Quality Evaluation of Cashew Apple Varieties Using Different Drying Methods

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ABSTRACT

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| **Background**: Cashew apple is packed with lots of bioactive properties. However, it is highly perishable. Quality analysis was determined on sun-dried red cashew (SDRC), sun-dried yellow cashew (SDYC), solar-dried red cashew (SODRC), solar-dried yellow cashew (SODYC), cabinet-dried red cashew (CDRC), cabinet-dried yellow cashew (CDYC), freeze-dried red cashew (FDRC) and freeze-dried yellow cashew (FDYC).  **Study Design:**  Statistical software application SPSS, version 22, with one-way ANOVA and a post-hoc Duncan test were used to assess the statistical significance of the difference in multiple group comparison.  **Aims:** The study aimed to evaluate two different colour of cashews, in respect to nutrients, phytochemical and antioxidant properties.  **Methodology:** Fresh red and yellow cashew apples was harvested, sliced into 2 mm thickness, pretreated by dipping into sodium metabisulphite and divided into batches. One batch was dried under the sun for 72 h at 28±4° C, the second batch was solar-dried for 48 h at 45-67°C, the third batch was dried in a cabinet at 65 °C for 12 h and the last batch was freeze-dried -65°C for 72 h. All the dried batches was evaluated. Statistical analysis was conducted to determine the result.  **Results:** Higher (2.88; 8.10; 49.55; 20.64; 73.31; 35.87; 23.15; and 11.07) concentration in ash, ºBrix, colour, flavonoid, phenolic, alkaloid, tannin, phytate, DPPH and FRAP contents respectively in the yellow cashew than the red cashew slices, irrespective of their drying methods. However, higher values (8.20; 292.75) of crude fat and ascorbic acid was recorded in the red cashew slices than the yellow samples. Freeze-drying (FD) followed by solar-drying (SOD) and sun-drying (SD) samples had high levels of bioactive components, nutritional and antioxidant capacity in comparison to other drying methods.  **Conclusion**: Higher concentration in the nutrient and bioactive components was recorded in the yellow cashews slices than the red. The application of FD, SOD and SD can reduce post-harvest losses and increase its economic value. |

***Keywords:*** *Nutrients; pre-treatment; proximate; phytochemical; antioxidant*

1. INTRODUCTION

Cashew apple (*Anacardium occidentale L*.) belongs to a tropical evergreen tree native to Brazil. It can grow in any type of soil, especially in fertile sandy–loam soil as it can withstand drought. Cashew trees are cultivated in 34 countries around the world, with Brazil, Vietnam ranking No 1 in the world, India, Ivory Coast, Nigeria, No 13 as the main producer (FAO, 2021**)**. Cashew apple loss is estimated at 90% worldwide owing to it high moisture content. In contrast to cashew nuts, cashew apples are a little-known product in the consumer market although packed with nutrient and bioactive compound (Ghislain *et al.,* 2021). The tree is mostly valued for the nut; they are harvested once a year. After the nut develops, its stalk becomes enlarged and changes color to give a “false fruit” known as the cashew apple. When ripe, this cashew apple is red, yellow or orange in colour. The edible part of the fruit is between 85% and 100% higher than that of other traditional tropical fruits, and its juicy and sweet flesh is free of seeds or pits (Sahie *et al.,* 2023).

By drying, post-harvest losses of cashew apples can be inhibited by transforming them into a stable intermediate product, the process also inhibits the microbial growth of the plants, influences the change of physicochemical properties (appearance and aroma), retain some levels of nutrients and antioxidants (Ghislain *et al.,* 2021). The selection of appropriate drying methods such as sun-drying, which is very cheap, solar-drying is affordable and safe, cabinet-drying is fast and economical while freeze-drying, although expensive almost all the nutrient are intact. This work investigated the influence of four drying methods (sun, solar, cabinet and freeze-drying methods on the proximate, physicochemical, phytochemical and antioxidant capacity for red and yellow cashew slices.

2. methodology

2.1 materials

Freshly plucked, matured ripe red and yellow cashew apples was harvested from Ara Village, authenticated (UILH/001/970) at the Department of Plant Biology, University of Ilorin, Kwara State, Nigeria.

