



Mango Peels and Kernels from Selected Varieties of Côte d'Ivoire are Potential Sources of Antioxidative Bioactive Compounds

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Authors' contributions

This work was carried out in collaboration among all authors. Author LTZ designed the study and wrote the first draft of the manuscript. Author GYK wrote the protocol, managed the analyses of the study and the statistical analysis. Author EA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed to quantify the bioactive compounds and the antioxidant activity of mango peels and kernels from two main varieties (Kent, Keitt) cultivated in Côte d'Ivoire.

Study Design: Processing of mango varieties, determination of bioactive compounds content of mango peels and kernels, evaluation of antioxidant activity of mango peels and kernels.

Place and Duration of Study: Felix Houphouët-Boigny University, Biotechnology Laboratory (March to September 2019).

Methodology: Ripe mango (*Mangifera indica* L) fruits from Kent and Keitt varieties were processed to obtain peels and kernels powders. Methanolic extracts of peels and kernels were used to determine the content of phenolics, flavonoids and tanins while hexanic extracts were used to determine the content of carotenoids and phytosterols. DPPH scavenging and ferric reducing power tests were used to evaluate antioxidant activity of peels and kernels.

Results: Total phenolics content of kernels of Kent (4371.22 ± 24.98 mg/100g dw) and Keitt (4037.93 ± 20.43 mg/100g dw) were higher ($P < 0.05$) than those of peels from the two varieties

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(2564.37 – 3082.07 mg/100g dw). The values for carotenoids content of peels varied from 37.53 to 57.74 µg/g dw while those of kernels varied from 1.48 to 3.46 µg/g dw. Based on DPPH test The IC50 values ranged from 0.2 to 0.7 mg/mL with the highest antioxidant activity reported for kernels from Kent variety. The absorbance at 700 nm was found to be 0.4 for kernel of Keitt variety and 0.3 for ascorbic acid at a dose level of 0.03 mg/mL.

Conclusion: Peels and kernels from Kent and Keitt varieties are potential sources of bioactive compounds especially phenolics, tanins, carotenoids and phytosterols. These valuable bioactive compounds in mango by-products may have greater application in the food, cosmetic and pharmaceutical industries.

Keywords: Mango; peel; kernel; bioactive compounds; antioxidant activity.

1. INTRODUCTION

Mango (*Mangifera indica* L) which belongs to the family of Anacardiaceae is one of the most important fruit growing in tropical and subtropical areas of Asia, South America and Africa [1]. The world production of mango was estimated to 52 million tons in 2018 with India as the major producing country (25 million ton) [2]. Mango fruits play important economic role in tropical Africa and particularly in Côte d'Ivoire ranked as the number one African exporter country with more than 30 000 tons shipped to European market [3]. In Côte d'Ivoire, mango is cultivated in the Northern with «Kent» as the dominant variety followed by «Keitt» and «Amelie».

Apart from economic importance, mango fruits are valuable sources of bioactive compounds (provitamin A carotenoids, vitamin C, phenolics, dietary fiber) essential to human nutrition [4,5]. The main processed mango products are puree, juice, nectar, concentrate and dried mangoes. Besides these products, other commercially products including pickles, mango leather, sweet or sour chutney and dried mango powder have been mentioned [6]. The processing of mango into juice, nectar, puree, and jam generates large amount of waste (30 – 60%) consisting of peels and kernels [7,8]. This large amount of waste (peels and kernels) may cause environmental issues due to microbial spoilage [9,10]. Furthermore, improper disposal of waste from mango processing may increase environmental pollution and can become a source of insect multiplication.

Despite their negative impact on environment, fruits by-products are often considered as sources of phytochemicals that acquired the attention of scientists and researchers. Indeed, fruit residues are known to contain vitamins, minerals, fiber, and particularly natural antioxidants that are important for numerous

physiological functions [11,12]. These natural antioxidants have considerable interest compared to synthetic ones due to their nutritional and therapeutic value. Indeed, the extensive use of synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) in food industries have revealed some side effects on human health [13]. Thus, the use of mango peels and kernels to produce new functional foods appears to be a valuable way for their valorization as reported by some authors [14].

Due to the growing consumption and commercialization of mango, this study aimed to quantify the bioactive compounds and the antioxidant activity of mango peels and kernels from two main varieties (Kent, Keitt) cultivated in Côte d'Ivoire. This approach will constitute the starting point for the formulation of low-cost valuable foods and non-foods ingredients from mango by-products.

