±0.34*	*1.88±0.19*	*41.68±0.00*
Variety × Source area^{SD}	*0.85±0.45*	*16.81±0.00*	*1.13±0.36*	*1.92±0.19*	*1.35±0.30*

Values represent F-ratios ± p-values

TABLE 10: Effect on variety and Source area on the proximate composition of fresh pineapple (Mean ± SE**)**

Source area	Protein (%)	Fat (%)	Carbohydrates (%)	Ash (%)	Dietary Fiber (%)
Kayunga	1.640 ± 0.171^{a}	0.796 ± 0.196^{a}	10.992 ± 0.476^{a}	2.477 ± 0.109^{a}	5.978 ± 0.309^{b}
Luwero	1.718 ± 0.171^{a}	1.320 ± 0.196^{c}	11.902 ± 0.476^{a}	2.511 ± 0.109^{a}	3.880 ± 0.309^{a}
Masaka	2.400 ± 0.171^{b}	1.057 ± 0.196^{b}	11.805 ± 0.476^{a}	2.582 ± 0.109^{a}	8.919 ± 0.309^{c}
SC	1.847 ± 0.140^{a}	1.067 ± 0.160^{a}	11.052 ± 0.389^{a}	2.651 ± 0.089^{a}	6.977 ± 0.252^{b}
Queen	1.992 ± 0.140^{b}	1.048 ± 0.160^{a}	12.080 ± 0.389^{b}	2.396 ± 0.089^{a}	5.541 ± 0.252^{a}

Mean values of the same letter in column are not significant at 0.05 level, SC = Smooth Cayenne

Mineral composition of fresh and solar dried pineapple

The contents of six different mineral elements of different pineapple varieties are shown in Table 11. Results show that the mineral composition varied between cultivars and source areas. Potassium was the most abundant mineral present in fresh pineapple fruit ranging from 1878 mg/100g to 239.72 mg/100 g. Magnesium varied between 117.1 mg/100g and 44.4 mg/100g. Calcium varied between 16.91 mg/100g and 89.34 mg/100g. The pineapple varieties had lower levels of iron, ranging from 2.54 to 6.28 mg/100g. Sodium varied from 92.45 mg/100g to 12.8 mg/100g while phosphorous ranged from 83.54 mg/100g to 5.40 mg/100g. Main and interaction effects of Source area and variety are shown in Table 12. Findings revealed significant main and interaction effects of variety and Source area on the calcium, iron and sodium content of the fresh pineapple varieties ($p=0.000$). Magnesium, potassium and phosphorus content was significantly influenced by simple main effects of differences in Source area ($p=0.000$) and the interaction effect of varietal and Source area differences ($p=0.001$). Effects of variety and Source area on the mineral composition of fresh pineapple are presented in Table 13. Results showed significant variations ($p<0.05$) on the mineral composition of fresh pineapple between varieties and source areas. Mineral composition of all varieties was significantly different ($p<0.05$). Mineral composition was maximum in the Queen variety for iron (4.86), magnesium (81.97), sodium (43.53), potassium (884.47) and phosphorus (54.48). Only calcium content was found to be highest in smooth cayenne variety (52.87). Masaka grown pineapples had the highest Calcium, Iron, Phosphorus and Magnesium contents with mean values of 53.12, 5.52, and 101.07 and 71.32mg/100g respectively. Kayunga pineapples had the highest Sodium (52.62) and Potassium (1822.63) mg/100g values respectively. Results in Table 11 show the mineral composition of solar dried pineapple varieties. The mineral content of solar dried pineapple differed from cultivar to cultivar and from one Source area to another. Findings revealed that potassium was the most abundant mineral retained in pineapple fruit after solar drying ranging from 243.05 mg/100 g to1876.05 mg/100 g.

Magnesium was the second abundant mineral retained in pineapple ranging from 59.92 mg/100 g to 111.07 mg/100g. Calcium was the third highest mineral retained in pineapple with values ranging from 16.24 mg/100g to 89.33 mg/100g. As shown in Table 11, the mineral composition showed lower levels of Fe, this ranged from 2.47 to 6.21 mg/kg. Sodium content ranged from 12.77 mg/100g to 92.45 mg/100g. Phosphorous content was found to be in the range of 25.50 mg/100g to 83.87 mg/100g.