**2.2 Sample Preparation**

Ripe matured apples was sorted, washed and the nuts was removed. The cashew apples were then sliced into 2 mm thickness using a sharp stainless-steel knife when the cashew was resting in a longitudinal position. The initial moisture contents of red and yellow cashew were 83.10 mg/100 g and 84.76 mg/100 g. To determine the brix, 5 g of the powdered samples was dissolved in 50 ml of distilled water, the solution was filtered and a drop from the filtrate into the surface of the refractometer. Total soluble solids were 8.0 and 7.0 ºBrix for yellow and red cashew apples, respectively using a handheld refractometer (Hanna Instruments, Italy).

**2.2.1 Pre-treatment of the cashew slices**

After slicing and weighing, 1 kg of each red and yellow cashew slices was soaked in sodium metabisulphite (5%) differently for 5 min (Suneetha and Lakshman, 2017). Afterwards, they were removed and drained.

**2.3 Drying Processing**

The initial samples were divided into four batches for each red and yellow cashew slice which contained four sets of 1000 g each. The samples were dried using the following methods:

**2.3.1 Sun drying (SD):** Samples of red and yellow cashew apples were drained differently and placed on a perforated tray and sun-dried for 72 h. This was achieved at a temperature of 28 ± 4 ºC; relative humidity (RH) 45 (Nwankwo *et al.,* 2021**)**. The drying procedure was terminated when there was no noticeable change in the weight of the slice’s samples.

**2.3.2 Solar drying SOD:** The cashew apple slices were spread on an aluminum tray, placed on an existing enclosed structure with a transparent cover which allows sun to shine on the samples. At a temperature between 45 and 67 ºC for 48 h (Nwankwo *et al.,* 2021).

**2.3.3 Cabinet drying:** An air-convective method of drying was employed to remove moisture through the application of heat in a cabinet dryer of Rhong Machinery Manufacturing Limited series (Model RCD-5). Sliced drained cashew apples were laid out on a screen placed inside the cabinet dryer. It was dried at a temperature of 65 ºC, relative humidity of 55% for 12 h at drying air speed of 3 m/s (Nwankwo *et al.,* 2021).

**2.3.4 Freeze drying:** Drained pretreated cashew slices (200 g) were distributed on aluminum plates. Samples were immediately frozen in a conventional freezer (Liebherr Mediline LGT 2325, Liebherr, Baden. Where the samples were frozen for 3 h at −38 ºC in a blast freezer (Hiber RDM051S, Hiber, Cernusco sul Naviglio, Italy). After which the frozen samples were supplied with a controlled quantity of heat under vacuum to induce sublimation at pressures 5 Pa, -65 °C for 72 h (Nwankwo *et al.,* 2021).

After drying, using sun, solar, cabinet and freeze drying, all the dried samples were milled into fine flour for laboratory analysis using an electric blender (Super Diamond Blender model: NG-999, 400W power rating, stainless steel blades, 1.5 L capacity and 4 speeds). The blender was washed and drained before and after blending the samples from each dried red and yellow cashew apple. The dried milled cashew flour was then packed in a zip lock bag labelled accordingly and was stored at -18 °C for further analysis.

**2.4 Methods**

These studies was conducted in a lab, reagent used was purchased from Sigma Aldrich and are of analytical grade. All experiments were conducted in triplicate.

**2.5 Data Analysis**

The data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 22 (SPSS Inc; Chicago, IL USA) at a level of significance (*P*<.01).

**2.6 Quality Analysis of the Samples**

**2.6.1** **Nutrients analysis of the sample**

Moisture, ash, crude fat, crude fibre, protein and ascorbic acid were determined in accordance with the official methods of the (AOAC, 2005).

**2.6.2** **oBrix**

The oBrix of the cashew fruit pulp was determined by using a digital refractometer (make: ATAGO model RX-5000). The measurement was recorded directly from a digital display (AOAC, 2005).