2. MATERIALS AND METHODS

2.1 Chemicals

DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid, butylated hydroxytoluene (BHT), β-sitostérol, catechol and quercetin were obtained from Sigma-Aldrich (Germany). Folin Ciocalteu reagent was purchased from Fischer Scientific.

2.2 Fruits Sampling and Processing

Ripe mango (*Mangifera indica* L) fruits from Kent and Keitt varieties (n = 60 each) were obtained from local farmers of agricultural cooperative located at Korhogo, a city in the North of Côte d'Ivoire (Latitude: 9°27'28" N; Longitude: 5°37'46" W). The samples were transported in wood boxes to the laboratory and stored for two days at 4°C in the refrigerator until processing. After storage, mango fruits were washed with

soapy water and rinsed. Then clean mango samples were peeled with stainless steel knife, the pulp and kernels were removed. Peels and kernels were collected separately and were dried in a circulating drying oven (Mettler, Germany) at 50°C for 48 hours. Afterwards, dried peels and kernels from selected mango varieties were milled into powder by using a laboratory crusher before further analysis.

2.3 Major Bioactive Compounds Determination

2.3.1 Determination of total phenolic content

Total phenolics were determined according to the method described by Singleton et al. [15]. For this, 100 µL of methanol extract of mango peels and kernels were mixed with 500 µL of Folin-Ciocalteu reagent and 400 µL sodium carbonate (7.5 % w/v). The whole mixture was agitated in vortex and incubated at room temperature for 30 min. Afterwards, absorbance was measured at 745 nm and total phenolic content (mg/100g dw) was obtained by using a standard curve of gallic acid solution (0.1 mg/mL).

2.3.2 Determination of flavonoids content

Flavonoid content was evaluated by spectrophotometric method [16] with slight modifications. Fifty (50 µL) of methanolic extract of each sample were mixed with 100 µL distilled water and 10 µL NaNO₂ (15 %, w/v) solution. Then, the mixture was left to stand for 6 min at room temperature and 15 µL of AlCl₃ (10 %, w/v) solution were added and left to settle again for 6 min. Next, 200 µL of NaOH (4 %, w/v) solution were added, and absorbance was read at 510 nm. The standard curve was performed using quercetin (0 to 1 mg/mL) for calculation of flavonoids content (mg/100g dw).

2.3.3 Determination of tanins content

For the determination of tanins contents, the method of Bainbridge et al. [17] was performed. A quantity (1 mL) of methanol extract of peels and kernels was mixed with 5 mL of vanillin reagent. Then absorbance was read at 500 nm using UV-Visible spectrophotometer (PG Instruments, UK). Total tannin content (mg/100g dw) was calculated based on standard curve of catechol (0.1 mg/mL).

2.3.4 Determination of carotenoids content

A method previously described [18] was used for total carotenoids extraction. Powdered peels or kernels (0.5 g) were mixed with 5 mL ethanol containing butylated hydroxytoluene (0.1%, w/v) and the mixture was heated in a water bath at 85°C/5 min. Then, saponification was performed by adding 400 µL KOH solution (80% w/v) and the suspension was heated in a water bath at 85°C/5 min. Afterwards, 3 mL deionized water was added in the tubes containing the reaction mixture and carotenoids were extracted three times with 4 mL hexane. Total carotenoids content (µg/g dw) was calculated by using a standard curve of β-carotene (0.1 mg/mL).

2.3.5 Determination of phyosterols content

The method based on Liebermann-Buchard reaction [19] was used to quantify total phyosterols. For this, 1 mL of hexane extract from samples was mixed with 2 mL of Liebermann-Buchard reagent. The whole mixture was left to stand for 5 min at laboratory temperature and absorbance was measured in the UV/Vis spectrophotometer (PG Instruments, UK). The phyosterols content (µg/g dw) was determined by using a standard curve of β-sitosterol (0.1 mg/mL).

