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Research Article

Comparative analysis of the nutritional, medicinal, and sun protection properties of almond (*Prunus dulcis*) and tropical almond (*Terminalia catappa*) nuts

Gayani Mihirangika Panditharathna[1], Darshani Hansamani Dewage DewageDona[1], Chandima Shashikala Kumari Rajapakse[1]✉

[1]*Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka.*

Abstract
This study compares the nutritional, pharmaceutical, and photoprotective properties of methanolic extracts of *Terminalia catappa* (TC) and *Prunus dulcis* (PD) nuts. Phytochemical screening revealed both are rich in bioactive compounds. TC had higher moisture content (11.8%) than PD (3.40%), while other nutritional parameters showed minimal differences. PD exhibited stronger antioxidant activity (DPPH IC_{50}: 78.55 ± 5.10 µg.ml^{-1}; ABTS IC_{50}: 57.19 ± 0.32 µg.ml^{-1}) than TC (DPPH IC_{50}: 89.22 ± 4.40 µg.ml^{-1}; ABTS IC_{50}: 74.36 ± 3.34 µg.ml^{-1}), but TC had a higher FRAP value (41.6 ± 0.23 mg PFE.g^{-1}) than PD (39.15 ± 0.21 mg PFE.g^{-1}). PD showed greater phenolic (199.00 ± 14.65 mg GAE. g^{-1}) and flavonoid (4.78 ± 0.077 mg QE. g^{-1}) contents. TC demonstrated stronger α-amylase inhibition (IC_{50}: 113.40 ± 1.56 µg.ml^{-1}), while PD had better anti-lipase activity. Both exhibited moderate UV-B protection (SPF: 14.52 for TC, 12.92 for PD). These findings highlight TC as a promising alternative for functional foods, cosmeceuticals, and medicinal applications.

Keywords
antioxidant, anti-diabetic, anti-lipase, photoprotective

Abbreviations
TC – *Terminalia catappa*; PD – *Prunus dulcis*; DPPH – 2,2-diphenyl-1-picrylhydrazyl; IC_{50} – Sample concentration which gives 50% inhibition; ABTS – 2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid; FRAP – Ferric ion reducing antioxidant power; PFE – Potassium ferricyanide equivalent; TPC – Total Phenolic Content; GAE – Gallic Acid Equivalents; TFC – Total Flavonoid Content; QE – Quercetin equivalent; UV – Ultraviolet; SPF – Sun Protection Factor.

✉*Corresponding author: Prof. Chandima Shashikala Kumari Rajapakse, PhD, Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka; tel.: +94 112903275; E-mail: shashikala@kln.ac.lk*

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Introduction

Terminalia catappa L.**,** a member of the Combretaceae family, is commonly referred to as the tropical almond, country almond, or sea almond. This tropical plant is widely grown as an ornamental shade tree in various regions (Venkatalakshmi et al. 2016). Its fruits and seeds are edible, and different parts of the plant, including the leaves, fruit, bark, and trunk, have been traditionally utilized in folk medicine across Southeast Asia (Akpakpan and Akpabio 2012). *Terminalia catappa* L. is known to contain antioxidants, anticancer and anti-diabetic compounds. Jayaweera et al. (1982) described that the fruits, bark, and leaves of the plant are utilized for the treatments of dermatitis, pyresis, and diseases such as diabetes, sexual inadequacies, and cancers. Despite being biologically rich, the fruit residue is typically disregarded by the nutraceutical and food industries (Sulaiman et al. 2015). The fruit is an indehiscent, ellipsoid drupe between 3 and 6 cm long. The shape, size, and color of fruit vary widely. The color of the fruit is green, yellow, or red, and tastes like commercially grown almonds. This fruit's antibacterial properties help keep fish in aquariums healthy (Dubale et al. 2023). The kernel of this fruit is used in medicine in Sri Lanka and Taiwan as an antibacterial and aphrodisiac (Wijesekara et al. 2024).