**2.6.3 Acidity**

Acid-base titration method of AOAC 2005 was used. The titrant was put into the burette. While the analyte was put into the Erlenmeyer flask. A few drops of acid-base indicator was added (methyl orange) to the analyte. The titrant was dropped into the analyte, till colour changes. The following formula was used :

Ma x Va x a = Mb x Vb x b

Where:

Ma= molarity of acid solution (M)

a= valence of acid solution

Mb= molarity of base solution (M)

Vb= volume of base solution (ml)

b= valence of base solution

**2.6.4 Colour determination**

The colour of the samples before and after drying was measured using a tristimulus colourimeter (Minolta Chromameter, Model CR 200, Osaka, Japan) where L\*, a\*, and b\* colour values were estimated. The L\*, a\*, and b\* indicate lightness, red/green and yellow/blue chromaticity, respectively. The colour parameters of the sample were concurrently measured for comparison. The colourimeter was calibrated against a standard white colour plate (L = 96.87, a + = 0.55, and b + = 2.14) (Hutchings, 1999).

**2.6.5 Tannin, alkaloid, flavonoid, total phenolic and phytate contents**

One gram of cashew sample was ground with 10 ml of methanol and ultrasonically extracted at room temperature for 60 min. The mixture was centrifuged at 4,000 ⨯ g for 5 min and the supernatant was used for the determination of total phenolic, (TP), flavonoid, tannin, alkaloid and phytate content according to the method described by Onwuka (2018).

**2.6.6 DPPH assay**

The DPPH radical scavenging activities of samples were measured according to the method of Irina and Constantin (2021) with slight modification. A 10 µl aliquot of the sample was added to the test tube and mixed with 30 µl of distilled water. Then 2 cm3 of 0.1 mM DPPH was dissolved in 95% ethanol was added to the sample. The mixture was then shaken and left for 30 min in the dark at room temperature (26 ± 2 ⁰C). Absorbance was recorded at 515 nm.

**2.6.7 FRAP assay**

Fresh FRAP reagent was prepared using 300 µm acetate buffer, pH 3.6 (3.1 g sodium acetate trihydrate, 16 cm3 glacial acid was mixed up with distilled water as 1:1); 10 µM TPTZ (2,4,6-tris(2-pyridyl)-s-triazine), in 40 µm HCl; and 20 µm FeCl₃ . 6H₂O with the ratio of 10:1:1 to prepare the working reagent. Then after 30 min, 1 cm3 of FRAP reagent was added with 100 µl of cashew apple samples by using a spectrophotometer, and the absorbance was read at 595 nm wavelength. The result was presented in mg of Trolox equivalent (TE) as per 100 g of fresh sample (mg TE/100 g of FW) (Irina and Constantin, 2021).

**3.0. RESULTS AND DISCUSSION**

**3.1 Influence of drying method on the nutrients of dried cashew samples**

The values of moisture content was between 7.85-14.64 mg/100 g found in Table 1. The SODRC and SODYC had the lowest moisture content due to the effectiveness of the solar panel to generate high energy from the sun leading to efficient removal of water from the sample. SDYC had the highest yield, 14.64 mg/100 g followed by CDYC and FDYC. Generally, the low moisture content observed in this study is a good indication of their potential to have a longer shelf life. The lower the moisture content (10.15 mg/100 g) the better the keeping quality of properly stored dried fruits. The moisture content of all the drying samples was lower than values reported by Dimoso *et al.* (2020) that recorded 16% in the drying of cashew apple slices using osmotic loss from the cashew slices which increased with an increase in drying temperature and time of drying (Mohammed and Kayondo, 2020).