2.4 Antioxidant Activity Determination

2.4.1 Evaluation of DPPH radical scavenging activity

The scavenging activity of DPPH radical was evaluated using the method described by Choi et al. [20]. Briefly, 50 µL of methanolic extracts from mango peels and kernels (0 to 1 mg/mL) was added to 200 µL 0.1mM DPPH solution (in methanol). The mixture was shaken for 1 min and left to stand for 30 min in the dark at laboratory temperature. After the time of reaction, the absorbance was read at 517 nm with UV/Vis spectrophotometer (PG Instruments, UK). Ascorbic acid (Vitamin C) was used as standard in the same conditions. The radical-scavenging activity was calculated in percentage (%) as follow:

$$DPPH_{inhibition} (\%) = \left[1 - \frac{As}{Ac} \right] \times 100$$

As: Absorbance of sample
Ac: Absorbance of control

2.4.2 Evaluation of ferric reducing power activity

The reducing power of the mango peels and kernels were determined according to the potassium ferricyanide method [21]. An aliquot (500 μ L) of water extracts of peels and kernels (0 to 0.125 mg/mL) in 0.2 M phosphate buffer (pH 6.6) were mixed with 1 mL of potassium ferricyanide (0.1%, w/v) and the mixture was incubated at 50°C for 20 min. Then 500 μ L of trichloroacetic acid (10%, w/v) solution was added to the reaction mixture and centrifuged at 3000 g for 10 min. The supernatant was mixed with equal volume of distilled water and 300 μ L of ferric chloride (1%, w/v) was added. Absorbance was recorded at 700 nm with UV/Vis spectrophotometer (PG Instruments, UK). Ascorbic acid (Vitamin C) was used as standard in the same conditions. Increased reducing power was indicated by increased absorbance.

2.5 Statistical Analysis

All analyses were carried out in triplicates and data were expressed as means \pm standard deviation. One-way analysis of variance (ANOVA) and Duncan's multiple range test were carried out to assess significant differences between means ($p < 0.05$) using XLStat 2020 software.

3. RESULTS AND DISCUSSION

3.1 Bioactive Compounds Content

In our study, the content of bioactive compounds namely phenolics, flavonoids, tanins, carotenoids and phytosterols were determined. Figs. 1, 2 and 3 show the content of phenolics, flavonoids and tanins in the peels and kernels of Kent and Keitt varieties. It was observed that total phenolics content of kernels from Kent (4371.22 ± 24.98 mg/100g dw) and Keitt (4037.93 ± 20.43 mg/100g dw) were higher ($P < 0.05$) than those of peels from the two varieties ($2564.37 - 3082.07$ mg/100g dw). As for total phenolics, kernels from Kent and Keitt varieties highlighted higher values ($105.64 - 223.44$ and $605.36 - 790.39$ mg/100g dw) of flavonoids and tanins, respectively. The contents of total phenolics in our study were different of those ($285 - 49.16$ mg/100g dw) reported for other mango cultivars [1,22]. These differences might be due to many factors such as geographical conditions and extraction methods used. Overall, peels and

kernels from Kent and Keitt varieties may be used as functional ingredients in food formulations due to the presence of phenolic compounds which are known for their antioxidant properties [13].

The contents of carotenoids and phytosterols of peels and kernels from Kent and Keitt varieties are depicted in Figs. 4 and 5. For carotenoids, peels of Kent and Keitt showed higher contents than those of kernels. Indeed, the values for carotenoids content of peels varied from 37.53 to 57.74 μ g/g dw while those of kernels varied from 1.48 to 3.46 μ g/g dw. For phytosterols, the contents ranged as follow: 25.68 – 45.90 μ g/g dw for kernels and 8.32 – 9.15 μ g/g dw for peels. The carotenoids content in our study was lower than those (74 – 436 μ g/g dw) reported for Raspuri and Badami varieties in India [13]. Indeed, carotenoids content in peels are dependent of fruit maturity stage and the type of the cultivar. Carotenoids are lipid-soluble compounds known as provitamin A and may also act as free radical scavengers to prevent lipid oxidation [23]. The distribution of phytosterols indicated higher amount in kernels compared to peels of Kent and Keitt varieties [24]. This result may be due to fatty fraction of kernel. Indeed, mango kernels are important sources of fat (7 – 15%) mainly composed of triglycerides, phytosterols and tocopherols [25].

3.2 Antioxidant Activity

Fig. 6 shows the DPPH radical scavenging activity of the mango peels and kernels extracts. The IC₅₀ values ranged from 0.2 to 0.7 mg/mL with the highest antioxidant activity for kernels from Kent variety. Furthermore, the DPPH scavenging activity of kernels from Kent and Keitt varieties were higher than that of ascorbic acid (0.5 mg/mL) used as standard. The scavenging activity of mango kernels extracts may due to the hydrogen donating ability of phenolic compounds found in kernels [13].

