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Physicochemical properties and potential use of six mango varieties from Burkina Faso

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Abstract

The quality profile of the six most important mango varieties from Burkina Faso, as well as their potential use, was investigated. It appeared that *Amélie* variety showed the highest levels of total sugars (74.49±0.04 % dry weight), β-carotene (1752.72±41.64 µg/100 g of fresh weight), vitamin C (58.94±1.77 mg/100 g of fresh weight), titratable acidity (1.56±0.01 %), and energy value (80.55±0.01 Kcal/100 g dry weight). However, this variety has the lowest soluble solids/titratable acidity ratio (TSS/TA) of 11.24±0.17 and the lowest total fiber content (1.87±0.03 % fresh weight). *Kent* variety contained the highest levels of pulp (81.31±1.67 % fresh weight), total soluble solids (23.1±0.00 % fresh weight), total fiber content (2.77±0.08 % fresh weight) and the lowest β-carotene content (220.21±14.97 µg/100 g fresh weight). All varieties have significant levels of total phenolic compounds (mini-maxi content). This study not only showed significant differences in biochemical contents and physical characteristics among mango varieties but will also guide mango processors and nutritionists in choosing the most suitable varieties according to target food products.

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Introduction

Mango (*Mangifera indica* L.) fruit is among the main speculation of the fruit sector in most tropical countries worldwide. In Burkina Faso, its cultivation covers 58 % of the orchards and its production is estimated to be 56 % of the annual all fruits production (APROMAB, 2016). The annual production of mango has increased from 337 101 tons in 2008 to 404 400 tons in 2014 (Ouédraogo *et al.*, 2017) with an operating area of 33,700 hectares. About forty varieties of mango are available in Burkina Faso. Among these, varieties of mango trees identified in the orchards in the largest production area (Comoé, Kénédougou and Houet provinces located in western Burkina Faso) are *Brooks* (29.61 %), *Lippens* (25.15 %), *Amélie* (18.96 %), *Kent* (18.65 %), *Keitt* (5.52 %) and *Springfield* (2.07 %) (Guira, 2008). The distribution of mango varieties in orchards has been studied by Rey *et al.* (2004). This distribution varied according to the area. For instance, in the province of Houet, the *Amélie* variety represents a high proportion of the mangoes produced compared to the colored varieties (*Kent*, *Keitt*). *Amélie* variety occupied 40 to 50 % of the cultivated land (PAFASP, 2011). The production yield is around 150 to 200 kg of fruit/tree for *Brooks* and *Lippens* varieties, 100 to 150 kg of fruit/tree for *Amélie*, *Keitt* and *Kent* varieties and 50 to 100 kg of fruit/tree for *Springfield* variety (Guira, 2008). In addition to the high agricultural potential of mango, the pulp of this fruit has a high nutritional value. Indeed, it is an excellent source of β-carotene (pro-vitamin A), vitamin C, carbohydrates, fibers, phenolic compounds and minerals (Robles-Sanchez *et al.*, 2009; Ma *et al.*, 2011; Liu *et al.*, 2013; Somé *et al.*, 2014). Levels of these compounds are significantly different among varieties and are dependent on agronomic, climatic and environmental conditions. Furthermore, mangos being a climacteric fruit, the degree of maturity, growing conditions and storage conditions highly influence the levels of these metabolites. Secondary metabolites are powerful anti-oxidants that reduce oxidative stress and have anti-cancer properties ((Kim *et al.*, 2003; Chiou *et al.*, 2007). For instance, carotenoids play an important role in human health by acting as a source of pro-vitamin A or as protective anti-oxidants necessary for good reproduction and growth, in the normal operation of the eye system, and in the integrity of epithelial cells and the functionality of the immune system (Murkovic *et al.*, 2002).

Studies on mango varieties from Burkina Faso with respect to diseases and pest attacks have been previously performed (Vayssieres *et al.*, 2008; Ouédraogo, 2011). Moreover, *Amélie* fruit variety has been studied on aspects related to technological valorization, chemical composition and nutritional value and on the storage effects on vitamin C, carotenoids and browning (Sawadogo-Lingani and Traoré, 2001, 2002a; Sawadogo-Lingani *et al.*, 2002; Sawadogo-Lingani *et al*, 2005). Other studies dealt with methods of producing unconventional food for pigs based on mango wastes in Burkina Faso (Kiendrebeogo *et al.*, 2013). The drying technology of the *Brooks* variety has been studied and the physicochemical, biochemical, and technological characterization of the different existing mango varieties were determined (Rivier *et al.*, 2009). Yet, without the knowledge and mastery of these characteristics, qualitative and standardized processing cannot be achieved. Production of puree, concentrates and beverages from mango require specific characteristics, where the ratio of total sugar content/acid (TSS/TA) associated with an intense yellow-orange color and soft texture play major roles. On the other hand, the production of dried mangoes, frozen or canned fruit pieces requires firmer fruits for which color is important. The present work aims to determine the biochemical characteristics of the six most exported and most processed mango varieties in Burkina Faso. The characterization of these six varieties will allow proposing of appropriate use technologies for each variety.

Material and methods

Plant materials and samples preparation

Mango varieties samples of *Amélie*, *Brooks*, *Keitt*, *Kent*, *Lippens* and *Springfield* were collected in April 2017 (Fig.1). They were grown in the experimental

station of INERA (Banfora: latitude: 10°37'59, North; longitude: 4°46'00 "West) located in the western part of Burkina Faso. Ten mangos of each variety were picked up at physiological maturity on the same tree of mango, labeled and transported to the laboratory, where they were stored at room temperature. When they reached commercial maturity, mangoes were washed, wiped and peeled. The proportion of each part of the fruit (stone, peel and pulp) was weighed. The pulpwas collected and crushed using an electric grinder until a homogeneous mash was obtained and then stored at -20°C. Prior to physicochemical analysis, the crushed flesh was lyophilized and stored at –20°C.

Proximate composition analysis

Mango pulp of each variety was homogenized before determining pH with a digital pH-meter (Type H1 122 by HANNA, Romania), total soluble solids content (TSS) using a digital refractometer (Bellingham + Stanley No. BX 16050, UK), titratable acidity (TA) by titration of 20 mL of mango pulp with 0.1 N NaOH and results were expressed in % eq. citric acid. Water content and total minerals (ash) were determined using routine protocols (5 g of mango flesh were heated at 105°C for 24 hours and then oven at 595°C for 24 hours).

