UMYU Scientifica, Vol. 3 NO. 2, June 2024, Pp 114 – 126
https://doi.org/10.56919/usci.2432.012
ISSN: 2955 – 1145 (print); 2955 – 1153 (online)
A periodical of the Faculty of Natural and Applied Sciences, UMYU, Katsina

ORIGINAL RESEARCH ARTICLE

Nutritional and Phytochemical Evaluation of Kanya (*Diospyros mespiliformis*) Juice: A Potential Functional Beverage for Enhanced Food Security

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ABSTRACT

Diospyros mespiliformis is a fruit not used much but has remarkable micronutrients and a phytochemical composition that may improve food security and human nutrition. *Diospyros mespiliformis* is an indigenous wild- tree whose importance has not been fully explored. This study aimed to assess the nutritional qualities of *kanya* and *kanya* juice for potential usage as a functional beverage. Riped and dried samples of the fruits were collected from a forest in Wudil Kano state. Fruit pulp and fresh and dried kanya peel were assessed for their proximate and mineral contents using standard procedure. Juice from the fresh pulp, peel, and pulp and the dried pulp, peel, and pulp alone were made, and their phytochemicals, vitamins, physicochemical, antioxidant activity, and sensory qualities were analyzed. The results obtained from the proximate analysis were: moisture content (4.92 – 65.20%), Ash (0.44 – 0.88%), Fiber (0.29 – 2.60%), Fat (1.41 – 6.76%), Protein (0.90 – 6.86%) and Carbohydrate (31.72 – 86.56%). The mineral analysed were: Calcium (16.27 to 62.03 mg/100g), Potassium (495.55 – 1891.00mg/100g), magnesium (9.050 –9.841 mg/100g), Sodium (12.840 – 46.643mg/100g) and Zinc (0.534 – 1.111mg/100g) are both found in good amounts in *kanya* fruit. The Vitamins analysed were: Vitamin B1 (0.120 – 0.147mg/100g.), Vitamin B2 (0.03- 0.071mg/100g), Vitamin B3(1.68- - 4.29mg/100g), Vitamin B6(0.11- 0.277mg/100g) and Vitamin C (23.20- 45.92mg/100g). Phytochemicals analysed were: Flavonoids (4.941 – 5.369mg/100g), Tannins (27.649 – 94.434mg/100g), Alkaloids (90.511 – 0.562mg/100g), Saponins (18.760-256.000mg/100g), and Steroids (0.150-2.115mg/100g). The findings suggest that *Diospyros mespiliformis* fruit juice consumption could overcome malnutrition, maintain a healthy state, and prevent various diseases. Furthermore, the fruit can be used as new food ingredients for formulation. It is another less expensive source of raw materials for juice production, and juice is enjoyed for its unique qualities and sensory advantage. Its moderate calcium value could also be used to manage oesteomalacia.

ARTICLE HISTORY

Received January 14, 2024.
Accepted May 20, 2024.
Published June 23, 2024.

KEYWORDS

Kanya, underutilized crops, juice nutritional components, fruit juice, beverage drinks

INTRODUCTION

Diospyros mespiliformis belongs to the plant family Ebenaceae, commonly known as "Jackal berry or African ebony" (Ebbo et al., 2020). In Benin, it is referred to as Igidudu in Yoruba, Mwibu in Batonu, and Gunaga in Fongbe. Its leaves are simple and arranged alternately, displaying a dark green coloration. The tree's height ranges from 15 to 50 meters (Chivandi & Erlwanger, 2011). It exhibits dioecious characteristics, with flowers appearing in April and May and yielding large yellow berries upon maturity (Dangoggo *et al.*, 2012). The tree's bark is black or grey-black (Palgrave, 1981), and it bears white flowers, reproducing through seeds, suckering, and layering (Janick & Paull, 2008). Traditional medicine uses various parts of the tree to treat ailments such as sleepiness, malaria, cough, inflammation, cardiovascular diseases, cancer, and arthritis (Olanlokun *et al.*, 2021). Additionally, the edible fruits of D. mespiliformis are commonly consumed during times of scarcity (Chivandi & Erlwanger, 2011). *Diospyros mespiliformis*, commonly known as jackfruit or African ebony, belongs to the family Ebanaceae, a deciduous tree (Abba *et al.,* 2015). The tree fruits ripen in the dry season (Chivandi and Erlwanger, 2011). The fruit is popularly known as "Kanya" among the Hausa-speaking people of northern Nigeria. When ripe, the fruit is yellowish to

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How to cite: Muhammad, H. S., Atiku, M. K., Basheer, D. H., Zubairu, I. K., & Muhammad, S. M. (2024). Nutritional and Phytochemical Evaluation of Kanya (*Diospyros mespiliformis*) Juice: A Potential Functional Beverage for Enhanced Food Security. *UMYU Scientifica*, 3(2), 62 – 67. https://doi.org/10.56919/usci.2432.012

orange in color and has a sweet lemon-like taste. It is eaten raw by children and adults or dried and kept for later use. This study provides scientific insight into the potential health and nutritional benefits of *Diospyros mespiliformis* fruit by evaluating its health-promoting components. Analysis of bioactive compounds, functional properties, nutritional composition, and bioaccessibility of minerals will help support claims of indigenous knowledge about the value of fruit and guide future value-adding efforts.

Shagal *et al.* (2012) studied the antimicrobial properties of aqueous and ethanol extracts derived from the leaves, stem bark, and roots of *Diospyros mespiliformis*. The efficacy of these extracts was tested against various pathogens, including *Klebsiella pneumonia, Salmonella typhi, Staphylococcus aureus, Escherichia coli, Shigella spp, and Streptococcus spp,* through clinical evaluation. The LD_{50} value for the aqueous stem bark extract of Diopyros mespiliformis was above 5000 mg/kg, and clinical trials utilized doses ranging from 25mg/kg to 500mg/kg (Orisakwe *et al.*, 2003). *Diospyros mespiliformis* fruits, belonging to the Ebanaceae family, are considered edible and nutritious. Phytochemical analysis revealed the presence of tannins, alkaloids, saponins, flavonoids, glycosides, and steroids in D. mespiliformis extracts (Ebbo *et al.*, 2014). Additionally, it has been traditionally used in medicine for wound healing, treatment of syphilis, as an anthelmintic, and to alleviate fever (Dangoggo *et al.*, 2012).