The ferric reducing power activity of peels and kernels from mango samples is shown in Fig. 7. The reducing power increased with the concentration of peels and kernels extracts. The ferric reducing power of kernel extracts from Kent and Keitt varieties was higher than ascorbic acid used as standard in this test. For example, the absorbance at 700 nm was found to be 0.4 for kernel of Keitt variety and 0.3 for ascorbic acid at a dose level of 0.03 mg/mL. This result could be explained by the fact that phenolics and

carotenoids present in the peels and kernels are good electron donors for reducing ferric/ferricyanide complex which indicates antioxidant activity [26].

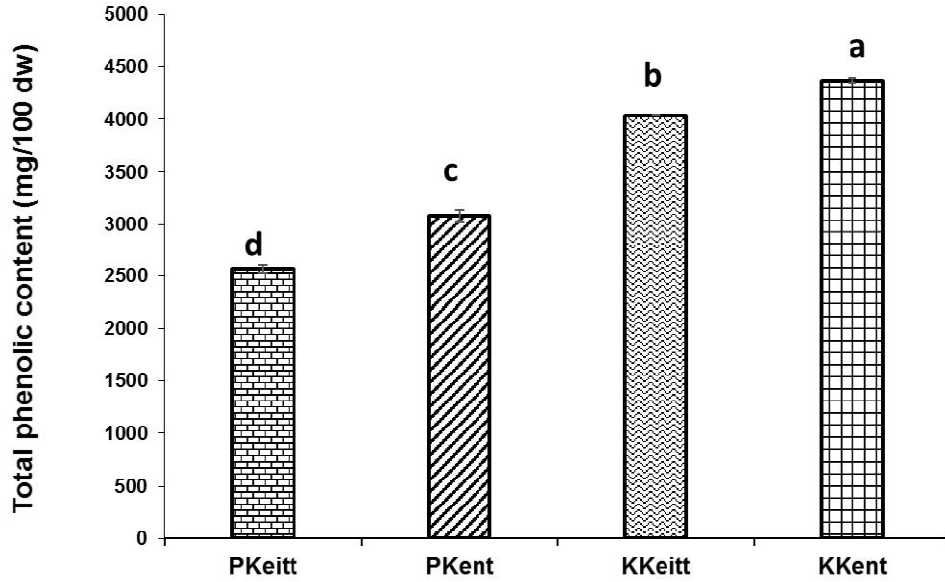


Fig.1. Total phenolic content of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent
Values with different letters are significantly different ($P < 0.05$)

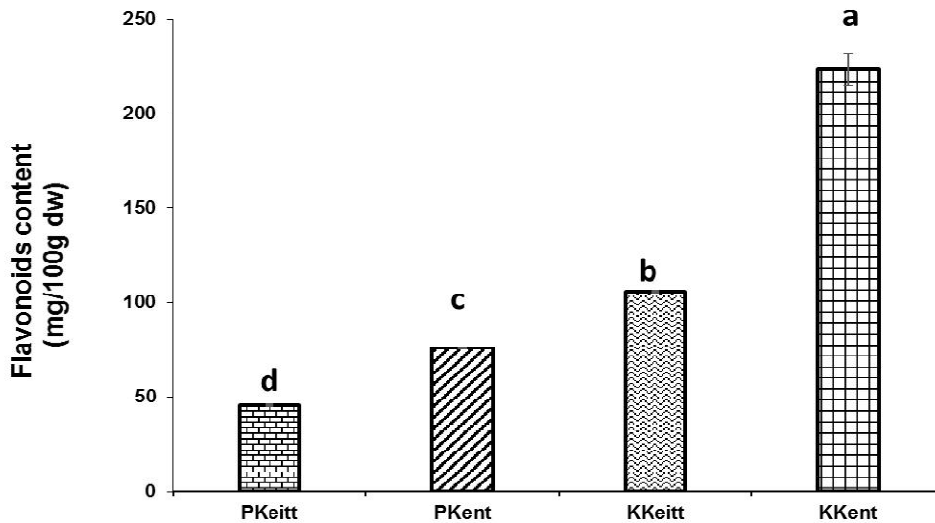


Fig.2. Total flavonoids content of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent
Values with different letters are significantly different ($P < 0.05$)