**Table 1. Nutritional composition of dried cashew apple using different drying methods (mg/100 g of dried cashew)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Samples** | **Moisture** | **Ash** | **Crude-fat** | **Crude-fibre** | **Protein** | **Ascorbic acid** |
| SDRC | 10.71±0.19C | 2.45±0.43a | 7.20±0.03b | 1.33±0.28b | 12.21±0.06b | 216.53±5.57c |
| SDYC | 14.64±0.32a | 2.88±0.33 a | 6.84±0.08b | 2.12±0.31b | 11.34±0.06c | 203.62±0.00c |
| CDRC | 12.53±0.79b | 2.59±0.44 a | 2.60±0.11e | 1.82±0.63b | 13.77±0.47a | 169.29±16.70e |
| CDYC | 12.99±0.79b | 2.60±0.17a | 1.92±0.33f | 1.48±0.27b | 14.14±0.02a | 106.29±5.57d |
| SODRC | 7.85±0.32d | 2.13±0.66 a | 5.40±0.14c | 2.16±0.03b | 12.17±0.12b | 236.22±11.14b |
| SODYC | 8.13±0.38d | 2.06±0.56 a | 4.28±0.06d | 1.18±0.06b | 12.20±0.06b | 244.09±11.14b |
| FDRC | 8.86±0.03d | 0.71±0.62b | 8.20±0.60a | 3.89±0.75b | 14.14±0.06a | 292.75±3.00a |
| FDYC | 8.38±0.44d | 2.48±0.00 a | 7.11±0.32b | 7.84±0.07a | 14.05±0.06a | 274.01±11.14a |

*Values were expressed as mean ±SEM and considered significant at P<.01. Values with different superscripts along the same column are significantly (P<.01) different.*

*SDRC – Sun-Dried Red Cashew; SDYC – Sun-Dried Yellow Cashew; CDRC – Cabinet Dried Red Cashew; CDYC – Cabinet Dried Yellow Cashew; SODRC – Solar Dried Red Cashew; SODYC – Solar Dried Yellow Cashew; FDRC – Freeze Dried Red Cashew; FDYC – Freeze Dried Yellow Cashew*

Table 1 showed the SDYC had more ash content (2.88 mg/100 g) followed by CDYC (2.60 mg/100 g), SODRC and SODRC had (2.13 and 2.06 mg/100 g) respectively. The least was the FD red cashew (FDYC) at 0.71 mg/100 g. The values obtained in this study is within the range of 0.24 to 3.72 mg/100 g reported by Emelike and Ebere (2016) for cashew apple using different treatments, probably due to the uptake of moisture from the atmosphere. The SDYC 2.88 mg/100 g had the highest ash value this might be due to the length of days of drying using the sun among different drying methods, this was similarly observed by Babarinde *et al.* (2009**)**. It was observed that there was increase in the ash content using all the drying methods, except for the freeze-dried red cashew sample. This might be due to the low temperature of the freeze drier. The high ash content is regarded as an indication of high contents of mineral elements of food which are beneficial to the body.

It can be deduced form Table 1 that the FDRC had the highest crude-fat 8.20 mg/100 g, followed by the SDRC, while the lowest 1.92 mg/100 g was observed in the CDYC, this might be due to fat evaporation due to high thermal temperature of the cabinet drier. The freeze-dried values reported in this study are higher than the 2.2 and 2.5 mg/100 g observed by Igor *et al.* (2020) in the freeze-dried cashew and acerola fruit.

The FDYC (Table 1) had the highest (7.84 mg/100 g) crude-fibre, and there was a significant difference (P<.01) between the FDYC and all other drying samples. The lowest 1.18 mg/100 g was found in SODYC. This result showed that high temperature was unable to favour the fibre content which records are lower than the FD samples. The freeze-dried yellow cashew could support the use of pulp powder as health ingredients due to their richness in fibre. Biscuits formulated with mango and apple pomaces showed an increase in mineral and fibre content.

The values of protein content ranged between 11.34 and 14.14 mg/100 g. The result (Table 1) showed that FDRC and CDYC exhibited the highest (14.14 mg/100 g) retention of protein, followed by 14.05 mg/100 g FDYC, CDRC, SDRC SODRC, SODYC and SDYC respectively. The values obtained in this study are higher than the values (5.16-12.69 mg/100 g) observed by Suneetha and Lakshman (2017). Although, it is generally rare to have a high protein in fruit and vegetable, however this study reveals that the amount of protein in the red and yellow varieties are relatively high, this further confirms the findings of Oloche *et al*. (2013) who reported (14.72-16.41 mg/100 g) higher values than the protein content reported in this research. The high protein content observed in this study generally favored all the drying method especially the freeze-dried (FD), cabinet-dried (CD), solar-dried (SOD) and sun-dried (SD) respectively, and this further suggest that some cashew apple varieties can serve as a source of protein. Protein is essential for good health, it is needed to put meat on bones, and to make hair blood connective tissues, antibodies, enzymes maintenance, and body building. The cashew fruit powder inclusion in biscuit-type cookie formulation, bread, infant porridge seems to be better suited for partial ingredient for wheat flour substitution as well as functional ingredients in formulated foods (Ghislain *et al.,* 2021).