Fruits, rich in fiber, vitamins, and minerals, have been a dietary staple since ancient times, including a wide array of wild fruits consumed for aesthetic and nutritional purposes (Rathod and Valvi, 2011; Duguma, 2020). With over a billion people relying on wild fruits like *Diospyros mespiliformis* for daily nutrition, these plants serve as vital sources of micronutrients, contributing to food security and development in rural communities (Lulekal *et al.*, 2011; Feyssa *et al.*, 2011; Getachew *et al.*, 2013). Fruit juice, whether made from whole fruits or specific parts, is gaining popularity worldwide due to its nutritional benefits, convenience, and refreshing taste, offering health advantages and protection against chronic diseases (Landon, 2007; Alaka *et al.*, 2003; Ndife *et al.*, 2013; Hossain *et al.*, 2012; O'Neil, 2008; Oranusi *et al.*, 2012; Cashwell, 2009).

A significant research gap lies in the lack of thorough scientific investigation into the specific bioactive compounds of *Diospyros mespiliformis* responsible for its reported medicinal properties. Despite extensive ethnobotanical knowledge, studies are scarce to elucidate the chemical composition of its various parts. Identifying these compounds and understanding their mechanisms of action could lead to developing novel pharmaceuticals or natural remedies, validating traditional uses, and unlocking the plant's full therapeutic potential for global healthcare.

MATERIALS AND METHODS

Materials, sample collection, and identification

Materials used in this research were: Fresh and dried samples of *Kanya (Diospyros mespiliformis)* fruit were sourced from a forest in Wudil Local Government (11º49'N and 8º51'E) of Kano south, Kano State, Nigeria, and the samples were identified at the Department of Forestry and Wildlife study of the Aliko Dangote University of Science and Technology Wudil. Other food-grade analytical materials, equipment, and apparatus were from the food analysis laboratory of the Aliko Dangote University of Science and Technology and the Department of Biochemistry, Bayero University Kano, Nigeria.

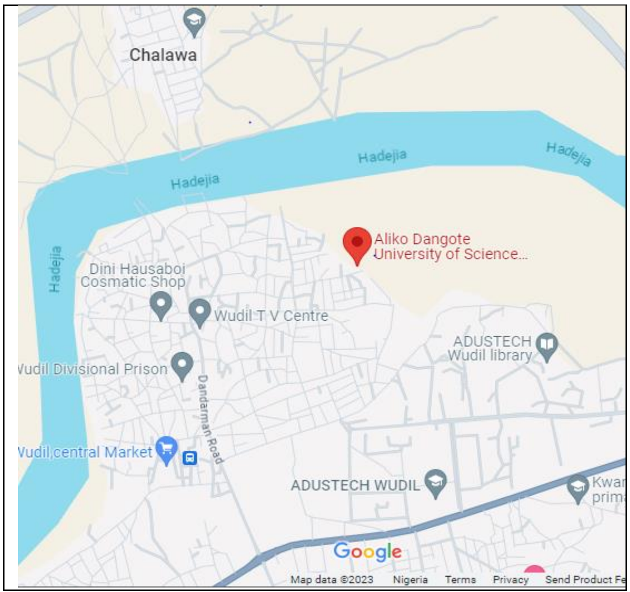

Figure 1: A picture depicting the location of the source of the sample from Google map

Source: Google Maps (n.d.)

Sample preparation.

Freshly ripe *Diospyros mespiliformis* fruit was sorted to remove decayed or injured fruits and washed to remove sand and unwanted parts, if there were any, for further processing. The dried *Diospyros mespiliformis* was also sorted to remove the unwanted parts. The seeds of fresh and dried *Diospyros mespiliformis*were then manually removed, along with the peel and the pulp of fresh and dried Diospyos mespiliformis were also separated manually and labeled. The pulp and peel were then blended in a mechanical blender to a smooth paste. Water was added to the paste in a ratio of 1:9 to improve its consistency and facilitate filtration. It is then filtered to remove solid particles from the *Diospyros mespiliformis* juice. This was done on fresh and dried kanya, which was made up of four samples: Dried Fruit pulp as DF pulp, Dried Fruit peel & pulp as DF peel+pulp, Fresh Fruit peel & pulp as FF peel+pulp, and Fresh Fruit pulp as FF pulp. Physiological, vitamin, and sensory evaluations were analyzed on the juices.

Methods

Proximate analysis of Kanya fruit juice

The proximate analysis was carried out on the fresh and dried *Kanya* pulp and peel varieties, and the AOAC (1990) method of analysis was used for the determination of the moisture content ash, protein, fat, and crude fiber content of the *Kanya* fruit juice samples, while the percentage carbohydrate was determined by difference as described in the following mathematical expression.

$$\text{Carbohydrate (\%)} = 100 - (\%\,\text{Fiber} + \%\,\text{Protein} + \%\,\text{Moisture} + \%\,\text{Fat} + \%\,\text{Ash})$$

Phytochemical analysis of Kanya fruit juice

Qualitative analysis: The presence of certain classes of natural products was determined in all three fractions. The phytochemical analysis covered the tests of alkaloids, flavonoids, tannins, steroids, saponins, and terpenoids.

Test for alkaloids: Mayer's test, described by Velavan (2015), was used. To a few milliliters of the filtrates, 1 ml of Mayer's reagent (potassium mercuric solution) was added by the side of the test tube. A cream-colored precipitate indicates the test is positive.

Test for steroids: Extract (2 ml) with 2 ml of chloroform, and 2 ml of concentrated H_2SO_4 was added to the extract. The appearance of red color and yellowish-green fluorescence indicates the presence of steroids (Vishnu *et al.,* 2019).