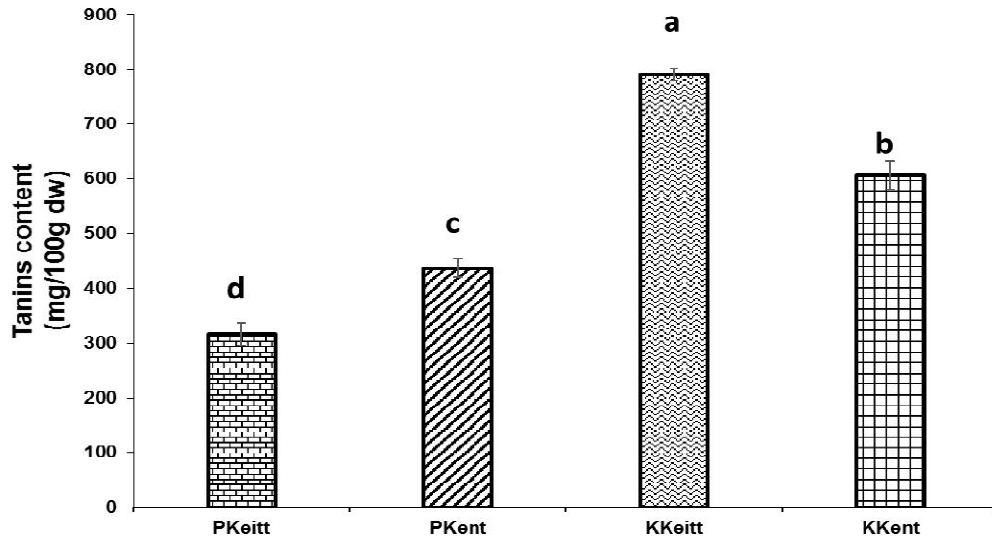


Fig.3. Total tanins content of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent
Values with different letters are significantly different ($P < 0.05$)

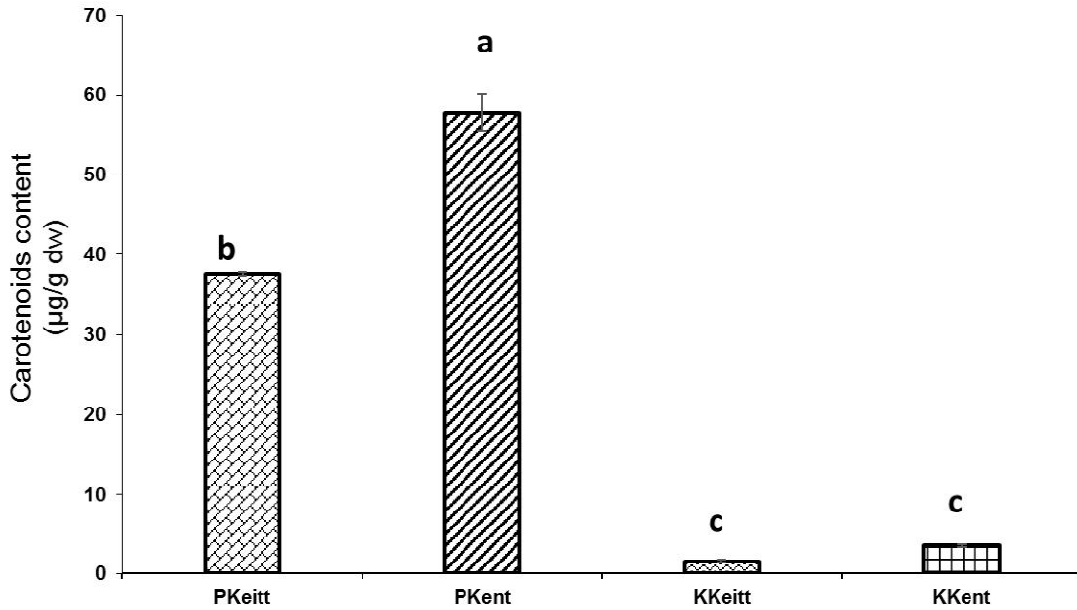


Fig.4. Total carotenoids content of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent
Values with different letters are significantly different ($P < 0.05$)