Due to the limited information in the scientific literature on the chemical composition and bioactive properties of its nuts, this study explored the phytochemicals, nutritional content, antioxidant, amylase inhibitory, anti-lipase, and photoprotective properties of *T. catappa* (tropical almond) nuts while comparing them with those of *P. dulcis* (almond). *Prunus dulcis* is classified under the Rosaceae family. *Prunus dulcis* is commonly known as a sweet almond (Pandey and Rajbhandari 2015). According to Keser et al. (2014), almonds help to reduce cholesterol, by reducing especially low-density lipoproteins/LDL cholesterol, while preserving the beneficial high-density lipoproteins/ HDL. Koksal et al. (2011) described that almonds are usually used as a snack and ingredient in various foods. Almonds are considered as a healthy food because they contain protein, monounsaturated fats, dietary fiber, Vitamin E, riboflavin, and important minerals including magnesium, manganese, copper, and phosphorus. According to Rakholiya et al. (2015) almonds are rich in essential nutrients and contain various bioactive compounds, including vitamins, phenolic compounds, fatty acids, phytosterols, phenolic acid, and flavonoids. This study aimed to explore the viability of tropical almond nuts as a sustainable and economically viable alternative to almond nuts in the food and pharmaceutical industries.

Materials and Methods

Sample collection. Tropical almond (*Terminalia catappa*/TC) nuts were collected between August and November 2022 from the premises of University of Kelaniya, Sri Lanka. Then the nuts were ground into small pieces. Almond (*Prunus dulcis* /PD) nuts were purchased from a supermarket in Kiribathgoda, Sri Lanka. The dried nuts were pulverized into a fine powder and homogenized using a mechanical grinder (BL2168ABC/50Hz, 218W, China) equipped with stainless steel blades. Grinding was carried out at 3,000 rpm for 3 minutes to achieve a uniform particle size.

Extraction of chemical constituents. Powdered samples (TC and PD) (20.0 g) were macerated with methanol (150.0 ml) for four days at room temperature in a mechanical shaker. Subsequently, the extracts were filtered, and the solvent was removed using a rotary evaporator (IKA®RV 10 digital, Germany) at 36°C and 30 rpm under reduced pressure, in order to gently remove methanol without degrading heat-sensitive compounds. The samples were kept at 4°C for future use.

Analysis of proximate composition. The powdered samples of both nuts were analyzed for moisture, ash content, crude protein, crude fiber, and crude fat contents by AOAC (2000) protocols using the methods reported by Ranjitha et al. (2018) with slight modifications. Protein content was determined using the Kjeldahl method, and crude fat was measured by Soxhlet extraction with hexane. Carbohydrate content was estimated by difference, subtracting the sum of other major components from 100%, following the method described with minor modifications (Ranjitha et al. 2018).

Preliminary screening of phytochemicals. Preliminary phytochemical analysis was conducted using standard protocols (Banu and Cathrine 2015) to detect alkaloids, phenols, flavonoids, steroids, terpenoids, glycosides, tannins, saponins, cardiac glycosides, and triterpenes.

Determination of antioxidant activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity. DPPH radical scavenging assay was carried out according to the method described by Chatatikun and Chiabchalard (2013) with slight modifications using butylated hydroxytoluene (BHT) as the standard. Different concentrations of the nuts of the methanolic extracts of both samples (TC and PD) or standard (BHT/ 1000, 500, 250, 125, 62.5, 31.25, 15.625, 7.8125 $\mu g.ml^{-1}$) (160 µl) were added to methanolic DPPH solution (40 µl/ 0.1 $mg.ml^{-1}$) in the microtiter plate. The samples were incubated for 30 min. at room temperature in the dark, and the absorbance at 517 nm was measured for each well using a microplate reader (Multiskan Go, Thermo Fisher Scientific). A control was prepared using methanol (160 µl) and DPPH (40 µl). The experiment was conducted in triplicate (n=3). The percentage inhibition (%) was calculated using equation (1).

$$\%\ Inhibition\ = \frac{A_c - A_s}{A_c} \times 100 \qquad (1)$$

Where,
A_c, absorbance of control (containing all reagents except the test sample/ standard),
A_s = absorbance of the test sample (sample/ standard)

The concentration that generates 50% DPPH inhibition (IC_{50}) was determined by the plot of percentage inhibition versus concentrations of the samples/standard.