Total fibers or alcohol-insoluble solids were determined by using a gravimetric method (Renard, 2005b). One gram of freeze-dried mango pulp was added to 20 mL of 70 % ethanol (Sigma Aldrich). The mixture was shacked for 10 min and then filtered on 75 mL Sep-pack prep columns (Interchim, France) equipped with a sinter of porosity 20 µm until the filtrate was sugar-free, as attested by the method described by Dubois *et al.* (1956). The residue was then dried by solvent exchange (ethanol:acetone, 96:4) at 40°C overnight in an oven. So the total fibers content of the sample (expressed in %) was estimated from the net mass of alcohol-insoluble material.

The contents of simple sugars (fructose, glucose and sucrose) were determined by HPLC (Agilent 1200 Series) coupled to an ESLD detector (Sedex 60LT, Sedere). Fifty milligrams of freeze-dried mango pulp were homogenized with 1.5 mL of distilled water. The mixture was shaken for 10 min and then centrifuged. The supernatant was recovered and filtered through a 0.45 µm PTFE filter. Samples (20 µL) were injected using a Phenomenex column (Rezex™ RCM-monosaccharide Ca^{2+} (8 %), 300x7.8 mm) heated at 70°C and equipped with Phenomenex guard column (Rezex™ RCM-monosaccharide Ca^{2+}, 50x7.8 mm). The mobile phase consisted of 100 % distilled water at a flow rate of 0.5 mL/min. The ESLD detector was set up at 40°C and quantification was carried out using sucrose (Sigma-Aldrich), glucose (D-+-Anhydrous Sigma-Aldrich) and fructose (Sigma-Aldrich) as external standards. Results were expressed as grams per 100 g of fresh weight. Each measurement was done in triplicate.

Color measurement

The color of the mango pulp was evaluated with a tristimulus colorimeter (KONICA MINOLTA CM-700d, D11012063, INC. Japan) based on the CIELAB color system (L, a*, b* and L C*, h*, ΔE, YI). These parameters were measured 5-fold for each sample by placing the objective of the colorimeter on a homogeneous surface of the pulp. L, a*, b* respectively described as: L (0=black, 100=white); a* (-a= green, +a= red); b* (-b= blue, +b = yellow). The intensity of the color chroma noted C* is given by the equation (1):

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

The hue angle (h*), considered the qualitative attribute of color, is the attribute according to which the colors have been traditionally defined as reddish, greenish, yellowish, etc. It is expressed according to equation (2):

$$h^* = \tan - 1\left(\frac{b^*}{a^*}\right) \quad (2)$$

The total color index (ΔE) indicates the color difference from the standard plate calculated according to Rhim *et al.* (1999). It is given by equation (3):

$$\Delta E = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}} \quad (3)$$

The yellowness index (YI) indicates the degree of yellowing (Hirschler, 2012). It is calculated according to equation (4):

$$YI = 142{,}86\, b^*/L^* \quad (4)$$

Determination of β-carotene and vitamin C contents

β-carotene and vitamin C analyses were carried out using RP-HPLC(Agilent 1200 Series) with a diode array detection (DAD, Agilent 1200 Series).

The β-carotene content was determined according to the method described by Frenich *et al.* (2005) with some modifications. Freeze-dried mango pulp (100 mg) was added to 1 mL of hexane (anhydrous 95 %, Sigma-Aldrich), shaken and centrifuged at 15,000 rpm at 4°C for 10 min. After the centrifugation, the supernatant was collected, transferred to a clean tube and evaporated. The procedure was repeated by adding 1.0 mL hexane to the pellet and the solvent was evaporated to dryness. An aliquot of 1.0 mL of tetrahydrofuran (Sigma Aldrich) was added to the dry residue before filtration with a PTFE filter (0.45 µm, Interchim). This extract (10 µL) was injected into the HPLC column (Kinetex C18, Phenomenex, 5 µm, 250 × 4.6 nm) using a mobile phase with a flow rate of 0.8 mL/min, at 35°C.

The eluent consisted of tetrahydrofuran (THF) (eluent A), methanol (eluent B, Sigma Aldrich) and acetonitrile (eluent C, Sigma Aldrich). The following gradient was used: 0 % A to 5 % B and 95 % C (0-2 min), 20 % A to 20 % B and 60 % C (20-25 min), 0 % A to 5 % B and 95 % C (27-35 min). The detection was carried out at 450 nm with a DAD detector. The concentration was calculated using β-carotene standard (Sigma Aldrich) as an external standard and expressed as µg of β-carotene per 100 g of fresh weight (FW).

The vitamin C content was determined according to the method described by Hernández *et al.* (2006) with some modifications. Freeze-dried mango pulp (50 mg) was added to 1 mL aqueous solution 0.1 % formic acid (≥98 %, Sigma Aldrich), shaken and centrifuged at 15,000 rpm at 4°C for 10 min. The extract was filtered through a 0.45 µm PTFE filter and 8 µL was injected into the HPLC column (LUNA C18, Phenomenex 150 × 4.6 nm, 100 A, 3 µm) heated at 25°C with a flow rate of 0.8 mL/min. The gradient used consists of 0.1 % formic acid in (phase A) and methanol (phase B). The elution gradient was (A/B) 95/5 (0-10 min), 20/80 (10 to 12 min) and 95/5 (12 to 15 min). Elution was monitored at a wavelength of 245 nm using a DAD detector.

The concentration of vitamin C was calculated using L-ascorbic acid (Sigma-Aldrich) as standard and expressed in milligrams of ascorbic acid per 100 g fresh weight. Total phenolic compounds were determined by the Folin Ciocalteu method (Singleton *et al.*, 1999) using Gallic acid as the standard.

Assessment of nutritional value

The energy value was estimated using Atwater coefficients. The total fat content of the samples was determined by Soxhlet extraction on a test portion of 5 g of the mango pulp with hexane (HPLC plus >95 %, Sigma Aldrich) as solvent according to ISO 659 (1998). The results were expressed in percentage (%) relative to the dry matter. Total proteins were determined by the Kjeldhal method according to NF V03-050 (1970). The results were expressed in percentage (%) relative to the dry matter.

The total sugars content in the samples was determined by the differential method (Pearson, 1976) using the equation (5):

$$\text{total Sugar (\% DM)} = 100 - (\%\text{water content} + \%\,PT + \%\,Ash + FT) \quad (5)$$

Where: DM= dry matter, PT= total Protein, TF= total Fiber.