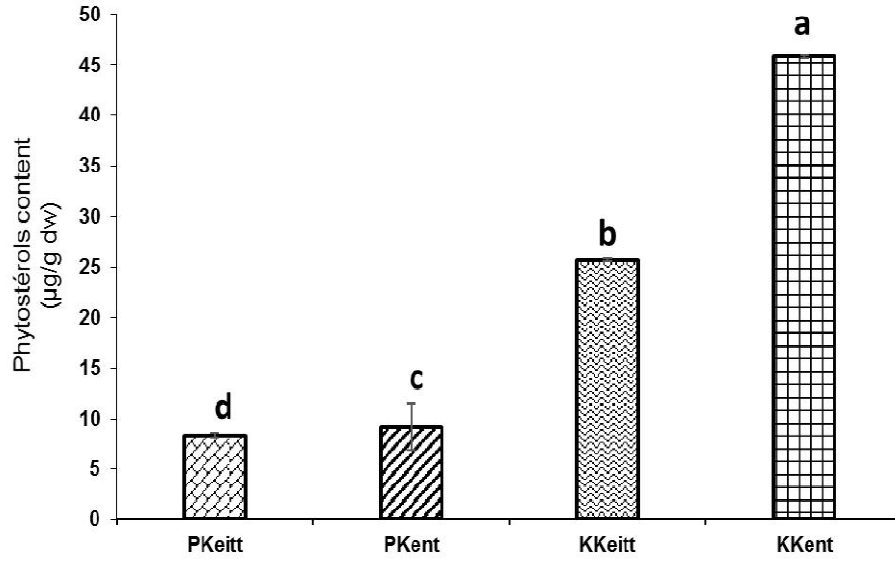


Fig.5. Total phytsterols content of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent
 Values with different letters are significantly different (P < 0.05)

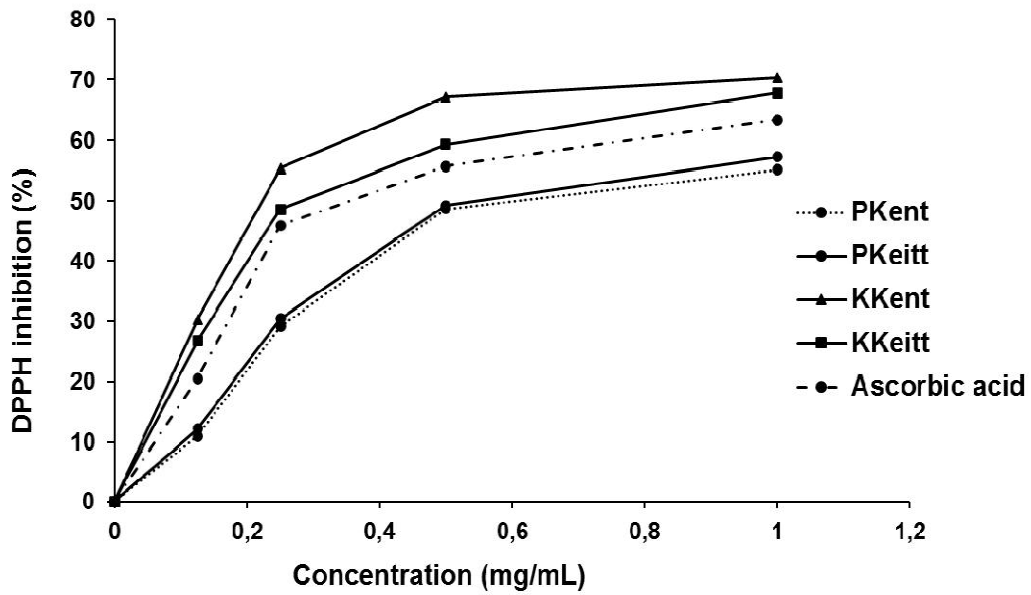


Fig.6. DPPH scavenging activity test of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent

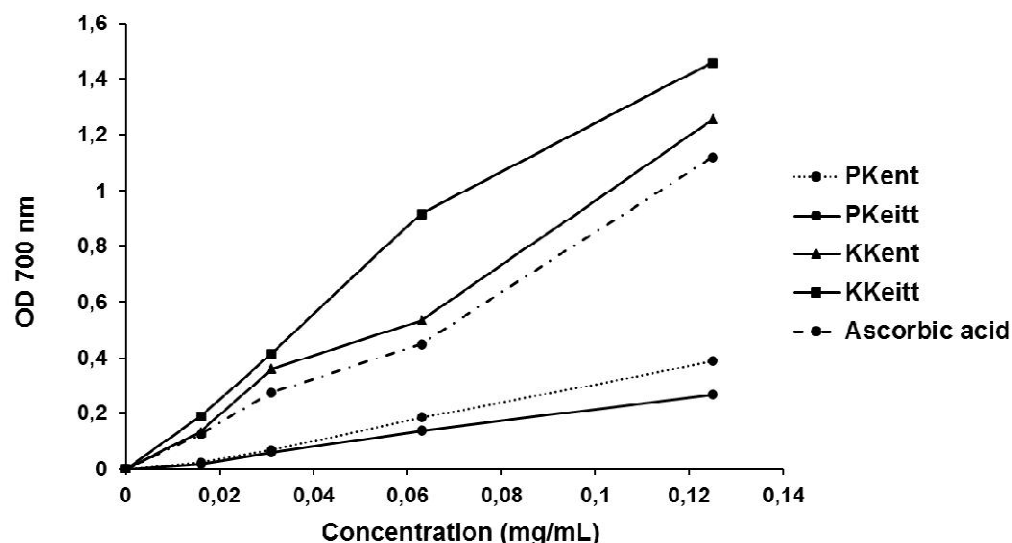


Fig.7. Ferric reducing antioxidant power (FRAP) test of mango peels and kernels

Pkeitt: Peels from Keitt; Pkent: Peels from Kent; Kkeitt: Kernel from Keitt; Kkent: Kernel from Kent

4. CONCLUSION

The aim of this investigation was to evaluate the antioxidative potential of bioactive compounds of mango peels and kernels from Kent and Keitt varieties cultivated in Côte d'Ivoire. This study showed that peels and kernels from Kent and Keitt varieties are potential sources of bioactive compounds especially phenolics, tannins, carotenoids and phytosterols. In addition, kernels from Kent and Keitt varieties highlighted relatively high antioxidant activity. These valuable bioactive compounds in mango by-products may have greater application in the food, cosmetic and pharmaceutical industries. Further studies are needed to establish the complete profile of bioactive compounds of peels and kernels of the studied varieties. This may help perform other studies based on food formulation using peels and kernels of mango as functional ingredients.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of

knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Huang CY, Kuo CH, Wu CH, Kuan AW, Guo HR, Lin YH, et al. Free radical-scavenging, anti-inflammatory, and antibacterial activities of water and ethanol extracts prepared from compression-puffing pretreated mango (*Mangifera indica* L.) peels. *J. Food Qual.* 2018;1-3. Available: <https://doi.org/10.1155/2018/1025387>
- Skyes. Holiday market review; 2018. Retrieved from www.sykescottages.co.uk.
- The mango in Côte d'Ivoire; 2018.