2,2'-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) radical scavenging activity. The ABTS radical scavenging assay was conducted following the procedure described by Re et al. (1999) with slight modifications, using BHT as the standard. Different concentrations of the methanolic extracts of nuts of both samples (TC and PD) or standard (BHT/ 1000, 500, 250, 125, 62.5, 31.25, 15.625, 7.8125 $\mu g.ml^{-1}$) (10 µl) were added to methanolic ABTS solution (190 µl) in the microtiter plate. The samples were mixed and incubated for 7 min. at room temperature in the dark, and the absorbance at 714 nm was measured for each well using a microplate reader (Multiskan go, Thermo Fisher Scientific). A control was prepared using methanol (10 µl) and ABTS (190 µl). All samples were triplicated (n=3). The percentage inhibition (%) was calculated using equation (1), and the corresponding IC_{50} values were reported.

Ferric ion (Fe^{3+}) reducing antioxidant power (FRAP). The FRAP assay was performed for both samples following the method outlined by Koksal et al. (2011) and Daneshniya et al. (2025) with minor modifications using BHT as the standard. Different concentrations of the methanolic extracts of both samples (TD and PD) or standard (BHT/ 1000, 500, 250, 125, 62.5, 31.25, 15.625, 7.8125 $\mu g.ml^{-1}$) (20 µl), sodium phosphate buffer (0.2 M, pH 6.6, and 25 µl) and potassium ferricyanide (1% w/v, 25 µl) were added into wells of the microtiter plate. The blank contained all the reagents except the sample/standard. The mixture was incubated at 45 °C for 20 min. and was terminated by the addition of (10% w/v, 25 µl) trichloroacetic acid. This mixture was then diluted with 85 µl of deionized water, and freshly prepared ferric chloride (0.1% w/v, 17 µl) was added and kept for 10 min. The absorbance of each sample was determined at 700 nm using a microplate reader. Antioxidant capacity was calculated using equation (2) based on the sample's capacity to reduce ferric ions and expressed it as mg potassium ferricyanide equivalents per gram of dry weight of methanolic extracts of samples (TD or PD) (mg PFE.g^{-1}).

$$FRAP\ value\ = \frac{cV}{m} \times DF \qquad (2)$$

Where,
FRAP value in mg Potassium ferricyanide (PFE).g^{-1} dry weight of methanolic extracts of both samples (TD and PD),
c – concentration of BHT obtained from the calibration curve in $mg.ml^{-1}$,
V – volume of extract in ml,
m – mass of extract in grams and
DF – dilution factor.

Determination of total phenolic content (TPC). TPC of the methanolic extracts of both samples was determined according to the method described by McDonald et al. (2001) with slight modifications by using Folin-Ciocalteu's reagent method. The assay was conducted in a 96-well microtiter plate. 20 µl of the extract and 100 µl of 10-fold diluted Folin-Ciocalteu's reagent were added to the microtiter plate. The mixture was incubated at room temperature for 15 min. Following this, 80 µl of 7.5 % sodium carbonate solution was added, and the

mixture was incubated for an additional 30 min at room temperature. The absorbance was subsequently measured using a microplate reader (Multiskan go, Thermo Fisher Scientific) at 760 nm wavelength against the blank. The calibration curve was constructed using gallic acid (100, 200, 300, 400, 500 μg.ml^{-1}) solution in distilled water. The TPC was expressed as gallic acid equivalent (GAE) in mg.g^{-1} of extract (mg of gallic acid.g^{-1} dry weight) based on equation (3)

$$C = \frac{cV}{m} \times DF \quad (3)$$

Where,
C – TPC/TFC,
c – Concentration of gallic acid obtained from the calibration curve in mg.ml^{-1},
V – Volume of extract in ml,
m – mass of extract in grams, and
DF is the dilution factor.

Determination of total flavonoid content (TFC). The TFC of the methanolic extracts of both samples was determined according to the method reported by Chavan et al. (2013) with slight modifications by using the $AlCl_3$ colorimetric method. The reaction mixture consisted of the extract (50 μl), methanol (50 μl), aluminum chloride (1.2 %, 25 μl), and potassium acetate (120 mM, 25 μl) was incubated at room temperature for 30 min. The absorbance was subsequently measured using a microplate reader (Multiskan go, Thermo Fisher Scientific) at 415 nm wavelength against the blank. The calibration curve was constructed using quercetin (37.5, 75, 150, 300, 600 μg.ml^{-1}) in methanol. The TFC content was expressed as mg quercetin equivalent/g of extracts dry weight (mg QE.g^{-1}) based on equation (3) where c is concentration of quercetin obtained from the calibration curve in mg.ml^{-1}.