Test for Tannins: About 0.5 g of the sample was stirred with distilled water (10 ml) and then filtered. A few drops of 5 % ferric chloride are then added. Black or a blue-green coloration or precipitate was taken as a positive result for the presence of tannins (Vishnu *et al.,* 2019).

*Test for Saponins***:** About 2 g of the sample was boiled in 20 ml of distilled water in a water bath and filtered. Filtrate (10 ml) was then mixed with 5 ml of distilled water and shaken vigorously for a stable, persistent froth. The frothing was then mixed with 3 drops of olive oil and shaken vigorously, then observed for the formation of an emulsion (Velavan, 2015).

Test for Flavonoids: The Sofowara (1993) procedure, as described in Velavan (2015), was used to determine the presence of flavonoids in the sample. Dilute ammonia solution (5 ml) was added to a portion of the aqueous filtrate of each extract, followed by the addition of concentrated H_2SO_4. A yellow coloration observed in each extract indicated the presence of flavonoids. The yellow coloration disappeared when standing.

Test for Terpenoids: The Salkowski test, as described in Velavan (2015), was used to determine terpenoids. Five ml of each extract was mixed in 2 ml of chloroform, and concentrated H_2SO_4 (3 ml) was carefully added to form a layer. A reddish-brown coloration of the interface formed shows positive results for the presence of terpenoids.

Quantitative determination of phytochemical

The Aluminum chloride method determined total flavonoid content using quercetin as a standard (Velavan, 2015). Sample (1 ml) and 4 ml of water were added to a volumetric flask (10 ml volume). After 5 min, 0.3 ml of 5 % Sodium nitrite and 0.3 ml of 10 % Aluminum chloride was added. After 6 min of incubation at room temperature, 2 ml of 1 M Sodium hydroxide was added to the reaction mixture. Immediately, the final volume was made up to 10 ml with distilled water. The absorbance of the reaction mixture was measured at 510 nm against a blank spectrophotometrically. Results were expressed as quercetin equivalents (mg quercetin/g dried extract).

*Total Saponins***:** The test sample was dissolved in 80 % methanol, 2 ml of Vanilin ethanol was added and mixed well, then 2 ml of 72 % sulphuric acid solution was added, mixed well, and heated in a water bath at 60 ^{0}C for 10 min, absorbance was measured at 544 nm against reagent blank. Diosgenin is used as a standard material and compared the assay with Diosgenin equivalents in mg/g (Velavan, 2015).

Total Tannins: The total tannins were determined using a folin-ciocalteur method with minor modifications (Indira *et al.*, 2016). About 0.1 ml of sample was added to a volumetric flask (10 ml) containing 7.5 ml of distilled water, 0.5 ml of folin-ciocalteur phenol reagent, and 1ml of 35 % sodium carbonate solution was then diluted to 10 ml with distilled water. The mixture was shaken well and kept at room temperature for 30 minutes. A set of reference solutions of tannic acid standard solution were prepared, the absorbance of the test and standard were measured using a UV spectrophotometer against blank (distilled water at 700 nm) the estimation of total tannins content was carried out in triplicate. The tannin content was expressed in terms of mg/g of tannic acid.

*Total Steroids***:** A test extract of steroid solution (1 ml) was transferred into 10 ml volumetric flasks. Sulphuric acid (4N, 2 ml) and iron (III) chloride (0.5 % w/v, 2 ml) were added, followed by potassium hexacyanoferrate (III) solution (0.5 % w/v, 0.5 ml). The mixture was heated in a water bath maintained at 70±2 ^{0}C for 30 minutes with occasional shaking and diluted to the mark with distilled water. The absorbance was measured at 780 nm against the reagent blank (Indira *et al.*, 2016).

Total Alkaloids: To 1 ml of test extract, 5 ml pH 4.7 phosphate Buffer was added, and 5 ml BCG solution and shaken a mixture with 4 ml of chloroform. The extracts were collected in a 10 ml volumetric flask and then diluted to adjust volume with chloroform. The absorbance of the complex in chloroform was measured at 470 nm against the blank prepared as above but without extract. Atropine is used as a standard material and compared the assay with the Atropine equivalent in (mg/g) (Velavan, 2015).

Determination of radical scavenging activity (DPPH)

The free radical scavenging activity of the extract against DPPH (1,1- diphenyl-2- picryhydrazyl) was carried out using the method of Onwuka (2005).

DPPH is a stable organic free radical, which loses its absorption spectrum band at 515-528 nm when it accepts an electron or a free radical species. The DPPH assay is a simple, acceptable, and widely used technique to evaluate the radical scavenging potency of plant extracts. The plants' antioxidants can enact the visually noticeable quenching of the stable purple-colored DPPH radical to the yellow-coloured DPPH (Aryal *et al.,* 2019).

The radical scavenging activity (RSA) of the crude extracts was used to measure antioxidant activity using the DPPH method of (Aryal *et al.,* 2019) with some modifications. 2 ml of extract solution (31.25 - 1000 µg/mL) in methanol was added to 2 mL of DPPH (0.1 mM) solution. The mixtures were kept in a dark area for 30 minutes, and absorbance was measured at 517 nm against an equal amount of DPPH and methanol as a blank. The percentage of DPPH_ scavenging (RSA %) was estimated using the equation:

$$\%\ scavenging\ of\ DPPH = [(A0 - A1)/A0] \times 100$$

Where A_0 = absorbance of the control and

A_1 = absorbance of the test extracts.

Physicochemical properties of Diospyros mespiliformis juice

AOAC (1990) standard method was used **to determine** pH, Brix**,** and Total Titratable acidity (TTA). The pH was measured using a standard pH meter (Hanna instruments, HI membrane PH meter), while the amount of total soluble solids (TSS) was determined using a bench-type Abbe refractor-meter (0 – 32 °C) and expressed as ° Brix. The Viscosity was determined using a viscometer with temperature control, sample adaptor, and spindle as described in the IUPAC methods (2000). From the fresh juice extract, 8 ml was taken and poured into the sample adaptor**,** and the spindle **attached to the viscometer** was then immersed into the sample. The viscosity of the extract was measured at 30 rpm rot or speed**,** and **the** extract temperature was maintained at 30 °C. **The** viscosity of the sample was measured in centipoises (cP).