The ascorbic acid (Table 1) content ranged from 106.29 to 292.75 mg/100 g. There was a significant difference (P<.01) among all samples. FDRC had the highest value 292.75 mg/100 g, followed by FDYC (274.01 mg/100 g) which showed no significant difference (*P*>.01) between them. Freeze drying was the best, in retaining ascorbic acid more than other drying methods. The result might be related to a disruption of the cell wall because of alternate compression and expansion of force on the solid sample which loosened the bound of ascorbic acid and the low temperature employed which prevents the oxidation of ascorbic acid (Abid *et al.,* 2013). The values of ascorbic acid for all the samples in this study were within the ranges of 126 and 372 mg/100 g reported by Suneetha and Lakshman (2017). However, the value is higher than 2.9-5.7 mg/100 g reported by Camel *et al.* (2019) for dried, red-sliced cashew. The lowest value of ascorbic acid was observed in CDYC (106.29 mg/100 g). A glass of cashew juice meets an adult individual daily ascorbic acid (30 mg) requirement. The higher content of ascorbic acid recorded in this study showed that cashew, even though was processed into dried form was still a good source of ascorbic acid. Ascorbic acid contribute to the antioxidant activity of fruits. This antioxidant effect in edible products and fruits is also not only related to the presence of polyphenols, but also of ascorbic acid which are also found in cashew apples according to Reina *et al.* (2022**).**

**Table 2. Physicochemical attributes of dried cashew apple using different drying methods (mg/100 g of dried cashew)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Samples** | **ºBrix** | **TTA (%)** | **L\*** | **Colour**  **a\*** | **b\*** |
| SDRC | 5.10±0.14f | 0.66±014b | 15.18±1.12g | 7.56±0.82f | 9.17±1.28f |
| SDYC | 8.10±0.14a | 0.55±0.00c | 23.92±0.42e | 12.54±0.33d | 11.68±0.66f |
| CDRC | 6.32±0.00d | 0.05±0.00g | 33.14±0.40c | 22.54±0.18a | 77.97±2.57a |
| CDYC | 6.62±0.14c | 0.05±0.00g | 49.55±0.31a | 15.38±0.11b | 60.86±1.26b |
| SODRC | 7.70±0.14b | 0.51±0.00d | 19.73±0.55f | 9.33±0.09e | 10.71±0.84f |
| SODYC | 5.15±0.21f | 0.99±0.01a | 28.00±2.30d | 10.72±0.62d | 14.77±1.67e |
| FDRC | 5.55±0.77e | 0.11±0.00f | 47.96±0.05a | 16.07±0.04b | 42.62±0.46c |
| FDYC | 5.70±0.00e | 0.12±0.00e | 39.60±0.22b | 12.27±0.52d | 24.98±0.49d |

*Values were expressed as mean ±SEM and considered significant at P<.01. Values with different superscripts along the same column are significantly (P<.01) different.*

*SDRC – Sun-Dried Red Cashew; SDYC – Sun-Dried Yellow Cashew; CDRC – Cabinet Dried Red Cashew; CDYC – Cabinet Dried Yellow Cashew; SODRC – Solar Dried Red Cashew; SODYC – Solar Dried Yellow Cashew; FDRC – Freeze Dried Red Cashew; FDYC – Freeze Dried Yellow Cashew*

**3.2 oBrix**

The SDYC had the highest 8.10 °Brix, followed by SODRC at 7.70 °Brix Table 2. There was a significant difference (P<.01) among the samples. The SDYC had more concentration than other drying methods. This might be due to the concentration of carbohydrate content through an extended time of drying. The values obtained in this study correspond to the range 7.4-12.8 °Brix and 7.10-11.85 °Brix reported by Arinzechukwu and Nkama (2019) in the production and quality evaluation of fruit bars from banana and cashew fruit blends. Based on the level of the sugar content of cashew apple, it can support the growth of yeast in the production of wine.