Determination of α-amylase inhibitory activity (AIA). The α-amylase assay was carried out according to the method described by Zhang et al. (2018) with slight modifications. Acarbose served as the positive control. Methanolic extracts of both samples (TC and PD) and standard positive control, Acarbose (0.0, 15.62, 31.25, 62.5, 125.0, 250.0, 500.0, 1000.0 μg.ml^{-1}) (500 μl) were pre-incubated with α-amylase (1 mg.ml^{-1}, 500 μl) for 10 min separately. Then starch (1 % w/v, 500 μl) solution was added. The mixture was then incubated at 37°C for 10 min. The reaction was terminated by adding DNS reagent, which consisted of sodium potassium tartrate tetrahydrate (12.0 g) in NaOH (2 M, 8.0 ml) and 3,5-dinitrosalicylic acid solution (96 mM, 500 μl). The contents were subsequently heated in a boiling water bath for 10 min. The negative control and blank samples were prepared without the test sample/standard and the amylase enzyme, with the volume replaced by an equal amount of buffer (sodium phosphate buffer/ 20 mM with sodium chloride/ 6.7 mM, pH 6.9). The absorbance was measured by using a microplate reader at 540 nm. The percent inhibition of α- amylase was calculated using equation (4).

$$\% \text{ Inhibition} = \frac{(A-a)-(B-b)}{A-a} \times 100\% \quad (4)$$

Where the,
A – Absorbance of control (without sample/ standard) with enzyme
a – Absorbance of control (without sample/ standard) without enzyme
B – Absorbance of inhibitor (sample/ standard) with enzyme
b – Absorbance of inhibitor (sample/ standard) without enzyme

The sample concentration which provides 50% inhibition percentage (IC_{50}) was calculated by plotting inhibition percentages against the concentration of the samples.

Determination of anti-lipase activity (ALA). The anti-lipase assay was performed following the method outlined by Mamdooh et al. (2018) with minor modifications. Orlistat was used as the positive control. Lipase inhibitory assay was conducted to evaluate the anti-obesity properties of methanolic extracts of both samples (TC and PD). Different doses of the test samples and standard positive control (31.25, 62.5, 125.0, 250.0, 500.0, 1000.0 μg.ml^{-1}) (100 μl) were incubated with lipase enzyme (1 mg. ml^{-1} in tris buffer, pH 7.4) (50 μl) for 10 min. Then, 50 μl of *p*-nitrophenyl acetate (4 mM in tris buffer, pH 8.0) was added to the test samples. The mixtures were incubated at 37°C for another 30 min. Negative control and blank samples were prepared by omitting the test sample/standard and lipase enzyme, replacing the volume with an equal amount of buffer. Absorbance was measured at 405 nm using a microplate reader. The inhibition of lipase activity was calculated using equation (4). The concentration of the sample required for 50%

inhibition (IC_{50}) was determined by plotting the inhibition percentages against the sample concentrations.

Determination of *in-vitro* sun protection factor (SPF). Methanolic extracts of both samples and a reference (commercially available sunscreen) (2.0 $mg.ml^{-1}$) were prepared. The UV absorbance of each sample was recorded using a microplate reader (n=3) from 290 to 320 nm, at 5 nm intervals. *In vitro* SPF of samples and reference at different concentrations was determined using equation (5) (Mansur et al. 2016; Sayre et al. 1979).

$$SPF_{spectrophotometric} = CF \times \sum_{290}^{320} EE\ (\lambda) \times I\ (\lambda) \times Abs\ (\lambda) \quad (5)$$

Where,
CF = Correction factor (10)
EE = erythmogenic effect of radiation with wavelength λ
I = Solar intensity spectrum, Abs = Absorbance of sunscreen product/sample

The values of EE and I are constants.

Table 1. Normalized product function used in the calculation of SPF

Wavelength (λ nm)	EE × I (normalized)
290	0.0150
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0839
320	0.0180
Total	1

Statistical analysis. Data from triplicate experiments were analyzed and are presented as mean ± standard deviation (SD). Statistical significance was assessed using one-way ANOVA followed by Tukey's post hoc test with a significance level set at $p < 0.05$.