There was significant variation in mineral composition of solar dried pineapple produced from different varieties ($p<0.05$) with regards to calcium, iron and sodium (Table 12). Magnesium, phosphorus and potassium did not vary significantly among the different varieties ($p>0.05$). Mineral composition varied significantly amongst the different production areas for all measured parameters. It is noteworthy that minerals are important not only for human nutrition, but also for plant nutrition. However, the mineral contents of plants could be affected by varietal differences, soil nutrient content, time of harvest, genetic and climates agronomic factor and seasonal variations among many other factors (Lu et al., 2014; Mongi, 2013). Minimum differences were observed in the mineral composition of both fresh and dried pineapples in this study (Table 11). This can be explained by the fact that minerals are thermo stable components even at temperatures as high as 550-600ºC, thus the solar drying process has a minimal effect on mineral content of fruits (Mongi, 2013). Iron was the least mineral in both the fresh and dried samples probably because pineapple plants are peculiar in a way that they have an inability to obtain iron even from an iron-rich soil under certain conditions (Lobo & Siddiq, 2016). As observed in the study the iron content was highest in Luwero and Masaka grown pineapples because the soil type within these areas is rich in iron as compared to the Kayunga district soil type (Luwero District Local Government, 2012; Masaka District Local Government, 2012; UBoS, 2017).

TABLE 11: Mineral composition (mg/100g) of fresh pineapple varieties grown in Uganda

Source	Calcium	Iron	Magnesium	Sodium	Potassium	Phosphorus
Kayunga ^{FR,SC}	24.18±3.97^{a,b}	2.78±0.15^{a,b}	71.60±6.07^{a,b}	12.80±1.05^{a}	1878.38±101.14^{d}	49.93±2.29^{b}
Kayunga ^{SD,SC}	24.17±3.96^{a}	2.74±0.12^{a}	71.62±6.09^{a,b}	12.77±1.03^{a}	1876.05±100.53^{c}	49.91±2.41^{b}
Luwero ^{FR,SC}	45.08±0.74^{c}	3.79±0.47^{b}	78.23±2.30^{b,c}	13.70±1.70^{a}	343.56±38.54^{a}	25.40±2.11^{a}
Luwero ^{SD,SC}	44.98±0.60^{c}	3.84±0.53^{b}	78.24±2.30^{b,c}	13.88±1.95^{a}	338.56±18.29^{a}	25.50±2.25^{a}
Masaka ^{FR,SC}	89.34±4.01^{e}	5.27±0.38^{c}	90.89±2.22^{c}	71.63±3.13^{c}	239.72±24.57^{a}	83.54±4.62^{d}
Masaka ^{SD,SC}	89.33±4.01^{e}	5.68±0.29^{c,d}	90.93±2.16^{c}	71.64±3.15^{c}	243.05±28.67^{a}	83.87±4.06^{d}
Kayunga ^{FR,Q}	27.56±1.60^{b}	2.54±0.31^{a}	59.98±4.53^{a}	92.45±1.65^{d}	1766.87±127.42^{d}	51.57±1.66^{b}
Kayunga ^{SD,Q}	27.62±1.69^{b}	2.47±0.20^{a}	59.92±4.43^{a}	92.45±1.65^{d}	1770.87±121.41^{c}	51.91±1.31^{b}
Luwero ^{FR,Q}	56.00±2.74^{d}	6.28±0.41^{c}	74.17±1.13^{b,c}	20.97±0.77^{b}	336.65±11.88^{a}	52.77±1.32^{bc}
Luwero ^{SD,Q}	56.22±2.39^{d}	6.21±0.33^{d}	74.04±1.07^{a,b}	20.97±0.77^{b}	336.72±11.73^{a}	53.44±1.13^{bc}
Masaka ^{FR,Q}	16.91±4.91^{a}	5.76±0.43^{c}	111.23±11.98^{d}	17.18±2.69^{a,b}	549.89±410.03^{b}	59.09±2.77^{c}
Masaka ^{SD,Q}	16.24±5.45^{a}	5.68±5.45^{c,d}	111.07±11.99^{d}	17.15±2.64^{ab}	549.97±41.12^{b}	59.75±3.41^{c}