Statistical analysis

All assays were carried out in triplicate and the means and standard deviations are reported. Differences in mean performance for each composition among mango varieties were analyzed with XLStat 2014 Software. Analysis of variance (ANOVA) and the averages of the variables were compared using the Newman-Keuls test at the probability level of 5 %.

Results and discussion

Physicochemical characteristics

The weights of mango fruit components (Table 1) are important parameters to assess the quality of mangoes for processing and exportation. The standards Codex Stan 184-1993 for mango established three sizing calibration categories A, B and C, of 200-350, 351-550, and 551-800 g, respectively, as quality parameters for exportation. The weight values of mango varieties in this study ranged from 291.17 g to 843.43 g. The highest value was found for *Springfield* (843.43±35.93 g), while *Lippens* presented the lowest value (291.17±19.42 g). *Springfield* showed a significant difference ($P<0.05$) compared to other varieties. The weight values found in this study corroborate those found by Bafodé (1988) for *Amélie*, *Brooks*, *Keitt* and *Springfield* varieties. On the other hand, these values were higher than those measured in the same varieties coming from the same locality (Banfora) (Somé *et al.*, 2014). This difference could be due to the difference in harvesting period, fields and climatic conditions. Passannet *et al.* (2018) reported weight values of 487.10±99.98 g for *Keitt* variety and 511.92±70.65 g for *Kent* variety from Tchad. Pulp rates ranged from 74.98 % to 81.31 %. The highest pulp rates were found for *Kent* (81.31±1.67 %), *Amélie* (80.73±0.45 %) and Springfield (79.99±1.17 %). The pulp rate of *Kent* obtained was close to that found by Bafodé (1988).

The pulp rates obtained from *Amélie* and *Brooks* were lower than those found by Bafodé (1988) which were 86.80 % and 80.20 %, respectively. Pulp rates were in the same order as values found for mangos from Bangladesh (Ara *et al.*, 2014) and Sri Lanka (Kothalawala and Jayasinghe, 2017).

Table 1. The physical composition of the six mango varieties.

Varieties	Weight (g)	Stone (%)	Peel (%)	Flesh (%)	Flesh/stone	Flesh/peel
Amélie	517.90±144.86^{b}	5.19±0.63^{c}	13.93±2.49^{a}	80.73±0.45^{a}	15.43±1.46^{a}	5.84±1.19^{c}
Brooks	536.27±67.73^{b}	12.31±1.88^{ab}	12.41±0.84^{a}	74.98±1.07^{c}	6.16±1.12^{c}	6.02±0.37^{c}
Keitt	412.20±99.62^{bc}	10.86±1.00^{ab}	11.56±0.79^{ab}	77.36±0.51^{bc}	7.01±0.73^{c}	6.57±0.42^{c}
Kent	525.27±89.31^{b}	10.50±1.01^{ab}	8.17±0.73^{b}	81.31±1.67^{a}	7.68±0.93^{b}	9.85±1.07^{a}
Lippens	291.17±19.42^{c}	13.00±2.14^{a}	10.64±0.21^{ab}	76.24±2.27^{bc}	5.80±1.25^{c}	6.92±0.34^{bc}
Springfield	843.43±35.93^{a}	9.10±1.17^{b}	10.48±2.03^{ab}	79.99±1.17^{ab}	8.68±0.94^{b}	7.70±1.77^{b}

The proportion of stone ranged from 5.19 to 13.00 %. The highest percentage was found for *Lippens* (13.00±2.14 %), while the lowest was recorded for *Amélie* (5.19±0.63 %). Regarding the peel, *Amélie* variety showed the highest peel percentage (13.93±2.49 %), whereas *Kent* exhibited the lowest peel percentage (10.64±0.21 %). Pulp/stone ratios were higher in *Amélie* (15.43±1.46) followed by *Springfield* (8.68±0.94). The highest Pulp/peel ratio was found in *Kent* (9.85±1.07) and the lowest in *Amélie* (5.84±1.19). Considering Pulp/stone and Pulp/peel ratios (Table 1), it appeared that *Kent*, *Amélie*, and *Springfield* varieties could be the best for industrial processing (Elsheshetawy *et al.*, 2016). Significant differences in dry matter (DM), total minerals (ash), titratable acidity (TA), pH, soluble solids content (TSS) and TSS/TA ratio values were found among varieties (Table 2).

Titratable acidity (TA) and pH values were used to evaluate the overall content of organic acids. The ratio of sugar/acid balance is an indicator of fruit maturity and quality (Malundo *et al.*, 2001; Vasquez-Caicedo *et al.*, 2004). The pH values obtained in this study were similar to those found (3.6 to 6) in Chinese, Bangladesh and Egyptian mango varieties (Liu *et al.*, 2013; Ara *et al.*, 2014; Elsheshetawy *et al.*, 2016).

However, TA contents obtained were higher than those found in Chinese, Bangladesh and Egyptian mango varieties. In general, fruit acidity decreased and TSS increased during ripening; thus, TSS was

directly correlated with fruit acidity (Padda *et al.*, 2011; Sajib *et al.*, 2014). For processing into mango nectar or for the preservation of the pulp by heat treatment at temperatures below 100°C, the pulp of *Lippens* (pH=5.02±0.01) required acidification. Based on the results of titratable acidity and pH, the *Amélie* variety was the most acidic fruit (pH=3.71), followed by *Kent* and *Brooks* (pH<4.0). The least acidic varieties were *Lippens*, *Keitt* and *Springfield* (pH>4.0).

Table 2. Chemical characteristics of the six mango varieties.

Varieties	DM (%)	pH	TA (%)	TSS (%)	TSS/TA	Ash (%DM)
Amélie	16.52±0.00^{f}	3.71±0.01^{f}	1.56±0.01^{a}	17.5±0.17^{e}	11.24±0.17^{f}	0.37±0.02^{e}
Brooks	21.59±0.01^{c}	3.8±0.00^{e}	1.24±0.03^{c}	22.53±0.06^{b}	18.15±0.43^{d}	1.41±0.43^{a}
Keitt	21.36±0.01^{d}	4.43±0.01^{b}	0.56±0.00^{e}	21.97±0.06^{c}	39.24±0.10^{b}	0.56±0.03^{c}
Kent	22.32±0.00^{b}	3.93±0.01^{d}	1.49±0.00^{b}	23.1±0.00^{a}	15.54±0.01^{e}	1.07±0.23^{b}
Lippens	20.32±0.02^{e}	5.023±0.01^{a}	0.32±0.02^{f}	20.7±0.00^{d}	62.59±0.55^{a}	0.39±0.00^{e}
Springfield	22.98±0.01^{a}	4.21±0.02^{c}	0.86±0.01^{d}	22.67±0.15^{b}	26.27±0.32^{c}	0.46±0.01^{d}

DM= Dry matter, TA= Titratable acidity, TSS= Total soluble solids.