Results and Discussion

Proximate composition. In Table 2, the results of the proximate composition of TC and PD are shown. TC nuts were found to have 11.8% moisture content and PD nuts were found to have 3.4% moisture content (on a wet basis). Also, the results indicated that there was a significant difference ($p < 0.05$) between TC and PD moisture content. According to Rakholiya et al. (2015), the quality and shelf life of seeds depend on their low moisture content since low moisture inhibits microbiological activities. The ash content of TC is comparable to that of PD nuts, which had a 4.11% content in this study. The low ash content of seeds may be explained by the movement of inorganic ions throughout maturity from different parts of the plant to the region of active growth (Sanchez et al. 1991). The results indicate that there was not a significant difference ($p > 0.05$) between TC and PD ash content. TC nuts have a 36.15% protein content. Due to the tropical almond nut's high protein content, it may be used as a nutritional supplement, which is particularly beneficial for individuals who need plant protein (such as those with hypertension).

The results showed that there was no statistically significant difference in the protein content of TC and PD ($p > 0.05$). In this study, it was discovered that the TC nut's oil content was 32.16%. and PD nut's oil content was found to be 35.48%. The results suggested that TC is a cheap source of edible oils that may be utilized in place of certain common oilseeds including palm, groundnut, and soybean. The results indicate no significant difference ($p > 0.05$) between TC and PD lipid content. In the present study, the total dietary fiber content of TC was found to be 15.66% and that of PD was 14.33%, both surpassing values reported for other common nuts such as walnuts (6.7%) and cashews (3.3%) (Snetselaar et al. 2021). According to the Codex Alimentarius Commission, foods containing at least 2.5 g of fiber per serving can be labeled as a "source of fiber," whereas the U.S. FDA defines a "source of fiber" as containing a minimum of 1.5 g per serving and a "good source of fiber" as containing at least 3.0 g of fiber per serving. Given their fiber content, both nuts exceed these thresholds, supporting their classification as sources of dietary fiber.

Table 2. Proximate composition of nuts of *Terminalia catappa* and *Prunus dulcis*

Composition	***Terminalia catappa*** **Value, %**	***Prunus dulcis*** **Value, %**
Moisture	$11.80^{a} \pm 0.34$	$3.40^{b} \pm 0.04$
Ash	$4.18^{a} \pm 1.01$	$4.11^{a} \pm 0.23$
Crude protein	$36.15^{a} \pm 4.30$	$33.85^{a} \pm 2.32$
Crude fiber	$15.66^{a} \pm 2.13$	$14.33^{a} \pm 1.21$
Crude lipid	$32.16^{a} \pm 0.12$	$35.48^{b} \pm 0.09$
Carbohydrate	$11.85^{a} \pm 1.92$	$12.23^{a} \pm 0.98$

Note: Each data point represents the means of three replicates ± standard deviation. Different letters (a and b) within the same row indicate a significant difference at $p < 0.05$

The digestive tract may respond better to the increased fiber content without experiencing significant constipation issues. The results showed that there is also no significant difference between the TC and PD fiber content ($p > 0.05$). The current study showed that TC had 11.85% carbohydrate while PD had 12.23%. The results indicate no significant difference ($p > 0.05$) in carbohydrate content between TC and PD.

Phytochemical screening. Various bioactive components, including flavonoids, phenols, tannins, alkaloids, glycosides, and saponins, were found in *Terminalia catappa* nut extracts (Salawu et al. 2018). The results of this study provide important information on the phytochemical makeup of TC nuts and PC nuts, demonstrating their potential as a source of natural bioactive chemicals and validating their long-standing usage in folk medicine. Table 3 shows the results of the phytochemical screening of TC and PD.

Table 3. Results of phytochemical screening of methanolic extracts of nuts of *Terminalia catappa* and *Prunus dulcis*

Constituent	***Terminalia catappa***	***Prunus dulcis***
Phenol	+	+
Alkaloids	+	+
Flavonoids	+	+
Steroids	+	+
Terpenoids	+	+
Glycosides	+	+
Tannins	-	-
Saponin	+	+
Cardial glycoside	+	+
Triterpene	+	+

'+' indicates the presence of the phytochemical, and '-' indicates the absence of the phytochemicals.