** Values are presented as means ± standard deviations of triplicate determinations, *Means of parameters in the same column followed by different superscripts are significantly different at p<0.05*

TABLE 12: ANOVA summary for Mineral composition (mg/100g) of Fresh and Solar Dried Pineapple

Source of variation	Calcium	Iron	Magnesium	Sodium	Potassium	Phosphorus
Variety FR	145.64±0.00	35.19±0.00	0.25±0.62	124.79±0.00	4.21±0.06	2.421±0.15
Variety SD	152.23±0.00	26.75±0.00	0.31±0.59	130.06±0.00	3.63±0.08	1.448±0.25
Source area FR	114.21±0.00	141.07±0.00	55.79±0.00	486.78±0.00	894.13±0.00	230.908±0.00
Source area SD	122.36±0.00	101.29±0.00	55.71±0.00	504.43±0.00	837.34±0.00	221.908±0.00
Variety × Source area FR	277.99±0.00	27.85±0.00	11.78±0.00	1619.87±0.00	14.52±0.00	145.382±0.00
Variety × Source area SD	287.28±0.00	21.61±0.00	11.28±0.00	1666.19±0.00	14.29±0.00	139.901±0.00

TABLE 13: Effect of variety and Source area on the mineral composition (mg/100g) of fresh pineapple (Mean ± SE)

Source area; Variety	Calcium	Iron	Magnesium	Sodium	Potassium	Phosphorus
Kayunga	25.870±1.36 a	2.659±0.152 a	65.791±2.428a	52.623±0.822c	1822.626±29.049b	50.749±1.095b
Luwero	50.538±1.36 b	5.036±0.152 b	76.203±2.428b	17.333±0.822a	340.108±29.049a	39.088±1.095a
Masaka	53.123±1.36 b	5.517±0.152 b	101.066±2.428c	44.403±0.822b	394.807±29.049a	71.314±1.095c
Smooth Cayenne	52.865±1.110b	3.950±0.124a	80.246±1.983a	32.706±0.671a	820.553±23.718a	52.956±0.894a
Queen	33.489±1.110a	4.858±0.124b	81.794±1.983b	43.533±0.671b	884.474±23.718b	54.478±0.894b

Mean values of the same letter in column are not significant at 0.05 level

CONCLUSION

Variety as well as area of production influences the quality properties of pineapples and pineapple products as observed in this study. The variables assessed showed significant differences with the exception of a few for both fresh and solar dried pineapple with regards to variety and area of production. The findings of this study clearly show that pineapple composition can be influenced by genetic and environmental differences. These findings can form the basis of further studies to establish critical parameters for processing of their raw materials to enable them make objective evidence-based decisions and maintain quality. Variability in quality of raw materials has a direct effect on the drying kinetics and overall quality of the subsequent products from the drying process. The physicochemical characteristics evaluated in this study can be important postharvest quality criteria for the processing, screening and breeding. Significant parameters/attributes necessary for making drying decisions include fruit weight, pulp to peel ratio, moisture content and Total soluble solids were analyzed in this study. Fruits for drying should have maximum weight, maximum pulp to peel ratio, minimum moisture content and maximum total soluble solids. The weight of fruits is expected to reflect on the amount of pulp and juice a variety contains and it also serves to determine the amount of waste generated. Smaller weight is convenient and easy to handle but for cut fruits intended for processing, larger fruits are desirable as they generate a considerable amount of pulp. The pulp to peel ratio affects the yield which is the amount of usable food after raw materials are prepared for processing. Moisture content has a direct effect on drying time and safety of the final product while TSS has direct positive influence on sweetness of pineapple more than total sugars. Based on these parameters, Masaka pineapples had the greatest weight but since weight has a direct correlation with amount of juice/moisture within the fruit implies they take a longer time to dry. Therefore, Kayunga pineapples would be the best for drying with respect to weight since they would relatively have a lower juice/moisture content and therefore dry easily. Pineapples grown in Kayunga also had the highest juice content and pulp to peel ratio and therefore considered the most ideal for processing into solar dried snacks. With the exception of the pulp to peel ratio which was high in the Queen pineapple, the smooth cayenne variety scored highest on most the attributes mentioned above and therefore considered most ideal for processing solar dried snacks. Findings from this study show that solar drying has varied significant effects on quality of dried fruits and vegetable; It reduces or enhances antioxidant activity, reduces proteins, fat, vitamin C and color and it enhances flavor (sweetness and aroma) as compared to the nutritional value of fresh pineapple. With exception of vitamin C which suffered greater loss, substantial amount of biochemical and sensory parameters was retained in concentrated form in this study in the solar dried pineapple. Furthermore, solar drying was observed to have no significant effect on ash, crude fiber, minerals and sugars contents of dried pineapple snacks ($p>0.05$).