TSS contents ranged from 17.50 to 23.10 %. TSS/TA ratios ranged from 11.24 to 62.59. *Kent* variety had the highest TSS content (23.10 ± 0.00 %); however, its TSS/TA ratio was low (15.54±0.01). *Amélie* had the lowest TSS content (17.50±0.17 %) and the lowest TSS/TA ratio (11.24±0.17) because of its high TA content. *Lippens* had the highest TSS/TA ratio (62.59±0.55), although it had a TSS content of 20.70±0.00 %. This could be due to its low TA content. TSS contents of the six varieties were higher than the minimum °Brix value of reconstituted fruit juices and rectified purees which is 13.5 % (Codex Stan 247-2005). These values were higher than those of four Chinese mango varieties (13.4±0.02 to 17.9±0.01 %) (Liu *et al.*, 2013), as well as Egyptian mango varieties (Elsheshetawy *et al.*, 2016). TSS content of *Keitt* variety was higher than that obtained in *Keitt* variety from Mexico (Ibarra *et al.*, 2015), Bangladesh (Ara *et al.*, 2014) and from Sri-Lanka (Kothalawala and Jayasinghe, 2017).

Table 3. Proximate composition of the six mango Varieties.

Varieties	Fat (%)	Proteins (%)	Carbohydrates (%)	EV (Kcal/100 g DM)
Amélie	0.61±0.00^{b}	0.63±0.02^{b}	74.49±0.04^{a}	333,51 ± 0,13^{a}
Brooks	0.64±0.01^{a}	0.51±0.00^{d}	66.67±0.08^{f}	295,36±0,24^{e}
Keitt	0.50±0.01^{c}	0.56±0.00^{c}	70.49±0.02^{c}	305,11±0,49^{c}
Kent	0.58±0.01^{b}	0.61±0.01^{b}	67.19±0.08^{e}	294,39±0,34^{e}
Lippens	0.58±0.01^{b}	0.66±0.00^{a}	72.14±0.10^{b}	316,73±0,30^{b}
Springfield	0.60±0.01^{b}	0.61±0.00^{b}	68.88±0.05^{d}	301,50±0,26^{d}

EV= Energy values.

TSS/TA values from *Amélie*, *Brooks* and *Kent* in the present study were lower than those obtained in Egyptian mango varieties (Elsheshetawy *et al.*, 2016). Vásquez-Caicedo *et al.* (2004) reported that varieties with intense yellow-orange color, soft texture and low TSS/TA ratio are used for the production of mango puree, concentrates and beverages. In contrast, varieties that have a high TSS/TA ratio and a more intense texture were used for drying and for the production of frozen or canned mango pieces. Based on these observations, *Amélie*, *Brooks* and *Kent* could be used for the production of mango puree, concentrates and beverages. *Lippens*, *Keitt* and *Springfield* varieties could be used for drying and production of frozen or canned mango pieces. Total ash varied from 0.37 to 1.41 % (FW). The highest content was found in *Brooks* (1.41±0.43 %), while the lowest value was found in *Amélie* (0.37±0.02 %).

Table 4. Colorimetric parameters of pulps of the six mango varieties.

Variety	L	a*	b*	C*	h°	ΔE	YI
Amélie	47.53±4.73^{a}	9.84±0.40^{c}	40.30±5.78^{b}	41.45	76.26	63.07	120.6±6.18^{b}
Brooks	48.37±4.00^{a}	11.21±0.23^{b}	40.20±4.52^{b}	41.70	74.41	63.87	118.4±4.05^{bc}
Keitt	52.25±4.19^{a}	8.90±0.13^{d}	44.93±4.92^{b}	45.80	78.82	69.48	122.6±3.64^{b}
Kent	46.38±3.88^{a}	12.22±0.69^{a}	37.30±4.36^{b}	39.24	71.86	60.75	114.6±4.56^{c}
Lippens	51.50±2.41^{a}	11.20±0.20^{b}	51.55±3.75^{a}	52.75	77.75	73.72	142.9±5.01^{a}
Springfield	53.00±2.89^{a}	8.37±0.15^{e}	43.37±3.45^{b}	44.17	79.08	69.00	116.8±3.19^{bc}

The total mineral content of the six varieties was similar to those obtained in mango in general, which is around 0.22 to 0.5 % of the fresh product (Kothalawala and Jayasinghe, 2017).

Proximate composition

Total fat, protein, sugars and energy value were significantly ($p<0.05$) different (Table 3). The highest content of fat was found in *Brooks* variety (0.64±0.01 % FW), while the lowest was found in *Keitt* (0.50±0.01 % FW). Total protein contents varied from 0.51 to 0.66 % DM. *Lippens* contained the highest level (0.66±0.00 %) and the lowest value was found in *Brooks* (0.51±0.00 %). Total fat and total protein contents were similar to those obtained in mango in general, which are around 0.2 to 0.6 %. Free carbohydrates i.e fructose, glucose and sucrose contents varied from 1.76 to 4.63 g/100g, from 1.00 to 2.30 g/100g and from 5.21 to 13.66 g/100 g of fresh pulp, respectively (Fig. 2). Fructose content in *Springfield* was significantly different ($p<0.05$) from other varieties. Glucose levels in *Amélie*, *Keitt* and *Kent* were not significantly different. Similarly, the sucrose contents in *Keitt* and *Lippens* varieties were not significantly different ($p<0.05$).

The highest fructose content was found in *Keitt* (4.63±0.07 g/100 g of fresh pulp). *Brooks* showed the highest glucose content (2.30±0.03 g/100 g of fresh pulp). *Springfield* contained the lowest content of fructose (1.76±0.04 g/100 g of fresh pulp) and glucose (1.00±0.02 g/100 g of fresh pulp) but recorded the highest content of sucrose (13.66±0.40 g/100 g of fresh pulp). This could be due to the low conversion of sucrose into fructose and glucose catalyzed by endogenous invertase.