**3.3 Total titratable acidity** **(TTA)**

The TTA showed in Table 2 ranged from 0.05 to 0.99%. There was a significant difference (P<.01) among the samples. SODYC had significant highest value of 0.99%, while CDRC and CDYC had the lowest value of 0.05%, respectively and which showed no significant difference (*P*>.01) among the samples. The TTA of 0.51 (SODRC) and 0.99% (SODYC) observed is higher than 0.19% recorded by Dimoso *et al.* (2020) in solar dried cashew.

**3.4 Colour measurement**

Table 2 showed that drying methods significantly affected the colour of dried red and yellow cashew slices. The samples CDYC and FDRC showed no significant difference (*P*>0.01) among all other samples, with values L\*=49.55 and L\*=47.96, respectively. The CDYC had the highest value followed by the FDRC. Generally, dried fruits exhibited lower lightness (L\*), redness (a\*), and yellowness (b\*), compared to fresh fruit. The surface colour of the fruit is mainly because of chlorophyll (a and b), which is prone to degradation under heat treatment and oxidation. The CDYC (49.55), FDRC (47.96) and FDYC (39.60) had higher L\* values indicating brightness than other samples, because of the relatively lower temperature for FD while brightness in CD samples could be due to a higher temperature, faster moisture transfer and shorter processing time during the drying process. The CD and FD presented minimal colour change than others. In contrast, the SOD and SD samples respectively had the lowest value of L\*, a\* and b\*, which suggest that the samples were darker due to extended time of heat using the SOD and SD. The lightness observed in CD and FD agreed with the report of Camel et al. (2019) when cashew apple was dried using ultrasound as a drying medium.

**3.5 Flavonoid, total phenolic, alkaloid, tannin and phytate contents**

Table 3 showed FDYC had the highest 20.64 mg/100 g retention of flavonoid, followed by SDRC (20.00), CDYC (16.28), FDRC (12.69), CDRC (9.74) and SODRC (5.51 mg/100 g). The different drying methods had significant difference (P<.01). The result in this study is higher than 0.24 mg/100 g value reported by Camel *et al*. (2019) in dried red cashew apple slices. Similarly, higher than 3.37 and 3.47 mg/100 g reported by Akujobi *et al.* (2018) for red and yellow nuts, respectively. The result showed that cashew apple is a good source of flavonoids, and the drying of the cashew apple increased the concentration of the flavonoids.

Phenolic content found in Table 3 in this study ranged from 7.6 mg/100 ml to 73.31 mg/100 ml. The FDYC had the highest value 73.31 mg/100 ml. This might be due to low temperature that helps to retain the phenolic content while CDYC had the lowest 7.60 mg/100 ml value. Leaching caused by higher temperature and thermal degradation during cabinet drying could be responsible for the decrease in total phenol (Chipurura *et al.,* 2010). The result in this work is higher than 2.41 mg/100 ml observed by Camel *et al.* (2019) in the dried red cashew apple slices whereas, lower than 215-412.8 mg/100 ml reported by Uma and Khasim (2013**)** in the nutritional composition of cashew apple juice. The FDYC displayed strong antioxidant activities. Phenolic compounds are responsible for the colour of many plants, such as apples, they are part