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REFERENCES

[1] Ahmed, D., Khan, M., and Saeed, R. (2015). Comparative Analysis of Phenolics, Flavonoids, and Antioxidant and Antibacterial Potential of Methanolic, Hexanic and Aqueous Extracts from Adiantum caudatum Leaves. Antioxidants, 4(2), 394–409. https://doi.org/10.3390/antiox4020394

[2] Akhtar, S., Anwar, M., and Hossain, M. F. (2015). Nutritional Value and Medicinal Benefits of Pineapple. International Journal of Nutrition and Food Sciences, 4(1), 84. https://doi.org/10.11648/j.ijnfs.20150401.22

[3] Asare, R. (2012). Comparative assessment of quality of fruit juice from three different varieties of pineapple (ananas comosus l.) grown in Ghana.

[4] Australian Government Office of the Gene Technology Regulator. (2008). The Biology of Ananas comosus var. comosus (Pineapple). http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/pineapple/$FILE/biology pineapple08_2.pdf

[5] Bartolome, A. P., Ruperez, P., and Fuster, C. (1995). Pineapple fruit: Morphological Characteristics, Chemical Composition and Sensory Analysis of Red Spanish and Smooth Cayenne Cultivars. Food Chemistry, 53, 75–79.

[6] Bua, B., Karungi, J., and Kawube, G. (2013). Occurrence and Effects of Pineapple Mealybug Wilt Disease in Central Uganda. Journal of Agricultural Science and Technology A, 3(1), 410–416.

[7] 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. International Journal of Sustainable Crop Production, 3(February), 69–75.

[8] Edwige, Y., Salomé, S., Laurent, K. K., Jean, B., Irénée, P., Patrice, K., and Tanoh, K. (2011). Nutrition & Food Comparison of Pineapple Fruit Characteristics of Plants Propagated in Three Different Ways: By Suckers, Micropropagation and Somatic Embryogenesis. 1(4), 1–8. https://doi.org/10.4172/2155-9600.1000110

[9] FIT. (2007). Final Report - Study for Fruits Sub-Sector (Pineapples, Passion Fruits, Mangoes). 1–124. Retrieved from http://www.ssemwanga.com/

[10] Fournier, P., Dubois, C., and Soler, A. (2007). Considerations on growth characteristics of different pineapple varieties in Ivory Coast, Reunion Island and Caribbean Islands. Agronomy Journal, 41.

[11] Hossain, M., and Bepary, R. H. (2015). Post-harvest handling of pineapples: a key role to minimize the post. International Journal of Recent Scientific Research, 6(9), 6069–6075.

[12] Joy, P. P. (2010). Benefits and Uses of Pineapple. (January 2010). https://doi.org/10.13140/RG.2.1.2782.