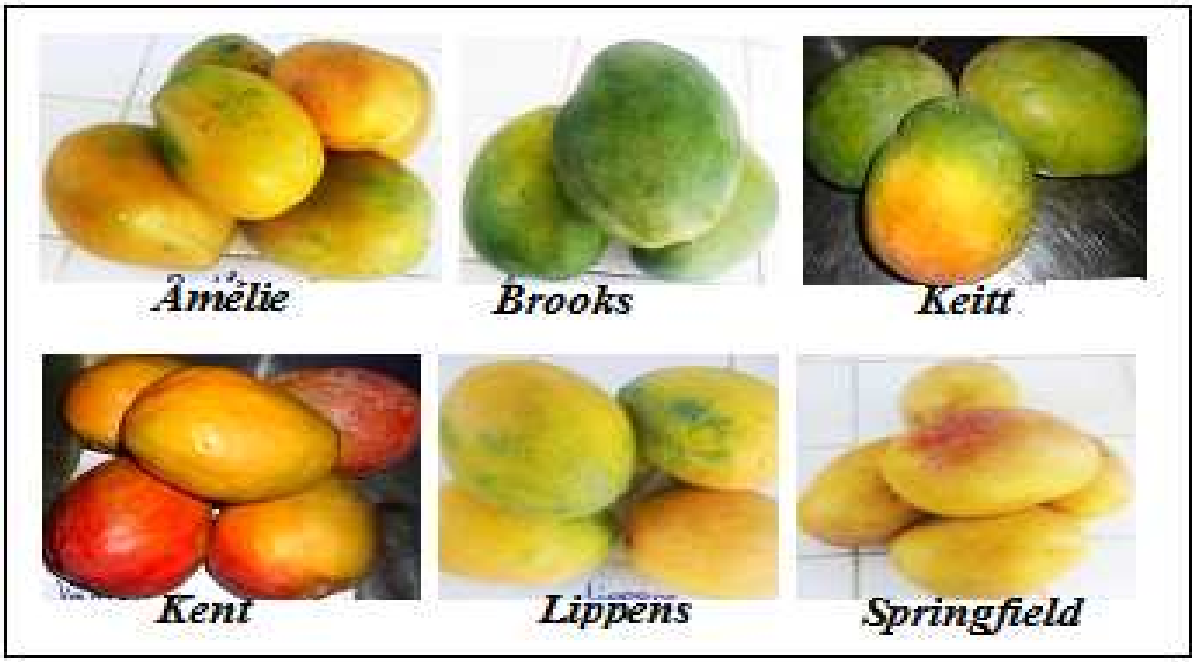

Fig. 1. Main mango fruit varieties in Burkina Faso.

The lowest sucrose content (5.21±0.24 g/100 g fresh pulp) was found in *Amélie*. Fructose, glucose and sucrose contents found by Liu *et al.* (2013) in four mango varieties from China ranged from 2.17 to 4.68, from 1.06 to 2.58 and 4.30 to 10.34 g/100 g of fresh pulp, respectively. In line with other results, sucrose appeared to be the most abundant sugar in mango, followed by fructose and then glucose (Medlicott and Thompson, 1985; Wongmentha *et al.*, 2015). Other data showed that sucrose represented 57 % of the total sugar content of ripe fruit, while fructose and glucose levels were 28 % and 15 %, respectively (Medlicott and Thompson, 1985). The High content of fructose can increase the sweet sensation of the fruit because of its high sweetener power than sucrose and glucose.

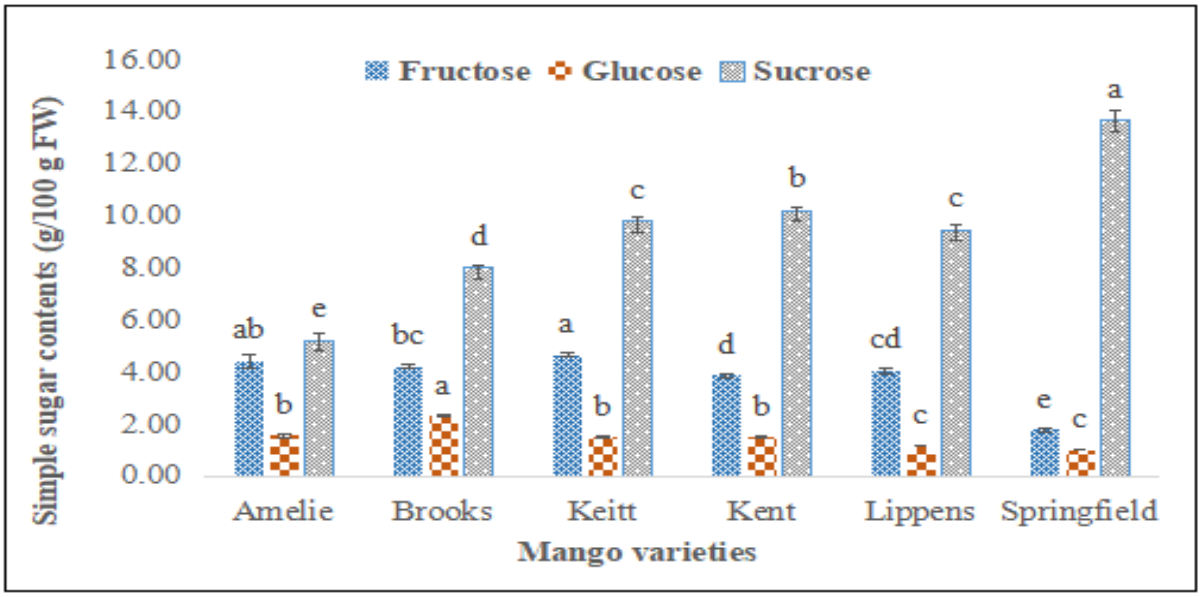

Fig. 2. Fructose, glucose and sucrose contents among varieties.

Energy values varied from 71.58 to 80.55 Kcal/100 g DM. The highest energy value (80.55±0.01 Kcal/100 g DM) was found in *Amélie*, followed by *Lippens* and *Keitt*, respectively. The lowest energy value (71.58±0.05 Kcal/100 DM) was found in *Brooks*, followed by *Kent* and *Springfield*. However, these differences were still low. Total energy values obtained were high compared with those obtained in *Amélie* (Sawadogo-Lingani and Traoré, 2002a).