Determination of mineral content

The minerals (Magnesium, Zinc, Potassium, Sodium, and Calcium) were determined using AOAC (1990) method. Aliquots of the digests were used to determine the Ca, Mg, and Zn levels by Atomic Absorption Spectrophotometer. Na and K were determined with a flame photometer.

Determination of vitamin content

Vitamin B_1 was determined as described by Onwuka (2005). British Pharmacopoedia (1988) was used for vitamin B_2 and the spectrophotometric method for Vitamin B_6.

The ascorbic acid content was determined using the oxidation-reduction titration method described by Mau *et al.* (2005). Metaphosphoric acid (10 ml of 3 %) was added to 5 ml of the sample and filtered to remove possible protein interference. The filtrate was titrated against freshly standardized 2,6 – dichloroindophenol (DCP). The standardization was with 10ml of standard ascorbic acid.

$$Vitamin\ C = mg/100ml\ juice = 20(v)\ (c)$$

Where c = ml indophenol solution in titration

C = mg vitamin c/ml indophenols

Sensory evaluation

Sensory evaluation of the *Diospyros mespiliformis* (*kanya*) juice samples was assessed by 20 semi-trained panelists from the Department of Food Science and Technology, Aliko Dangote University of Science and Technology, Wudil, Nigeria. Different samples of *Diospyros mespiliformis* (kanya) juice (from fresh and dried fruits) were assessed for their color, texture, flavor (aroma), taste, and overall acceptability using a 9-point hedonic scale. The panelists were instructed to sip water before and after assessing each product. The 9-point scale is as follows: 9 = extremely like; 8 = like very much; 7 = like moderately; 6 = like slightly; 5 = neither like nor dislike; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike very much and 1 = dislike extremely. Each was evaluated three times by each panelist (Ihekoronye and Ngoddy1985).

2.11 Statistical analysis

Data are expressed as mean and standard deviation (SD) of three replicates. The mean, SD, and analysis of variance (ANOVA) will be calculated using SPSS version 21, and Duncan's Multiple Range Tests (DMRT) will be performed to study the differences at a 5 % significance level.

RESULTS AND DISCUSSION

Proximate composition

The result of the proximate analysis of *Kanya* is presented in Table 1. The proximate content results show a change in moisture content value from 4.92 to 5.6 % in dried fruit peel and dried fruit pulp, respectively, and 65.2 and 45.0 % in fresh fruit pulp and fresh fruit peel, respectively. Ash content was 0.63 % and 0.88 in dried fruit pulp and dried peel and 0.68 to 0.44 % in fresh fruit peel and fresh fruit peel, respectively, while fat contents ranged from 6.76 to 2.89 % in dried fruit peel and dried fruit pulp and 1.41 to 1.76 % in fresh fruit pulp and peel respectively. The percentage of fiber was highest at 2.6 % in dried fruit peel and lowest in fresh fruit pulp with 0.29 %. Protein content was also 6.86 % and changed to 3.59 % in dried peel and dried fruit pulp, respectively, while 1.5 % to 0.90 % were found in fresh fruit peel and fresh fruit pulp, respectively. The highest carbohydrate content of 86.56 % was found in the dried fruit pulp sample, while the lowest of 31.72 % was in the fresh fruit pulp sample. Energy values were generally high, ranging from 133.07 % in fresh fruit pulp to 367.17 % in dried fruit pulp samples.

Table 1: Proximate composition of *Kanya* fruit

Sample	Moisture	Ash	Fiber	Fat	Protein	Carbohydrate
Dried peel	4.92±0.080[d]	0.88±0.030[a]	2.60±0.150[a]	6.76±0.122[a]	6.86±0.243[a]	77.93±0.038[b]
Dried pulp	5.60±2.50[c]	0.63±0.020[c]	0.73±0.020[c]	2.89±0.011[b]	3.59±0.015[b]	86.56±0.060[a]
Fresh pulp	65.2±0.110[a]	0.44±0.010[d]	0.29±0.010[d]	1.41±0.016[d]	0.90±0.010[d]	31.72±0.0160[d]
Fresh peel	45.0±0.020[b]	0.68±0.010[b]	0.99±0.010[b]	1.76±0.010[c]	1.50±0.010[c]	50.09±0.017[c]