**Table 3 Phytochemical properties of *dried cashew apple using different drying methods* (mg/100 g)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Samples** | **Flavonoid** | **Phenolic** | **Alkaloid** | **Tannin** | **Phytate** |
| SDRC | 20.00 ±0.36a | 64.76± 0.00d | 34.96 ±0.31b | 21.63 ±0.06b | 6.79 ±0.51bc |
| SDYC | 14.49 ±0.54c | 72.54 ±0.06b | 35.87 ±0.03a | 23.15 ±0.01a | 10.71 ±0.00a |
| CDRC | 9.74 ±0.36e | 7.94 ±0.04a | 21.41 ±0.05d | 7.80 ±0.02g | 2.67 ±0.00d |
| CDYC | 16.28± 0.18b | 7.50 ±0.04g | 16.03 ±0.05e | 5.31 ±0.01h | 6.57 ±0.56c |
| SODRC | 5.51± 0.18f | 39.34 ±0.04e | 23.60 ±0.02c | 20.54 ±0.00c | 8.93 ±2.53ab |
| SODYC | 8.85± 0.18e | 24.54 ±0.08f | 11.30 ±0.05f | 14.05 ±0.03f | 11.07 ±0.51a |
| FDRC | 12.69± 0.18d | 71.66 ±0.00c | 34.72 ±0.05b | 16.18 ±0.00e | 0.29 ±0.00e |
| FDYC | 20.64 ±0.91a | 73.31 ±0.02a | 34.63 ±0.74b | 17.49 ±0.22d | 0.29 ±0.00e |

*Values were expressed as mean ±SEM and considered significant at P<.01. Means with different superscripts along the same column are significantly (P<.01) different.*

*SDRC – Sun-Dried Red Cashew; SDYC – Sun-Dried Yellow Cashew; CDRC – Cabinet Dried Red Cashew; CDYC – Cabinet Dried Yellow Cashew; SODRC – Solar Dried Red Cashew; SODYC – Solar Dried Yellow Cashew; FDRC – Freeze Dried Red Cashew; FDYC – Freeze Dried Yellow Cashew*

of the taste and flavour of beverages (apple juice, tea), and are important antioxidants in plants **(Dibacto *et al.,* 2021)**. Phenolic compounds are the main components that contribute to the antioxidant activity of foods. This antioxidant effect in edible products and fruits is also not only related to the presence of polyphenols, but also of vitamins such as vitamin C which are also found in cashew apples according to Reina *et al*. (2022).

The alkaloid values in Table 3 ranged from 11.30 to 35.7 mg/100 g. There was no significant (*P* >.01) difference between FD and SDRC. The highest alkaloid content was in SDYC (35.87 mg/100 g) followed by SDRC (34.96 mg/100 g), FDRC (34.72 mg/100 g) and FDYC (34.63 mg/100 g). There was a low record of alkaloids in the SODYC (11.30 mg/100 g), CDYC (16.03 mg/100 g); this might be due to the high heat temperature applied to the drying of the cashew sample.

Tannin content was found to be between 5.3 to 23.15 mg/100 g in Table 3. The lowest value 5.31 mg/100 g was observed in CDYC while the highest 23.15 mg/100 g was observed in SDYC. There was a significant difference (P<.01) recorded among the samples. The lowest results recorded in this study were closely related to 5.9 mg/100 g as reported by Iwuozor (2019) on the tannin content of wine; whereas the range value of this study was lower than 84-304 mg/100 g reported by Dedehou *et al.* (2016) on the tannin and flavonoid contents of some fresh cashew apples. The presence of chemically active components (ascorbic acid, phenols and tannin) is responsible for the anarcadic content which contributes considerably to the antioxidant capacity of its fresh as well as processed forms which are responsible for the anti-mutagenic mechanism, which is shown to be involved in the stimulation of DNA repair or reversion of DNA damage. Tannin is mainly found in the waxy layer of cashew apple skin (Okpanachi *et al.,* 2016).

The Table 3 showed the phytate values obtained in this study ranged from 0.29 to 10.71 mg/100 g. The FDRC (0.29 mg/100 g) and FDYC (0.29 mg/100 g) had the lowest values of phytate, which showed that the freeze-dried technique had drastically reduced the phytate concentrations. However, the SODYC had the highest 11.07 mg/100 g followed by SDYC at 10.71 mg/100 g. The phytate value of the FD cashew samples observed in this study is closely related to 0.32 mg/100 g and 0.3 mg/100 g reported by Okpanachi *et al*. (2016) for sun-dried red and yellow pulp, respectively. Phytate is the salt form of phytic acid known as inositol hexakisphosphate (IP6). Phytin refers to the magnesium or calcium salt form of phytic acid. It is the principal storage form of phosphorus in many plant tissues. Phytate can chelate, that is to form complexes with proteins and inhibits the enzymatic digestion of ingested protein. It makes unavailable certain important micronutrients such as zinc and iron, and to a lesser extent, also macronutrients such as calcium and magnesium (Marilu *et al.,* 2020).