Determination of antioxidant activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity. Percentage inhibition and IC_{50} are the measures used by Koksal et al. (2011) and Widodo et al. (2025) to describe the capacity of radical scavenging activity. The stronger the radical scavenging activity, the lower the IC_{50}. The methanolic extract of TC nuts was studied for its antioxidant activity, and the findings were compared to that of the PD's. The outcome showed a significant difference ($p < 0.05$) in DPPH free radical scavenging activity between the two samples. In this study, it was discovered that the IC_{50} value of TC (89.22 $\mu g.ml^{-1}$) is significantly ($p < 0.05$) greater than that of PD (78.55 $\mu g.ml^{-1}$). BHT showed a 17.48 $\mu g.ml^{-1}$ IC_{50} value. The result of the IC_{50} value for TC nuts obtained in this study is lower than the previously reported IC_{50} of nuts of TC: 95.99 $\mu g.ml^{-1}$ (Abdulkadir et al. 2013), and leaves of TC: 2.26 $mg.ml^{-1}$ (Oyeniran et al. 2020). IC_{50} value for PD nuts found in this study is lower than the reported value for nuts of PD: 87.30 $\mu g.ml^{-1}$ (Keser et al. 2014). The differences in results among studies may be due to variations in the chemical constituent extraction procedures.

2,2'-azino-bis-3-ethylbenzthiazoline-6 sulphonic acid (ABTS) radical scavenging activity. According to the results (Table 4), TC shows an IC_{50} of 74.36 $\mu g.ml^{-1}$ and that of PD is 57.19 $\mu g.ml^{-1}$. There was a significant difference ($p < 0.05$) between the ABTS activity of TC and PD. BHT shows a 46.98 $\mu g.ml^{-1}$ IC_{50} value. The IC_{50} values of extracts from TC leaves have been examined in several studies. Research by Re et al. (1999) found that TC of leaves have considerable potential to scavenge free radicals, with a value of 0.06 mmol $TEAC.g^{-1}$. Similarly, studies by Oyeniran et al. (2020) and Rakholiya et al. (2015) reported scavenging capacities in the range of 17-38 $\mu g.ml^{-1}$. According to a previous study reported by Keser et al. (2014) PD nuts have an IC_{50} value of 89.50 $\mu g.ml^{-1}$.

Ferric ion (Fe^{3+}) reducing antioxidant power (FRAP). FRAP value in methanolic extracts of TC and PD was determined by the potassium ferricyanide reducing assay using BHT as the standard antioxidant and obtained from the linear regression equation of the calibration curve ($y = 0.0021 + 0.1007$, $R^2 = 0.9637$). The corresponding FRAP values are given in Table 4. According to the results, TC shows a FRAP value of 41.60 mg $PFE.g^{-1}$ of dry weight of the extract, and that of PD is 39.15 mg $PFE.g^{-1}$ of dry weight. There was a significant difference ($p < 0.05$) between TC and PD nuts' ferric reducing activity. There has not been much research on the FRAP assay using potassium ferricyanide to determine the antioxidant activity of plant parts of PD and TC. The IC_{50} value for the leaves of TC was found to be 250 $\mu g.ml^{-1}$ in a previous investigation (Anand and Kotti 2018). Abdulkadir et al. (2013) showed the FRAP value in terms of mM Fe (II).g^{-1} for TC nuts as 1505.11, which is carried out by reducing the ferric tripyridyl triazine (Fe^{3+}-TPTZ) complex to its ferrous tripyridyl triazine (Fe^{2+}-TPTZ) complex. Results of antioxidant activity (IC_{50}) are tabulated in Table 4.

Total phenolic content. The results showed that PD nuts have a higher phenolic content than TC nuts. In this study, the TPC content of TC was found to be 134.00 ± 9.54 mg $GAE.g^{-1}$ of the dry weight of the extract and that of PD was 199.00 ± 14.65 mg GAE. g^{-1} of the dry weight of the extract. It has been reported that the TPC of TC was 117.10 mg GAE. g^{-1} for ripened nuts, and 29.25 mg $GAE.g^{-1}$ for leaves of TC (Oyeniran et al. 2020). Another study reported that the TPC of leaves was 285.77 mg $GAE.g^{-1}$ (Abdulkadir et al. 2013). Rakholiya et al. (2015) reported that the TPC of leaves of 4 different species of TC ranges from 26.78 - 184.40 mg $GAE.g^{-1}$. The TPC value obtained for PD in the current study is lower than that of the previously reported value of 670.59 mg $GAE.g^{-1}$ (Keser et al. 2014).