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

The proximate composition of *Diospyros mespiliformis* fruit pulp and peel is presented in Table 1. The moisture content of the dried fruit peel was 4.92, while that of the dried pulp was 5.6 %. These values are similar to those obtained by Ezeagu *et al.* (1996) for a black plum fruit and Ilouno *et al.* (2018) for *Kanya* seeds. However, it was higher when compared to other wild fruits such as *Cassipourea congoensis, Nuclea latifolia, and Gemlina arboea* (Nkafamiya *et al., 2007*). The moisture content of fresh pulp and peel was found to be 65.2 to 45.0 %, respectively, which is almost similar to the findings from a study in China by Amzat *et al.* (2010) and study from Lagos, Nigeria, on the same plant by Garba *et al.*, (2022) and also Muhammad *et al.*, (2015), the moisture content was generally lower than the 67.55 % reported Muhammad *et al.*, (2015), but higher than the 14.33 % reported by Jamilu *et al.,* (2022). Higher moisture content increases microbial activities during storage (Abdel *et al.,* 2007). Therefore, the peels and pulp of the fresh whole fruit should be properly dried before storing because there is a significant link between microbial presence and spoilage (Kari *et al.*, 2022). Moisture content in fresh fruits influences the deterioration and shelf life of a fruit sample Ilouno *et al.,* (2021). Ash content is an indicator of a mineral element. Minerals are important in human nutrition due to their pro-oxidant activity and health benefits (Ilouno *et al.,* 2021). The ash content of *Diospyros mespiliformis* was moderate: 0.88 % in dried peel and 0.63 % in dried pulp, 0.44 % and 0.68 % in fresh pulp and peel which is lower than 5.33 % reported by Muhammad *et al.* (2015) for *Gawasa* fruit peel, lower than 10.20 % for *Sclerocarya birrea* peels reported by Muhammad *et al.* (2016), also lower than 8.00 – 11.20 % which is the range for ash content reported in the peels of some tropical fruits Hassan *et al.* (2008). But higher than lower Ash value as reported by Ezeagu *et al.* (1996) and Ilouno *et al.* (2021) for the same fruit seed. The value obtained is within the range reported for commonly consumed edible wild fruits. The ash content, which measures the total amount of minerals present in a food, suggests that wild *Kanya* contain a reasonable amount of minerals. The result also showed that the sample contained a moderate amount of inorganic matter, which needs to be confirmed by mineral analysis. The amount of crude fat was 6.76 % in the dried peel, 2.89 % in dried pulp, 1.41 % in fresh pulp, and 1.76 in the fresh peel, the value for dried peel is higher than the values reported by Ezeagu *et al.*, (1996) and Adewuyi *et al.* (2014) with values of 5.46 % and 4.72 % respectively for *Kanya* fruit and higher than 2.2 % in Ilouno *et al.* (2021), 2.3 % for *Gawasa* fruit peel (Muhammad *et al.*2015), 1.2 % in the peel of African star-apple (Leakey, 1999) but lower than 8.33 % reported for Hasta la pasta fruit (Hassan *et al.,* 2009). The result revealed that the fruit could not be classified as an oil fruit like groundnut and melon (Elinge *et al.*, 2012) as its fat content is below 15 %.This is expected as most fruits are generally known for their low lipid content (Hassan *et al.,* 2009). As a result of this, they could be used to control body weight. Lipids are utilized by cells and tissues during consumption to provide energy in a two-fold better fashion than carbohydrates and also play roles in making cell and tissue secretions (Okonwu *et al.,* 2015). However, the lipid value shown in this study is comparatively lower than the value reported from the gingerbread seed obtained in China (Amzat *et al.,* 2010).The fiber content of the dried fruit was 2.6 and 0.73 % in the dried peel and pulp, respectively, and fiber content decreased to 0.29 % and 0.99 % in the fresh pulp and peel, respectively. This reduction in fiber content indicates a higher fiber concentration in the peel than in the pulp of both dried and fresh fruit. The presence of fiber in foods helps to ease the passage of waste, thus preventing constipation. In addition to cleaning the digestive tract, fibers help absorb excess cholesterol and intake of excess starchy food (Ahamefula *et al.*, 2014). In addition, *Kanya* peel displayed a much lower level of dietary fiber than some other fruit peels too, especially avocado (43.9 %), pineapple (16.3 %), and papaya (16.6 %) (Damila *et al.,* 2017). This trend could be explained as a fruit defense against heat stress. Results agree well with Lamghari *et al.* (1998) and Gorinstein *et al.* (2002). Similar to the present study, these authors obtained significantly higher ($p < 0.05$) dietary fiber values in the studied peels than in pulps. It is well known that diets high in dietary fiber are associated with the prevention and treatment of various diseases, such as diverticular and coronary heart disease, colon cancer, and diabetes, besides contributing to weight loss in individuals with obesity (Pérez-jiménez, 2008). Based on the results observed, Kanya is a potentially good dietary fiber source and could contribute to preventing and treating several degenerative diseases. Therefore, these fruits could be included in some food formulations for fiber enrichment. Also, fiber in foods benefits the body such as in the prevention of constipation, lowering of blood cholesterol, and reducing the risk of various cancers; yet emphasis has been placed on the importance of keeping fiber intake low in the nutrition of infants and weaning children because high level in diet can lead to irritation of gut mucosa in children.

The high protein content of 6.86 % and 3.59 % was recorded for dried peel and pulp samples, and this value reduced to 0.90 % and 1.50 % in fresh pulp and peel, which is less than the value recorded for *Vitex doniana* (27.75 %) fruit and thus suggests that the seed of wild *Diospyros mespiliformis* is a relatively rich source of protein. The calculated value for carbohydrates was 77.93 % and 86.56 % recorded on dried peel and pulp samples and is relatively higher than pawpaw seed (36.2 %) (Mathew *et al.,* 2014) and dabai seed (44.6 %) (Okegori *et al.*, 2016) and is relatively high when compared to fat and protein contents. The carbohydrate content was lower with 31.72 % and 50.09 % for the fresh pulp and peel. Furthermore, the carbohydrate content of wild black plum seed can be considered on the high side when compared to levels reported in Mathew *et al.* (2014) and Okegori *et al.* (2016), pawpaw seed (36.2 %) and dabai seed (44.6 %) respectively.

Mineral content

The result of the mineral analysis confirmed the presence of calcium, potassium, magnesium, Sodium, and zinc in all the fruit juice samples, as shown in Table 2.

Table 2: Minerals content of *Kanya* fruit

Sample	Calcium	Potassium	Magnesium	Sodium	Zinc
Dried peel	16.27±0.021^{d}	763.53±0.289^{b}	9.841±0.002^{b}	46.643±0.015^{a}	1.111±0.001^{a}
Dried pulp	40.31±0.020^{c}	1891.00±1.000^{a}	9.941±0.002^{a}	29.607±0.021^{c}	0.534±0.002^{d}
Fresh pulp	62.03±0.050^{a}	556.43±0.153^{c}	9.240±0.001^{c}	39.547±0.015^{b}	0.805±0.005^{b}
Fresh peel	44.77±0.025^{b}	495.55±0.403^{d}	9.050±0.002^{d}	12.84±0.012^{d}	0.558±0.002^{c}

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

Minerals are essential nutrients that are said to be present in small amounts in the body or several parts per million (Gafar *et al.*, 2011). They are essential because they each play an important role in the body's metabolic processes, and their absence can cause deficiency symptoms in animals (Gafar *et al.*, 2011). The essential mineral elements of nutritional importance are macro (major) elements such as Ca, K, Na, and Mg. The micro (trace) elements are Fe, Mn, Zn, and Cu (AOAC, 1990). Macronutrient results on the analysis of macro mineral content of the *Kanya* revealed that Potassium and Calcium (Ca) content were very high, 1891.0 mg/100g and 62.03 mg/100g in the dried fresh fruit pulp, respectively, followed by Sodium with 46.643 mg/100g in dried fruit peel sample. The values observed for Magnesium (Mg) and Zinc (Zn) were 9.941 mg/100g and 1.111 mg/100g in dried pulp and peel samples, respectively. Most of the minerals are higher in dried samples than in fresh samples. This may be because of the reduced moisture concentration (moisture content) from fresh to dried.