**3.6 Antioxidant activity**

**3.6.1 Ferric reducing antioxidant power**

The FRAP (Figure 1) ranged from 11.07 to 449.03 mg/100 g. It was observed that FDYC (449.03 mg/100 g) had a significantly highest value, while CDRC (11.07 mg/100 g) had the least. There was a significant difference (*P*<.01) between FDYC and all other samples. This FRAP value indicated that the antioxidant properties were preserved using freeze-drying techniques. The values of the freeze-dried samples are higher than the range value of 91.0 to103.0 mg/100 g reported by Marilu *et al.* (2020) in the freeze-drying of orange puree and the result further showed that the FRAP result for freeze-drying of orange puree was higher than that of DPPH. There was no significant difference (*P*>.01) between CDRC (11.07 mg/100 g) and CDYC (11.55 mg/100 g).

**Figure 1 Antioxidant activity of dried cashew (red and yellow) apple fruit**

**3.6.2 2, 2-diphenyl-1-1-picrylhydrazyl (DPPH)**

The DPPH ranged (Figure 1) from 62.05 to 94.64 mg/ml where FDYC (94.64 mg/ml) had the highest value followed by FDRC (91.00 mg/ml) and the lowest value was recorded in CDRC (62.02 mg/ml). The antioxidant activity is closely similar to 86.5-94.3 mg/ml and 75.04-82.89% as reported by Marilu *et al*. (2020**)** in the freeze-dried orange puree and Camel *et al.* (2019**)** on the effect of ultrasound on cashew apple, respectively. It is, however, lower than slices subjected to blanching before drying, respectively. The DPPH results in this study using all the drying techniques were higher than 50.29%, 29.9% and 20.3% reported by **Damasceno *et al*. (2019)** in the dehydrated B. tomentosa fruit pulp and Igor *et al.* (2020**)** in the freeze-dried of guava and cashew pomaces, respectively. The FD cashew samples had the highest values due to the freeze-drying techniques that retain the nutrient quality of the cashew pulp. The high antioxidant potential presented by cashew-dried pulp extract in the FRAP and DPPH assay may be associated with the high levels of vitamin C and phenolic compounds present in the fruits. The results obtained by these authors suggest that ascorbic acid and phenolic compounds may be the most important contributors to the antioxidant capacity (Damasceno *et al.,* 2019).

**CONCLUSION**

The drying methods which include SD, SOD, CD and FD was applied in red and yellow cashew slices. There was higher concentration in yellow cashew slices in the ash, ºBrix, colour, phenol, phytate, tannin, alkaloid and DPPH than in the cashew red slices, irrespective of their drying methods. Whereas, higher values was recorded in crude fat and vitamin C in the red cashew slices. Among the drying conditions, the FD and SOD cashew products showed higher retention of protein, carbohydrate, crude-fat, crude-fibre, vitamin C, flavonoid, phenolic and phytate content. It was observed that the high vitamin C and phenolic content contributed to the high antioxidant present in the FRAP and DPPH assay in the FD samples. This study showed that drying methods affect the quality attributes of cashew apples. FD samples was the best followed by the SOD and SD respectively, in nutritional, antioxidant and phytochemical properties. However, FD is expensive, but the application of it for commercial purposes is feasible due to the availability of raw materials. People in less developed/developing countries can adopt the SOD method because it is less expensive and the techniques can reduce post-harvest losses and increase the economic value of cashew apples. Therefore, it is recommended that both red and yellow cashew apple should be used simultaneously to compensate for each unique attributes. Quality assessment of single mixed red and yellow cashew apple can be further investigated.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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