Total flavonoid content. In this investigation, the TFC content of TC and PD was determined to be 4.60 mg $QE.g^{-1}$ and 4.78 mg $QE.g^{-1}$, respectively. According to statistics, there was no significant difference ($p > 0.05$) in the TFC content between TC and PD. However, the results that were obtained for TFC for both samples were low when compared to that in nuts of ripened fruit of TC with TFC of 28.2 mg $QE.g^{-1}$ (Abdulkadir et al. 2013) and 19.54 mg $QE.g^{-1}$ (Keser et al. 2014). However, it is greater than the reported value (0.03 $QE.g^{-1}$) by Oyeniran et al. (2020) for leaves of TC. Low TFC in TC and PD nuts denotes a considerably lower content of flavonoids. This may indicate that the flavonoids in these nuts have a significantly lesser contribution to antioxidant and health-improving effects.

Table 4. Results of antioxidant activity by DPPH, ABTS assays, and FRAP value of methanolic extracts of nuts of *Terminalia catappa* and *Prunus dulcis*

Sample	IC_{50} values, $\mu g.ml^{-1}$		mg PFE.g^{-1}
	DPPH	ABTS	FRAP
BHT	$17.48^{a} \pm 1.90$	$46.98^{a} \pm 5.41$	
Terminalia catappa	$89.22^{b} \pm 4.40$	$74.36^{b} \pm 3.34$	$41.60^{a} \pm 0.23$
Prunus dulcis	$78.55^{c} \pm 5.10$	$57.19^{c} \pm 0.32$	$39.15^{b} \pm 0.21$

Note: Values represent the means of three replicates ± standard deviation. Superscripts with different alphabet letters (a - c) within the same column indicate a significant difference at $p < 0.05$.

TPC and TFC of methanolic extracts of nuts of *Terminalia catappa* and *Prunus dulcis* are listed in Table 5.

α-amylase inhibitory activity. The IC_{50} of the standard amylase inhibitor, acarbose was found to be 60 $\mu g.ml^{-1}$, while those of TC and PD were 113.4 $\mu g.ml^{-1}$ and 128.3 $\mu g.ml^{-1}$ respectively. There was a significant difference ($p < 0.05$) between the IC_{50} values of the two samples and between the sample and the standard. Though both samples (PD and TC) have low α-amylase inhibitory activity compared to acarbose, they have potential anti-amylase properties.

Oyeniran et al. (2020) proposed that the suppression of the activity of the α-amylase enzyme is caused by medicinal herbs with high polyphenol content. TC and PD extracts contain several phytochemicals including flavonoids, phenols, and tannins, which may contribute to their inhibitory effect on α-amylase activity.

Anti-lipase activity. The IC_{50} of the standard lipase inhibitor, Orlistat was determined to be 98 $\mu g.ml^{-1}$, whereas those of TC and PD were 190.4 $\mu g.ml^{-1}$ and 167.33 $\mu g.ml^{-1}$, respectively. The IC_{50} values between the two samples and between the sample and the standard differed significantly ($p < 0.05$). Compared to the standard, both samples had higher IC_{50} values, or in other words, low anti-lipase activity. However, the lipase enzyme tends to be inhibited by both samples, which could be used as an ingredient for the development of supplements for weight loss.

Flavonoids, phenolic compounds, and tannins may account for the lipase-inhibiting properties observed in TC and PD extracts. Ahmed et al. (2017) have reported that these substances (flavonoids, phenolic compounds, and tannins) slow down the digestion and absorption of dietary fats by interfering with the enzymatic activity of lipase. IC_{50} of α-amylase inhibitory activity (AIA), and anti-lipase activity (ALA) of methanolic extracts of nuts of TC and PD are tabulated in Table 6.

Table 5. Results of total phenolic content (TPC), and total flavonoid content (TFC) of methanolic extracts of nuts of *Terminalia catappa* and *Prunus dulcis*

Sample	TPC, mg GAE.g^{-1}	TFC, mg QE.g^{-1}
Terminalia catappa	$134.00^{a} \pm 9.54$	$4.600^{a} \pm 0.084$
Prunus dulcis	$199.00^{b} \pm 14.65$	$4.780^{a} \pm 0.077$`

Note: Values represent the means of three replicates ± standard deviation. Superscripts with different alphabet letters (a and b) within the same column indicate a significant difference at $p< 0.05$.