[13] Joy, P. P., and Anjana, R. (2015). Evolution of pineapple. Evolution of Horticultural Crops, 5(2), 1–39. https://doi.org/10.1016/S0140-6736 (03)13615-X

[14] Joy, P. P., and Minu, A. (2013). Fruits, benefits, processing, preservation and pineapple recipies - Pineapple Research Station. 1–20. Retrieved from http://prsvkm.kau.in/sites/default/files/documents/fruits_benefits_processing_preservation_pineapple_recipes.pdf

[15] Kamol, S. I., Howlader, J., Dhar, G. C. S., and Aklimuzzaman, M. (2014). Effect of different stages of maturity and postharvest treatments on quality and storability of pineapple. Journal of the Bangladesh Agricultural University, 12(2), 251–260. Retrieved from www.banglajol.info/index.php/jbau/article/view/2867

[16] keige, m. m. (1991). Production of pineapples for processing and fresh markets in Kenya. University of Nairobi.

[17] Kwikiriza, N., Mugisha, J., Kledal, P. R., Karatininis, K., and Namuwooza, C. (2016). Tracing Uganda's global primary organic pineapple value chain. African Crop Science Journal, 24(1), 15–33. https://doi.org/http://dx.doi.org/10.4314 /acsj.v24i1.2

[18] Lu, X. H., Sun, D. Q., Wu, Q. S., Liu, S. H., and Sun, G. M. (2014). Physico-chemical properties, antioxidant activity and mineral contents of pineapple genotypes grown in China. Molecules, 19(6), 8518–8532. https://doi.org/10.3390/mole cules19068518

[19] Magala, D., Beatrice, A., Sarah, M., Nasirumbi, S. L., Phyllis, K., Joseph, B. P., and Peter, S. (2010). Understanding the Dynamics of Pineapple Production and Marketing in Uganda. (September), 1–28.

[20] Mongi, R. J. (2013). Solar drying of fruits and vegetables: dryers' thermal performance, quality and shelf life of dried mango, banana, pineapple and tomato. Sokoine University of Agriculture. Morogoro, Tanzania.

[21] Morais, D. R., Rotta, E. M., Sargi, S. C., Bonafe, E. G., Suzuki, R. M., Souza, N. E., … Visentainer, J. V. (2017). Proximate composition, mineral contents and fatty acid composition of the different parts and dried peels of tropical fruits cultivated in Brazil. Journal of the Brazilian Chemical Society, 28(2), 308–318. https://doi.org/10.5935/0103-5053.20160178

[22] NAADS. (2014). User Guide on Pineapple Production - NAADS. (1), 1–5. https://doi.org/10.1007/s13398-014-0173-7.2

[23] Nielsen, S. S. (2017). Food Analysis Laboratory Manual (Third). https://doi.org/10.1007/978-1-4419-1463-7

[24] Rodriguez-Amaya, D. B., and Kimura, M. (2004). Harvest plus handbook for carotenoid analysis. Washington, DC: International Food Policy Research Institute (IFPRI).

[25] Shamsudin, R. (2007). Physicochemical Properties of the Josapine Variety of Pineapple Fruit Physicochemical Properties of the Josapine Variety of Pineapple Fruit. 3(5). https://doi.org/10.2202/1556-3758.1115

[26] Steiner-Aseidu, M., Wardy, W., Saalia, F., Budu, A., and Sefa-Dedeh, S. (2009). A comparison of some physical, chemical and sensory attributes of three pineapple (Ananas comosus) varieties grown in Ghana. African Journal of Food Science, 3(1), 22–25. Retrieved from http://www.cabdirect.org/abstracts/20103303586.html

[27] Tortoe, C., Johnson, P.-N. T., Slaghek, T., Miedema, M., and Timmermans, T. (2013). Physicochemical, Proximate and Sensory Properties of Pineapple (<i>Ananas</i> sp.) Syrup Developed from Its Organic Side-Stream. Food and Nutrition Sciences, 04(02), 163–168. https://doi.org/10.4236/fns.2013.42023

[28] Wardy, W., Saalia, F. K., Asiedu, M. S., and Budu, A. S. (2009). A comparison of some physical, chemical and sensory attributes of three pineapple (Ananas comosus) varieties grown in Ghana. 3(1), 22–25