- Available: <https://www.fruitrop.com/en/Articles-by-subject/Full-country-profile/2018/mangoRCI>
4. Lemmens L, Tchuente ES, van Loey AM, Hendrickx ME. Beta-carotene isomerisation in mango puree as influenced by thermal processing and high-pressure homogenisation. *Eur. Food Res. Technol.* Springer; 2013;236:155–63. Available: <https://doi.org/10.1007/s00217-012-1872-y>
 5. Rincon A, Kerr WJ. Influence of osmotic dehydration, ripeness and frozen storage on physicochemical properties of Mango. *J. Food Process. Preserv.* 2010;34:887–903. Available: <https://doi.org/10.1111/j.1745-4549.2009.00404.x>.
 6. Siddiq M, Akhtar S, Siddiq R. Mango processing, products and nutrition. *Trop. Subtrop. Fruits.* Oxford, UK: Wiley-Blackwell. 2012;277–97. Available: <https://doi.org/10.1002/9781118324097.ch15>.
 7. Rojas R, Alvarez-Pérez OB, Contreras-Esquível JC, Vicente A, Flores A, Sandoval J, et al. Valorisation of mango peels: extraction of pectin and antioxidant and antifungal polyphenols. *Waste and Biomass Valorization.* 2020;11:89–98. Available: <https://doi.org/10.1007/s12649-018-0433-4>
 8. Sana BO, Ivi J, Rajeev B. Bioactives from agri-food wastes: Present insights and future challenges. *Molecules.* 2020;25:510. Available: <https://doi.org/doi:10.3390/molecules25030510>.
 9. Ramasamy M, Ramesh PT. Composting of mango wastes. *Biotica Research Today.* 2020;2:C1034-1035.
 10. Athiappan M, Srinivasan S, Anandan R, Rajaram J. Novel process of ellagic acid synthesis from waste generated from mango pulp processing industries. *Emerg. Technol. Environ. Bioremediation;* 2020. Available: <http://dx.doi.org/10.1016/B978-0-12-819860-5.00020-1>
 11. Asif A, Farooq U, Akram K, Hayat Z, Shafi A, Sarfraz F, et al. Therapeutic potentials of bioactive compounds from mango fruit wastes. *Trends Food Sci. Technol.* 2016; 53:102–12. Available: <http://dx.doi.org/10.1016/j.tifs.2016.05.004>.
 12. Ellong EN, Adenet S, Rochefort K. physicochemical, nutritional, organoleptic characteristics and food applications of four mango (*Mangifera indica* L.) varieties. *Food Nutr. Sci.* 2015;6:242–53. Available: <https://doi.org/10.4236/fns.2015.62025>.
 13. Ajila CM, Naidu KA, Bhat SG, Rao UJSP. Bioactive compounds and antioxidant potential of mango peel extract. *Food Chem.* 2007;105:982–8. Available: <https://doi.org/10.1016/j.foodchem.2007.04.052>
 14. Lebaka VR, Wee YJ, Ye W, Korivi M. Nutritional composition and bioactive compounds in three different parts of mango fruit. *Int. J. Environ. Res. Public Health.* 2021;18:1–20. Available: <https://doi.org/10.3390/ijerph18020741>
 15. Singleton VL, Orthofer R, Lamuela-Raventós RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods Enzymol.* Academic Press; 1999;299:152–78. Available: [https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1).
 16. Zhishen J, Mengcheng T, Jianming W. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem.* 1999;64:555–9. Available: [https://doi.org/10.1016/S0308-8146\(98\)00102-2](https://doi.org/10.1016/S0308-8146(98)00102-2)
 17. Broadhurst RB, Jones WT. Analysis of condensed tannins using acidified vanillin. *J. Sci. Food Agric.* 1978;29:788–94. Available: <https://doi.org/10.1002/jsfa.2740290908>.
 18. Howe JA, Tanumihardjo SA. Carotenoid-biofortified maize maintains adequate vitamin A status in mongolian gerbils. *J. Nutr.* 2006;136:2562–7. Available: <https://academic.oup.com/jn/article/136/10/2562/4746697>
 19. Araújo LBDC, Silva SL, Galvão MAM, Ferreira MRA, Araújo EL, Randau KP, et al. Total phytosterol content in drug materials and extracts from roots of *Acanthospermum hispidum* by UV-VIS spectrophotometry. *Brazilian J. Pharmacogn;* 2013;23:736–42. Available: <https://doi.org/10.1590/S0102-695X2013000500004>.
 20. Choi CW, Kim SC, Hwang SS, Choi BK, Ahn HJ, Lee MY, et al. Antioxidant activity and free radical scavenging capacity

- between korean medicinal plants and flavonoids by assay-guided comparison. *Plant Sci.* 2002;163:1161–8. Available:[https://doi.org/10.1016/S0168-9452\(02\)00332-1](https://doi.org/10.1016/S0168-9452(02)00332-1).
21. Yen GC, Chen HY. Antioxidant activity of various tea extracts in relation to their antimutagenicity. *J. Agric. Food Chem. American Chemical Society.* 1995;43:27–32. Available:<https://doi.org/10.1021/jf00049a007>.
 22. El Makawy AI, Ashoush IS, Abd-Elmoneim OM. Evaluation of mango byproduct extracts as antioxidant against Pb-acetate-induced oxidative stress and genotoxicity in mice. *Polish J. Food Nutr. Sci.* 2015;65: 39–47. Available:<https://doi.org/10.1515/pjfn-2015-0009>.
 23. Tokas J, Punia H, Baloda S, Rn S. Mango peel: A potential source of bioactive compounds and phytochemicals. *Austin Food Sci.* 2020;5:1–7.
 24. Manthey JA, Penelope PV. Influences of harvest date and location on the levels of β -carotene, ascorbic acid, total phenols, the in vitro antioxidant capacity, and phenolic profiles of five commercial varieties of mango (*Mangifera indica* L.). *J Agric Food Chem.* 2009;57:10825–30. Available:<http://dx.doi.org/10.1021/jf902606h>.
 25. Jahurul MHA, Zaidul ISM, Ghafoor K, Aljuhaimi FY, Nyam K, Norulaini NAN, et al. Mango (*Mangifera indica* L.) by-products and their valuable components: A review. *Food Chem.* 2015;183:173–80. Available:<http://dx.doi.org/10.1016/j.foodchem.2015.03.046>.
 26. Chung YC, Chang CT, Chao WW, Lin CF, Chou ST. Antioxidative activity and safety of the 50% ethanolic extract from red bean fermented by *Bacillus subtilis* IMR-NK1. *J Agric Food Chem;* 2002;50:2454–8. Available:<http://dx.doi.org/10.1021/jf011369q>.

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