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"Evaluation of Sun Protection Factor (SPF) of Common Fruit and Vegetable Extracts Using UV-Visible Spectroscopy": An Herbal Approach

Sana Fatima[1], Ravindra Mishra[2*], Vinay Jain[3], Saloni Jain[2]

[1]Scholar, M. Pharma, Pharmacology, Shriram College of Pharmacy, Banmore, Morena
[2]Associate Professor Department of Pharmacology, Shriram College of Pharmacy, Banmore, Morena
[3]Principal, Department of Pharmacognosy, Shriram College of Pharmacy, Banmore, Morena
Email: Ravindra.mishra1412@gmail.com

Skin cancer is one of the many skin conditions brought on by excessive ultraviolet (UV) radiation exposure. Sunscreen is essential for preventing sun damage since it contains UV filters. Because sunscreen absorbs or reflects UV rays, it shields the skin from UV-induced damage. However, prolonged exposure to physical and chemical UV filters can have a number of negative impacts on the environment and skin. Because of their antioxidant qualities and UV absorption, natural ingredients like fruit and vegetable extracts have been emphasized in sunscreen formulations. By measuring the sun protection factor (SPF), total phenolic content, and antioxidant activity of fruits and vegetables, this study seeks to assess their potential application as photo-protective agents. The SPF of five vegetable samples—tomato, brinjal, ginger, sweet potato, and onion—and five fruit samples—guava, mango, sapodilla, dragon fruit, and apple—was examined. The spectrophotometric method was used to measure the photoprotective activity, and the Mansur equation was used to calculate the results. The Folin-Ciocalteu method and the DPPH radical scavenging assay were used to evaluate the antioxidant activity and phenolic content of each sample, respectively. There was a moderate association between TPC and DPPH ($r = 0.46$, $p > 0.05$), a weak correlation between SPF and TPC ($r = 0.02$, $p > 0.05$), and a substantial correlation between SPF and concentration ($r = 0.95$-0.99, $p < 0.05$). The study demonstrates the potential for adding a number of specific plant extracts to sunscreen formulations.

Keywords: SPF, Total phenolic content, plant extract, photoprotective,

antioxidant properties.

1. Introduction

X-rays, ultraviolet, visible, infrared, and micro and radio waves make up the extra-terrestrial sunlight. The electromagnetic energy wavelengths in the solar spectrum that reach the earth's surface range from 290 to 3000 nm. Electromagnetic radiation having wavelengths ranging from 100 to 400 nm is known as ultraviolet (UV) radiation. Three bands are used to further categorize UV radiation: UVA (320–400 nm), UVB (290–320 nm), and UVC (200–290 nm). About 95–98% of the UV light from the sun that reaches Earth is UV A, while the remaining 5% is UV B. All of the UV C is absorbed by the stratosphere's ozone layer. UV B radiation is fully absorbed by the stratum corneum and top layers of the epidermis, whereas up to 50% of the incident UV A radiation penetrates Caucasian skin deep into the dermis.

Concern over the destruction of the stratospheric ozone layer by nitric oxides, halons, and chlorofluorocarbons has grown in recent years. This could lead to UV B and C irradiance at the earth's surface, which would ultimately increase the risk of skin cancer and have other negative impacts on people.

The skin is significantly impacted by UV radiation exposure both acutely and over time. Acute reactions like sunburn or erythema, pigmentation, hyperplasia, immunosuppression, and vitamin D production are examples of skin impacts caused by UV radiation. Chronic consequences include photo carcinogenesis and photo-aging. The spectrum, intensity, and total dose of UV light all affect these short-term and long-term impacts. For most UVR-induced symptoms, the whole spectrum of activity has not yet been fully identified as inhuman skin. Furthermore, the thresholds for these responses vary, so that preventing UVR-induced alterations for one endpoint does not ensure that any other endpoint would be similarly protected.

It has been demonstrated that UVA filters or broad-spectrum sunscreens can minimize or eliminate photodamage caused by UVA rays, however sunscreens with an attenuation spectrum mostly in the UVB range cannot.

For ethical reasons, it is challenging to assess these outcomes in people concerning protection against cutaneous cancers. However, according to human reports, wearing a broad-spectrum sunscreen can effectively prevent and even lessen solar keratosis, which may, in turn, lower the long-term risk of developing skin cancer. Broad-spectrum sunscreens are more effective at preventing UV-induced cutaneous cancers than UVB filters, according to in vivo research. Broad-spectrum sunscreens are more successful in reducing DNA breakage in human melanocytes, immunosuppression, and skin cancers in mice.

A significant modifiable environmental risk factor for skin conditions such as keratosis, sunburns, photoaging, and the development of oxidative stress, malignant transformation, and cancer is exposure to ultraviolet radiation (UVR) from sunshine. The ultraviolet (UV) spectrum of the radiation is divided into three categories based on their wavelengths: UVA (320-400 nm), UVB (280-320 nm), and UVC (200-280 nm). While no UVC light may pass through the Earth's atmosphere, the atmosphere contains around 95% of UVA and 5% of UVB

radiation. Both UVA and UVB have a substantial impact on skin health because they can be absorbed by various cellular proteins found in skin cells.

UVB is responsible for the majority of UVR damage to the skin, even though it makes up a very minor portion of the atmosphere. When the skin is exposed to UVR, the cutaneous immune system is activated, which causes an inflammatory response through a variety of mechanisms. For instance, reactive oxygen species (ROS) and UV photo-products that contribute to skin carcinogenesis, such as pyrimidine-pyrimidone and cyclobutane-type pyrimidine dimers (CPD), are produced. Therefore, reducing UVR exposure through sun protection practices is the main goal of skin disease prevention. Sunscreen is thought to be an essential supplement to other forms of UVR radiation protection from the sun. It is an essential part of public health initiatives to avoid skin diseases.