Fresh peel sample has the lowest Sodium, 12.84 mg/100g, and magnesium, 9.050 mg/100g, whereas Na and K take part in the ionic balance of the human body and maintain tissue excitability. Because of the solubility of salts, Na plays an important role in the transport of metabolites. K is of importance as a diuretic. Calcium is high and constitutes a large proportion of the bone, human blood, and extracellular fluid; it is necessary for the normal functioning of cardiac muscles, blood coagulation and milk clotting, and the regulation of cell permeability. It also plays an important part in nerve-impulse transmission and the mechanism of the neuromuscular system. Calcium is also an important nutritional element required in diet as they are indispensable cofactor in blood coagulation. They also act as second messengers in the signal transduction pathway and control muscle contraction (Ilouno *et al.,* 2021). In addition to being the major constituent of bone, Ca is required by many enzymes for their activity (Koolman *et al.*, 2005). Magnesium was moderate because of the chlorophyll content in the fruit peel. In humans, Mg is required in the plasma and extracellular fluid, where it helps maintain osmotic equilibrium (Gafar *et al.*, 2011). Similar high calcium content (80.3 mg/kg) was reported for orange juice (Simpkins *et al.,* 2000) and 282 mg/kg for baobab fruit pulp (Adam *et al.*, 2016). Calcium is important for muscles and bone health (Pravina *et al.*, 2013). This makes the fruit of *Kanya* an excellent source of calcium supplements for lactating women and children. Potassium is also essential to body cells and fluid, while low Sodium is ideal for a healthy heart. The analysis shows a high amount of zinc falls within the range earlier published for edible vegetables (Ilouno *et al.,* 2021).

Vitamin content

The result of the vitamin analysis is shown in Table 3 below. The result shows the presence of vitamins B_1, B_2, B_3, B_6, and vitamin C. Vitamin B1 was found to be highest in the dried fruit peel and pulp mix, juice sample with 0.310 mg/100g, and dried pulp juice sample had the lowest value with 0.120 mg/100g while 0.147 mg/100g in the fresh fruit peel and pulp mix and 0.137 mg/100g.

Table 3: Vitamin content of *Kanya* juice

Sample	Vitamin B1	Vitamin B2	Vitamin B3	Vitamin B6	Vitamin C
Fresh(peel+pulp)	0.310 ± 0.010^a	0.071 ± 0.002^a	4.293 ± 0.052^a	0.277 ± 0.015^a	45.92 ± 0.015^a
Fresh (pulp)	0.147 ± 0.006^b	0.040 ± 0.002^b	3.187 ± 0.015^b	0.207 ± 0.006^b	38.34 ± 0.010^b
Dried(peel+pulp)	0.137 ± 0.010^c	0.032 ± 0.006^c	2.170 ± 0.010^c	0.150 ± 0.010^c	27.01 ± 0.015^c
Dried (pulp)	0.120 ± 0.010^d	0.030 ± 0.001^d	1.680 ± 0.020^d	0.110 ± 0.000^d	23.20 ± 0.025^d

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

Vitamin analysis of *Diospyros mespiliformis* fruit juice confirmed the presence of vitamins C, B_1, B_2, B_3, and B_6. The result shows that vitamin C was the highest, with 10.98 mg/100g found in dried pulp juice. The lowest vitamin content was B_2, 0.032 mg/100g, in all fresh juice samples. The recommended daily allowance (RDA) vitamins for humans showed that vitamin C is most needed among all the listed vitamins, with a recommended quantity of 75 mg daily. Although citrus fruits are previously recognized as important sources of vitamin C (Rudge *et al.*, 2012) having beneficial effects on humans, these findings established other underutilized tropical fruits, such as *Diospyros mespiliformis,* containing this valuable vitamin in a relatively highly average quantity. The amount of vitamin C observed in the juice blend samples could cover about 60 % of the recommended dietary allowance (RDA) based on the recommendation that dietary intake of 90-100 mg ascorbic acid/day could reduce the risk of non-communicable diseases (Carr and Frei, 1999). Vitamin C is an important nutrient that performs several biological functions in the human body, such as preventing free radical damage to DNA and supporting the immune system (Naidu, 2003).

Physicochemical content

The physiochemical content of all the fruit juice is shown in Table 4. The results show that all the juice samples are acidic, with pH ranging from 3.67 to 4.13 in the dried peel and pulp mix juice and fresh pulp juice samples, respectively.