Fiber contents

Total fiber contents ranged from 1.87 to 2.77 % DM. The highest content (2.77±0.08 %) was found in *Kent,* while the lowest (1.87±0.03 %) was found in *Amélie* (Fig. 3). Total fiber content of *Amélie* was significantly different from other varieties. The total fiber contents of the six varieties were similar to those reported by Ara *et al.* (2014) in ten varieties from Bangladesh (1.08±0.05 to 4.78±0.04 %) as well as those reported by Kothalawala and Jayasinghe (2017) in five Sri Lankan varieties (1.17±0.05 to 3.16±.06 %). The presence of fibers in diets is committed to displaying good nutritional attributes. For instance, soluble fibers may modulate the feeling of satiety and, by limiting the absorption of certain metabolites, can help to reduce the levels of serum cholesterol and blood glucose. The insoluble fibers, on the other hand, may affect the acceleration of intestinal transit and prevent constipation (Grundy *et al.*, 2016). Dietary fiber could prevent and control diabetes and lower blood cholesterol, which is important for preventing heart disease (Champ *et al.*, 2003).

Colors of the pulps

The color of the fruits and their end-products is an important parameter for assessing food and marketing qualities because it affects the organoleptic parameters. The color of mango peel plays an important role in the perception of overall quality (Gonzalez-Aguilar *et al.*, 2001) and can be a

determinant for judging the maturity for harvesting (Coccozza *et al*., 2004; Jha *et al*., 2007), processing (Mahayothee *et al*., 2004) and consumption. The L, a *, b*, Chroma (C*), the hue angle (h*), the total color index (ΔE) and the yellowness index (YI) parameters of the different varieties of mangoes are displayed in Table 4. The values of L* indicating lightness ranged from 46.38 to 53.00, with no significant difference. This indicated that the pulps of the varieties might not be significantly exposed to chemical or enzymatic browning. Values of a* varied from 8.37 to 12.22 and those of b* from 37.30 to 51.55, indicating that samples are rather yellow-orange.

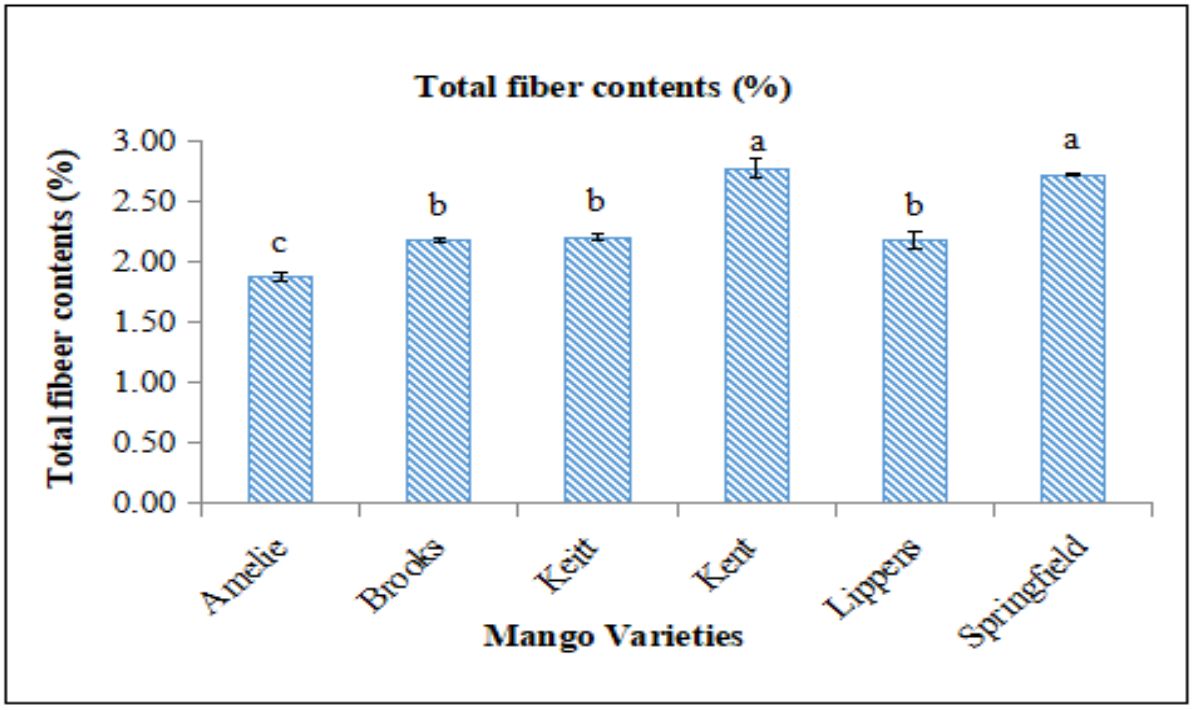

Fig. 3. Total fiber contents among varieties.

The intensity of the color given by C* and ΔE showed that this parameter was stronger in the *Lippens*, *Keitt* and *Springfield* than in others. However, it was lower in *Kent*, *Amélie*, and *Brooks*. The yellowness index (YI) was higher in *Lippens* (142.9±5.01), Keitt (122.6±3.64) and *Amélie* (120.6±6.18) varieties. Results indicated an intense and bright yellow-orange color in the pulp of *Lippens,* while pulps of *Springfield*, *Keitt*, *Amélie*, *Brooks* and *Kent* showed a yellow-orange color.

Anti-oxidants (β-carotene, vitamin C and total phenolic compounds)

Contents in β-carotenes ranged from 220.21 to 1752.72 µg/100 g of fresh pulp (Fig. 4). The highest content (1752.72±41.64 µg/100 g fresh pulp) was found in *Amélie* variety and the lowest content (220.21±14.97 µg/100 g fresh pulp) was found in *Kent*. β-carotene contents of *Keitt* and *Springfield* were not significantly different ($p<0.05$). Other studies performed in Burkina Faso found that *Amélie* had the highest β-carotene content among the six mango varieties (Somé *et al*., 2014). In Chinese mango varieties, β-carotene contents ranged from 2.57 to 6.14 mg/100 g pulp (Liu *et al*., 2013). The low contents of β-carotene found in *Brooks*, *Keitt*, *Kent* and *Springfield* could be due to genotype diversity but also to storage conditions. Indeed, the pulp was stored for 7 months at -20° C before analysis. During this storage, oxidation or hydrolysis may occur, causing losses of β-carotene molecules.