Table 6. Results (IC_{50}) of α-amylase inhibitory activity (AIA), and anti-lipase activity (ALA) of methanolic extracts of nuts of *Terminalia catappa* and *Prunus dulcis*

Sample	IC_{50} values, $\mu g.ml^{-1}$	
	AIA	ALA
Terminalia catappa	$113.40^{a} \pm 1.560$	$190.40^{a} \pm 5.220$
Prunus dulcis	$128.30^{b} \pm 1.120$	$167.33^{b} \pm 6.350$
Standard	$60.00^{c} \pm 0.002$	$98.00^{c} \pm 0.001$

Note: Values represent the means of three replicates ± standard deviation. Superscripts with different alphabet letters (a - c) within the same column indicate a significant difference at $p < 0.05$.

In-vitro sun protection factor (SPF). SPF is a numerical indicator of a sunscreen product's effectiveness in protecting against UV radiation. A sunscreen product should have an absorbance range between 290 and 320 nm to effectively prevent sunburn and other skin damage caused by UV-B rays. In this study, a UV spectrophotometric method was used to determine the SPF values for the methanolic extract of TC and PD nuts using the Mansur mathematical equation (Mansur et al. 2016). The SPF values of the methanolic extracts of TC and PD were 14.52 ± 2.34 and 12.92 ± 1.78, respectively, and that of a commercial sunscreen had an SPF of 32.12 ± 0.16 (Table 7). According to SPF ratings, goods with SPF values of 2 to under 12 are referred to as "minimal sun protection products," while those with SPF values of 12 to under 30 are referred to as "moderate sun protection products," and those with SPF values higher than 30 are referred to as "high sun protection products (Sutar and Chaudhari 2020). The findings imply that both extracts provide a moderate level of sun protection suggesting their potential to be used as a natural additive in sunscreen formulations. To our knowledge, this is the first study to report on the photoprotective properties of TC and PD nuts

Table 7. SPF values of reference, methanolic extracts of *Terminalia catappa* and *Prunus dulcis*

Sample	SPF
Terminalia catappa	$14.52^{a} \pm 2.34$
Prunus dulcis	$12.92^{b} \pm 1.78$
Reference sunscreen	$32.12^{c} \pm 0.16$

Note: Values represent the means of three replicates ± standard deviation. Superscripts with different alphabet letters (a - c) within the same column indicate a significant difference at $p < 0.05$.

Conclusions

This study provides a comparative assessment of the nutritional composition and biological activities of *Terminalia catappa* (tropical almond) and *Prunus dulcis* (almond) nuts. Both species exhibited strong antioxidant, α-amylase inhibitory, anti-lipase, and photoprotective properties, highlighting their potential for applications in food, pharmaceutical, and cosmeceutical industries. *Terminalia catappa* demonstrated high protein and fiber contents, comparable to those of *Prunus dulcis*, and met international dietary fiber standards as defined by the Codex Alimentarius Commission and U.S. FDA guidelines. While *P. dulcis* showed higher DPPH and ABTS radical scavenging activity, *T. catappa* exhibited superior FRAP activity, indicating complementary antioxidant profiles. Enzyme inhibition assays further suggest potential roles in managing diabetes and obesity, and both nuts displayed moderate UV-B protection. These findings support the viability of *T. catappa* as a sustainable and nutritionally valuable alternative to *P. dulcis*, warranting further exploration for industrial use, particularly in regions where almonds are less accessible or economically feasible. Future research should also focus on the identification of specific compounds responsible for the observed bioactivities to better understand and harness their functional potential.

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Author Contributions

Conceptualization, C.S.K.R.; methodology, G.M.P., and C.S.K.R.; formal analysis, G.M.P., and C.S.K.R.; investigation, G.M.P.; resources, G.M.P., and C.S.K.R.; data curation, G.M.P.; writing – original draft preparation, G.M.P., and D.H.D.D.D.; writing, G.M.P., and D.H.D.D.D.; review and editing, G.M.P., D.H.D.D.D., and C.S.K.R.; supervision, C.S.K.R.; All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest

The authors declare no conflicts of interest.

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