Table 4: Physiochemical properties of *Kanya* juice

Sample	pH	Viscosity(cp)	Brix(°)	TTA(%)
Fresh(peel+pulp)	3.97 ± 0.058^b	679.03 ± 2.72^d	9.33 ± 0.153^d	0.44 ± 0.012^c
Fresh(pulp)	4.13 ± 0.058^a	857.02 ± 3.080^c	14.57 ± 0.056^b	0.39 ± 0.010^d
Dried(peel+pulp)	3.67 ± 0.058^d	1111.5 ± 0.670^a	17.40 ± 0.100^a	0.54 ± 0.012^a
Dried(pulp)	3.87 ± 0.058^c	1000.4 ± 1.120^b	13.73 ± 0.029^c	0.49 ± 0.006^b

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

The results of the physicochemical analysis of fresh and dried juice of *Kanya* pulp and peeled fruit juice are shown in Table 4. The pH value of the juice ranged from 3.67-4.13. The fresh pulp juice had the highest PH of 4.13; low pH was found in the dried peel and pulp juice. Even though the pH of all the juices is acidic, the statistical analysis of variance shows a significant difference at $p<0.05$ between the juices, indicating that the parameters for acidity differ between the samples. The low pH of the fresh juice contributed to the lower pH of all juice blends and may be attributed to the high concentration of organic acid present, predominantly citric acid (Tembo *et al.,* 2016). The pH value obtained in this study was comparable to the pH of 3.12-3.88 reported in the study of Tawakalt *et al.* (2020) for baobab, pineapple, and black-plum fruit juice, 3.15 reported in Adansonia (Adam *et al.,* 2016) and 3.84-3.92 for pineapple-carrot-orange juice blends in the work of Hossain *et al.* (2016). Low pH in juice indicates good shelf stability as low pH has been recorded to inhibit microbial growth in food. Also the lower the pH of a fruit juice, the more microbiologically stable the fruit juice (Nwachukwu *et al.*, 2013).

The titratable acidity of the juices ranges from 0.39 % to 0.54 %, as shown in Table 4. The highest titratable acidity was found in dried peel and pulp mix juice. This research has confirmed that titratable acidity usually corroborates with pH, as food of low pH is expected to have high acidity. Titratable acidity is an important indicator of fruit juice quality that can be used to explain their shelf stability and their characteristics for carbonation, acidulation, color, and characteristics of taste on the buds. The sample's cloudiness, which is expressed as percentage brix, also ranges from 9.33 in fresh peel and pulp mix juice to 17.40 in dried peel and pulp mix juice, which is not surprising considering the characteristics of the fruit material used. Samples produced from fresh fruit without drying will have a clearer appearance, while the other processed from dried fruit material will have a higher concentration and characteristics of turbidity. The brix value recorded in this research was close to 12.3 % brix recorded for Pineapple juice in Tawakalt *et al.* (2020), Hossain *et al.* (2012), and Begam *et al.* (2018). The high brix may be attributed to the high sucrose content in the fruit (Akubor, 2017). The Viscosity of the samples was found to decrease with an increase in fruit dryness. All fresh samples show a higher viscosity (679 to 1111 cp), even though fruit juice is not expected to have high viscosity but still the viscosity of the dried samples is within an acceptable level for fresh fruit juice.

Antioxidant properties

The result of the antioxidant potential of *Kanya* juice is shown in Table 5. The result shows an increase in antioxidant potential with an increase in fruit concentration and is generally close to standard antioxidant control. The result shows no significant difference in ascorbic acid control at 1000 concentrations, with the dried peel and pulp mix juice sample having the highest inhibition of 86.3.23 compared with 83.73 in ascorbic acid.

Table 5: Antioxidant potentials of *Kanya* juice

Sample	Fresh(peel+pulp) juice	Fresh(pulp juice)	Dried(peel+pulp) juice	Dried(pulp) juice	Ascorbic acid (control)
IC_{50}	130.426± 10.583[a]	39.054± 10.583[b]	38.018± 6.4410[c]	29.175± 1.697[d]	15.483± 0.818[e]

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

Antioxidant activity explains the potential of fruit juice in unrestricted radical scavenging of hydrogen radicals to turn it into an unchanging diamagnetic molecule Andzouana *et al.,* (2014). The scavenging capability of the juices revealed a concentration-dependent activity profile. It improved with an increase in their concentrations and had no or less effect on processing into juice. Oxidative stress is associated with the pathophysiology of numerous ailments and conditions, including cardiovascular disorders, diabetes, inflammatory conditions, liver diseases, aging, and cancer. Antioxidants could offer opposition against oxidative stress by scavenging the unrestricted radicals and reactive oxygen components or by preventing lipid peroxidation and, therefore, averting impairment. The present study established the antioxidant potential of Kanya fruit juice. From the results, the antioxidant activity of the dried and fresh fruit juice and ascorbic acid (control) showed increased scavenging activity against DPPH with increased concentration. After the assay, the inhibition concentration of the fresh fruit peel and pulp mix juice was 130.426 μ/mg, while that of the dried fruit pulp juice was 29.175 μ/mg. The dried *Kanya* fruit pulp juice had stronger antioxidant activity than other juices. Their antioxidant ability is largely because of their redox capabilities, making them behave as reducing agents, singlet oxygen quenchers, and hydrogen donors. They could have too a metal chelating ability (Salah *et al.,* 1995). *Kanya* juice has high antioxidant properties and can prevent the risk of diseases such as cancer and diabetes resulting from the free radical-induced oxidative reaction (Braca *et al.*, 2018). The synergetic effect resulting from the combined relatively high scavenging ability, high reducing potential, high ascorbic acid content, and high polyphenol contents of the juice blends observed in this study translates into increased antioxidant capacity, thus its potential benefits of reducing free radicals when consumed in sufficient amount. Similarly, Aderinola *et al.* (2019) and Olagunju and Sandewa (2018) reported increased antioxidant content of cucumber and carrot juice, soursop juice, and milk, respectively.

Qualitative phytochemical content

The qualitative screening of all the juices shows the presence of saponins, tannins, alkaloids, flavonoids, steroids, and terpenoids in fresh and dried samples. Terpenoids were absent in the dried pulp juice sample while present in all other samples, indicating that some of the important active phytochemicals in *Kanya* juice are easily lost with the drying of the fresh fruit, as shown in Table 6.