Interestingly, color parameters may be correlated with levels of carotenoids. Some investigations indicated that L and a* values were strongly correlated with lycopene content in tomato between

hue angle (h°) and β-carotene content (D'Souza *et al.*, 1992; Arias *et al.*, 2000). Ornelas-Paza and Yahiab (2014) reported a strong correlation between the contents of the main carotenoids of the pulp of the *Manila* and *Ataulfo* mango varieties and a* and Hue angle (h°). Veda *et al.* (2007) reported that the bio-accessibility of β-carotene in mango varieties from India ranged from 24.5 to 39.1 % and this bioavailability is higher in varieties with high vitamin C content.

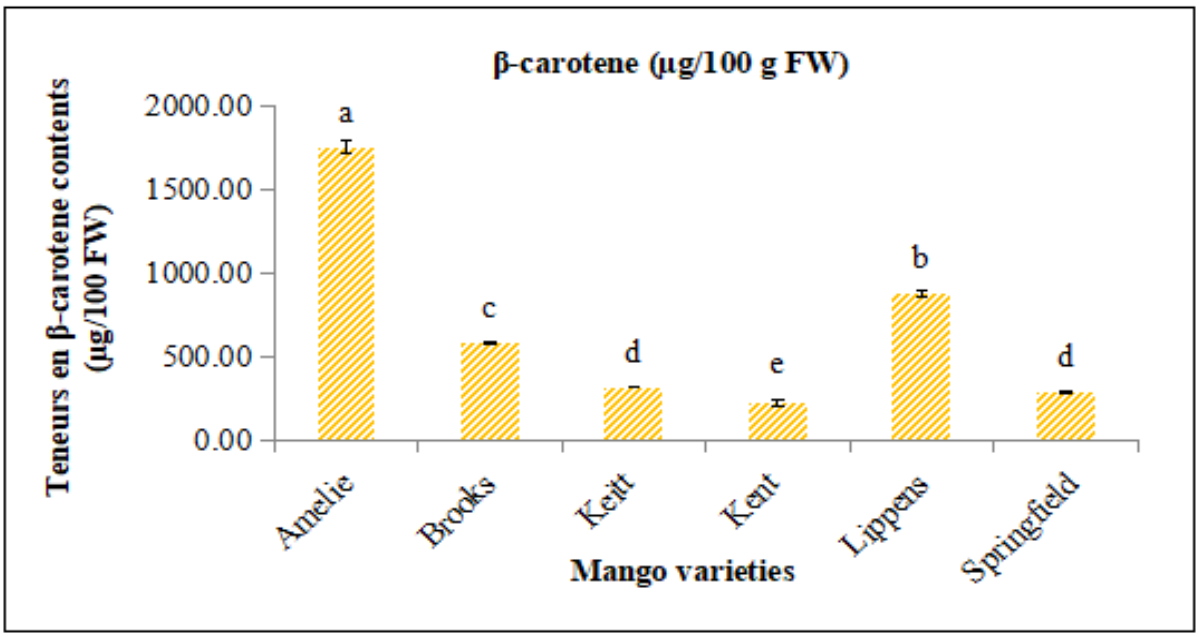

Fig. 4. β-carotene contents among varieties.

This observation is verified in the present study because *Amélie* and *Lippens* varieties, which showed the highest levels of β-carotene, also have the highest levels of vitamin C. Thus, organic acids (exogenous or inherent) contribute to the retention of β-carotene in the food matrix during the heat treatment and to the improvement of it bioaccessibility . Veda *et al.* (2007) also reported that the addition of milk to mango pulp increased the bioaccessibility of β-carotene. The stimulating effect of milk on the bioaccessibility of ß-carotene could probably be attributed to the proteins and fats present in it. Small amounts of fat are essential for the optimal absorption of carotenoids that are fat soluble. The presence of protein in the small intestine contributes to the stabilization of lipid emulsions and promotes the formation of micelles (West and Castenmiller, 1998). Vitamin A deficiency is very often observed among school children in several countries, including Burkina Faso where the prevalence of hyporetinolemia is about 43.7 %. Regular consumption of the *Amélie*, *Lippens* and *Brooks* varieties of mango, alone or in formulation with other products, could be recommended to help cover the needs of the population and thus reduce this prevalence. Vitamin C contents (Fig. 5) varied from 2.38 to 58.94 mg/100 g of fresh pulp. The highest content (58.94±1.77 mg/100 g pulp) was recorded in *Amélie* variety. Vitamin C content in *Amélie* obtained is higher than that obtained (49.5±9.7) by Sawadogo-Lingani and Traoré (2001). However, vitamin C contents obtained in this study are similar to or slightly lower than those found in other mango fruits, notably in *Keitt* and *Kent* (Ma *et al.*, 2011; Liu *et al.*, 2013). Vitamin C is recognized as having anti-oxidant properties that protect human body cells and tissues against free radicals and oxidative stress (Ma *et al.*, 2011). Vitamin C can reverse the browning diphenolase activity of polyphenol oxidases by reducing formed *O*-quinones to initial *O*-diphenols (Hu et Jiang, 2007). Different studies showed that maturity and post-harvest treatment decreased vitamin C content in fruit. Robles-Sánchez *et al.* (2009) reported that vitamin C content in mango slices (*Kent* variety) dipped in a solution of vitamin C,

citric acid and calcium had significantly increased levels compared to untreated slices. This treatment may be an alternative to correct the observed losses. Similar results were found by González-Aguilar *et al.* (2001), who showed that vitamin C levels in end-product increased four-fold in fresh pineapple slices after tissue treatment with a mixture of anti-oxidants as vitamin C.

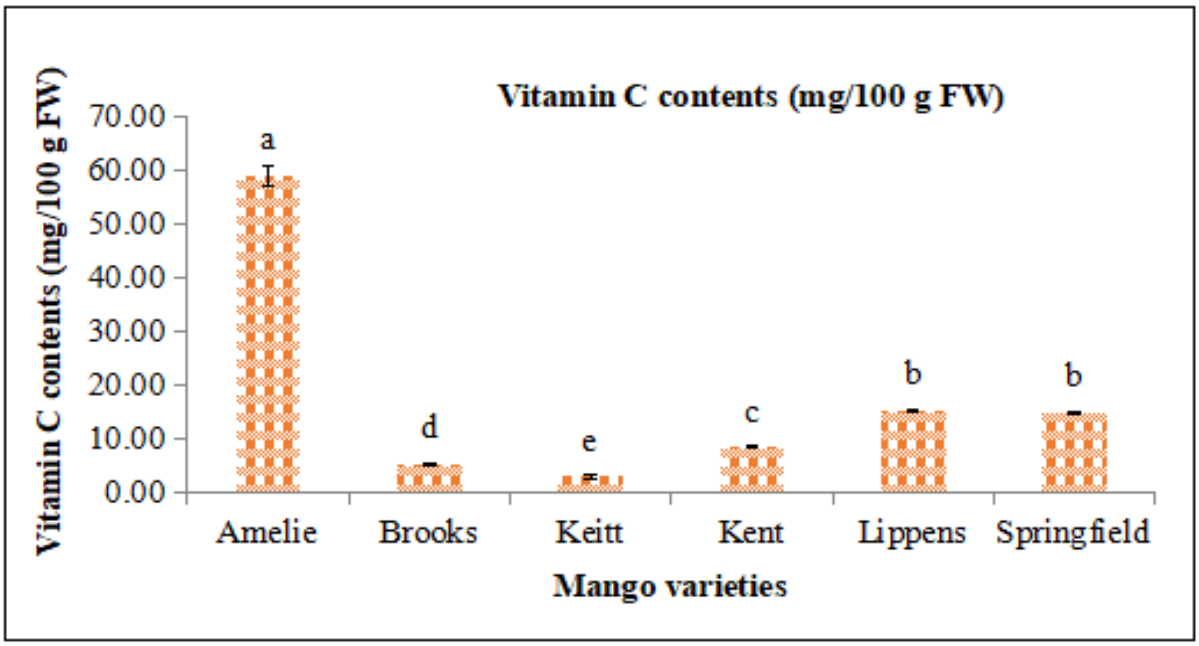

Fig. 5. Vitamin C contents among varieties.

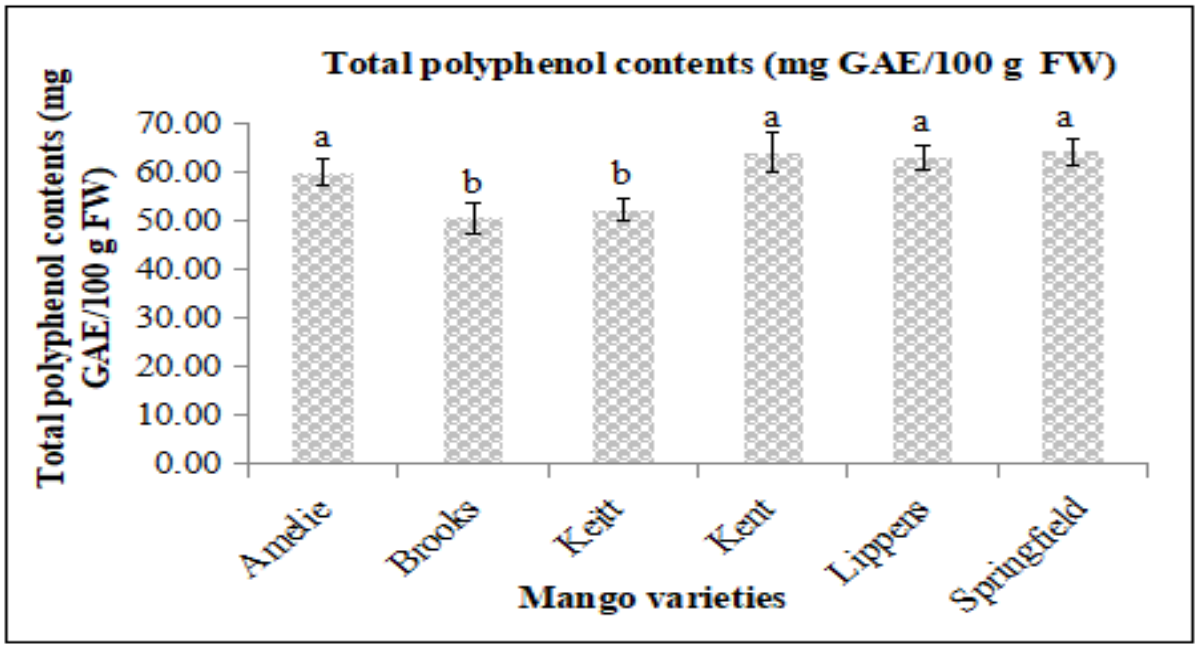

Fig. 6. Total polyphenol contents among varieties.

Total phenolic compounds varied from 50.51 to 64.15 mg GAE/100 g fresh pulp (Fig. 6). The highest content (64.15±2.66 mg GAE/100 g fresh pulp) was found in *Springfield*, followed by *Kent*, *Lippens* and *Amélie*. Total phenolic compounds in *Brooks* and *Keitt* were significantly different from those in *Springfield*, *Kent*, *Lippens* and *Amélie*. The contents of total phenolic compounds in *Keitt* and *Kent* were higher than those found by Liu *et al.* (2013). However, Liu *et al.* (2013) found a value of 139.71 mg

GAE/100 g pulp in *Tainong*. Ma *et al.* (2011) also reported a content of 193.36±3.21 mg GAE/100 g pulp in *Tainong* variety. Phenolic compounds are known to be affected by both biotic and abiotic stresses, especially sunlight. Polyphenols as anti-oxidants may prevent neurodegenerative, cardiovascular and cancer diseases (Robles-Sanchez *et al.*, 2009; Liu *et al.*, 2013). Data showed that all six mango varieties contained significant levels of phenolic compounds. *Springfield*, *Kent*, *Lippens* and *Amélie* could be more exposed to enzymatic or non-enzymatic browning during long-term pulp preservation due to their high phenolic compounds.

Conclusion

Proximate compositions, as well as levels of phytochemicals and bioactive compounds such as β-carotene, vitamin C and phenolic compounds, are significantly different among mango varieties. *Amélie* variety was particularly rich in phytochemicals with high potential anti-oxidant activities. *Kent* variety is a good source of natural fibers. *Amélie*, *Brooks* and *Kent* varieties may be potential candidates to produce mango purée and beverages. *Lippens*, *Keitt* and *Springfield* may be recommended for drying and for the production of frozen and canned mango pieces. The study showed that nutritionists, small-scale food enterprises, or food industries might select mango varieties according to targeted food end-use products.

Conflict of interests

The authors have not declared any conflict of interest.

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