Table 6: Qualitative phytochemical content of *Kanya* juice

Parameter	FF (peel and pulp)	FF (pulp)	DF (peel and pulp)	DF (pulp)
Saponin	+	+	+	+
Tannins	+	+	+	+
Alkaloids	+	+	+	+
Flavonoids	+	+	+	+
Steroid	+	+	+	+
Terpenoid	+	+	+	-

Key= Sign "+" = Present; Sign "-" = Absent; FF=Fresh Fruit; DF=Dried Fruit

Quantitative phytochemicals content

The quantitative phytochemical screening (Table 7) revealed the highest amount of saponin, 256.0 mg/100g in dried fruit peel and pulp mix juice, followed by tannins with 94.434mg/100g in fresh fruit pulp juice sample and flavonoids with 5.369 mg/100g in fresh fruit pulp juice samples. Fresh fruit juices had high concentrations of flavonoids and tannins, while dried fruit juices had high concentrations of alkaloids, saponins, and steroids.

Phytochemical analysis and anti-nutrients showed Kanya fruit contained tannins, saponins, Alkaloids, and traces of terpenoids on the dried peel and pulp. Saponins (in excess) cause hypocholesterolemia because they bind cholesterol, making them unavailable for absorption (Soetan et al., 2009). therefore, these vital components are maintained since no unit operation in Kanya juice preparation involves heat. Saponins also have haemolytic activity against RBC (Shimoyamada et al., 1998). Saponins-protein complex formation can reduce protein digestibility (Shimoyamada et al., 1998). Alkaloids have been implicated in the inhibitory activities of many bacterial species (Tor-Anyiin, 2009). Quantitatively, among the phytochemicals, tannin, and saponin are the most abundant, with 94.434 mg/100g and 256 mg/100g in fresh fruit pulp juice and dried fruit peel and pulp mix juice, respectively, followed by flavonoid (5.369) in fresh pulp juice and steroid (2.115 mg/100g) in the dried pulp juice. The level of flavonoid obtained for Kanya is two times lower than the value reported for watermelon Olorode et al. (2014) but higher than the flavonoid content reported for voandzeia susterranea seed (4.93 %) (Andzouana et al., 2014). Flavonoids have been reported as potent free radical scavengers that prevent oxidative cell damage and as having strong anticancer activity protecting against all stages of carcinogenesis, while alkaloids were also being reported to have basic medicinal agents for their analgesic and bactericidal effects.

Table 7: Quantitative Phytochemical Content of *Kanya* juice

Sample	*Total flavonoids*	*Total tannins*	*Total alkaloids*	*Total saponins*	*Total steroids*
Fresh(peel+pulp)	5.343 ± 0.109^{b}	75.863 ± 1.076^{b}	0.511 ± 0.002^{d}	42.506 ± 0.879^{c}	0.150 ± 0.125^{c}
Fresh(pulp)	5.369 ± 0.003^{a}	94.434 ± 3.613^{a}	0.526 ± 0.007^{b}	18.760 ± 0.843^{d}	0.999 ± 0.402^{d}
Dried(peel+pulp)	5.011 ± 0.055^{c}	42.351 ± 0.273^{c}	0.517 ± 0.001^{c}	256.0 ± 0.722^{a}	1.911 ± 0.121^{b}
Dried(pulp)	4.941 ± 0.018^{d}	27.649 ± 0.273^{d}	0.562 ± 0.002^{a}	247.037 ± 4.848^{b}	2.115 ± 0.105^{a}

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

Sensory evaluation

The result of the sensory evaluation revealed the highest acceptability of the dried fruit peel and pulp mix juice sample, with an 8.385 mean score in overall acceptability, an 8.0 mean score in taste, a 7.933 mean score on flavor, and a 7.867 mean score on color. Fresh pulp juice had the lowest score in all the parameters tested scoring, 6.308 in taste, 6.467 in flavor, and 6.538 in overall acceptability, followed by a dried fruit pulp juice sample with a 7.467 score on color, 7.733 on flavor, 7.462 on taste and 7.462 on overall acceptability. Indicating that people prepare dried pulp juice rather than fresh fruit pulp juice and dried peel and pulp juice than fresh peel and pulp juice.

The results of sensory properties evaluation, such as taste, flavor, color, and overall acceptability of the fruit juice samples, are shown in Table 8. Fresh pulp juice was rated lowest for all the evaluated parameters except for the color, which was slightly higher than fresh fruit peel and pulp mix juice. While dried fruit peel and pulp mix juice of *Kanya* was more acceptable, fresh pulp *Kanya* juice was less considered for overall acceptability. The taste of all the juices was acceptable and within range. Dried fruit peel and pulp mix juice were rated the highest for taste, flavor, color, and overall acceptability. This may be due to the characteristics of sweet taste and high sugar content reflected in the high Brix value of the sample and the familiar color of the juice to consumers (Akubor, 2017; Zubairu *et al.,* 2019). Fresh pulp juice rated high only for color but low/same for other parameters. This may be due to the attractive color (light yellow) resembling orange juice formed from the high anthocyanin content. Therefore the sensory testing shows that dried *Kanya* peel and pulp mix juices preferred more than all the fresh *Kanya* fruit juices in all parameters.

Table 8: Result of Sensory Evaluation of *Kanya* Juice

Sample	Color	Flavor	Taste	Overall Acceptability
Fresh(peel+pulp) juice	6.800±1.082[d]	6.467±1.506[c]	6.308±1.750[c]	6.538±1.450[c]
Fresh(pulp) juice	7.267±1.223[c]	6.067±1.831[d]	6.077±1.55[d]	6.231±0.599[d]
Dried(peel+pulp) juice	7.867±1.125[a]	7.933±1.100[a]	8.000±1.23[a]	8.385±1.121[a]
Dried(pulp) juice	7.467±0.743[b]	7.733±0.961[b]	7.462±0.8771[b]	7.462±0.877[b]

Values are presented as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different at $p<0.05$.

CONCLUSION

This study demonstrates that *Kanya* fruit is rich in minerals and nutrients, making it valuable for food security due to its high protein and fiber content. Additionally, its juice offers economic benefits. The fruit's ash content suggests its mineral richness, which is known to support bone development in humans, especially children. Its abundance of phytochemicals and vitamins indicates potential medicinal and antioxidant benefits, preventing lipid oxidation and free radical formation. These findings highlight the potential of *Kanya* fruit for both edible and non-edible purposes.

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