Usually, sunscreens are intended to protect against the harmful effects of ultraviolet light. Human interest in adding plant extracts with UV-absorbing properties and antioxidant activity to sunscreens has grown significantly in recent years. SPF serves as a crucial metric for evaluating the quality and efficacy of sunscreens. The energy needed to produce a low erythema dosage (skin reddening or mild sunburn) with sunscreen application divided by the energy needed to accomplish the same result without sunscreen application is the SPF value. Since it is believed to have the largest occurrence during the day when people are exposed for longer periods, it is mostly against UVB radiation. Hence, sunscreen product is considered to be more effective in preventing sunburn when the SPF value is higher.

By absorbing, dispersing, or blocking UVR rays that can cause cancer and damage to the skin, sunscreens both chemical and physical are items with photoprotective qualities that can help shield the skin. Chemical sunscreens with active chemicals including para-aminobenzoic acid (PABA), sulisobenzones, benzophenone, and avobenzone function by absorbing UV rays and excitation to a higher energy state. Heat is produced when the absorbed energy is transformed into longer, lower-energy wavelengths, like infrared radiation, as a result of its return to the ground state. By physically reflecting or dispersing the incident radiation, physical sunscreens made with zinc oxide (ZnO) and titanium dioxide (TiO2) protect the skin from UV rays. It is said that a mix of chemical and physical sunscreens works well to block UVA and UVB exposure.

Although these UV filters offer UV protection, their widespread use in sunscreen products may have negative skin consequences if applied consistently for an extended length of time. Certain compounds used in the goods, such as benzophenone-3, have been connected to toxicity, adverse effects, and even environmental problems when exposed frequently. Skin reactions such as contact dermatitis, photo-irritation, and photosensitivity may result from these artificial chemicals' interactions with cutaneous cells. Reactive oxygen species (ROS) overproduction or possible systemic toxicity are the two main causes of oxidative DNA damage, which results in these adverse effects. In addition, UV filters are a serious environmental hazard. The ecological system is harmed by the presence of oxybenzone, ZnO, and TiO2 in the sea. Finding additional possible UV filters to include in sunscreens that might provide the same level of UV protection as other common sunscreens has therefore sparked attention. Research has been done to find novel active chemicals that are natural and have the potential to filter UVR. These compounds should be safer and more effective.

The sun protection factor (SPF) is a crucial indicator of sunscreen efficacy. A product's ability to prevent sunburn increases with its SPF. These plants' strong antioxidant properties and capacity to absorb UV light are attributed to the presence of phenolic substances, such as flavonoids and phenolic acids. High-antioxidant plant extracts may offer protection against free radicals by deactivating ROS, the primary source of UVR-induced skin damage, and by enabling the absorption of UV radiation. Because of their capacity to enhance photo protection and aid in the filtering function of multifunctional sunscreen formulations, natural ingredients like fruit extracts have gained attention in recent years and provide additional protection against free radicals. When compared to the usage of standard UV filters alone, the inclusion of these antioxidant compounds in sunscreens is thought to be beneficial. This is due to the presence of phenolic chromophores in fruits and vegetables, which possess antioxidant properties and UV protection.

Determining the SPF values of a few chosen fruits and vegetables that are frequently included in daily diets was the aim of this study. Five fruits guava (Psidium guajava), mango (Mangifera indica), sapodilla (Manilkara zapota), dragon fruit (Hylocereus polyrhizus), apple (Malus domestica), and vegetables (onion (Allium cepa), brinjal (Solanum melongena), tomato (Solanum lycopersicum), sweet potato (Ipomoea batatas), and ginger (zingiber officinale) were analyzed for their UV absorption capacity. Furthermore, experiments were performed to ascertain the fruits and vegetables listed above's total phenolic content and antioxidant potential.

The results of this study offer the possibility of using plant extracts in place of UV filters in the creation of sunscreen products that have a higher level of UV protection and a lower risk of side effects. Furthermore, the growing demand for safe, natural plant-based ingredients in cosmetics and other beauty goods portends significant future economic growth for other associated industries. As a result, the current study's findings provide a wealth of opportunities for additional research and investigations in the creation of novel, safe plant-based cosmetics or beauty products using regional plants.

Bioactive substances including flavonoids, tannins, and phenolic acids, which are abundant in plants, are known to have potent antioxidant and UV-absorbing qualities. By neutralizing UV-generated free radicals, these substances help lessen inflammation and oxidative stress. Plant-based photoprotective compounds are frequently safer for extended use, biodegradable, and environmentally friendly than synthetic sunscreens.

2. Material and methods

Chemicals and Materials

Merck supplied the methanol (RCL Labscan). Veolia Water Technologies, Maharashtra, India's ELGA PURELAB® Option water purification system purified the ultra-pure water at a pressure of 18 MΩ cm. Sigma-Aldrich provided the folate-ciocalteu reagent, gallic acid, ascorbic acid, and 2,2-Diphenyl-1-picrylhydrazyl (DPPH). One frequent regent that is available in the lab is sodium carbonate.

Five fruit samples guava, mango, sapodilla, dragon fruit, and apple and vegetable samples

onion, brinjal, tomatoes, orange-fleshed sweet potatoes, and ginger were gathered from the neighborhood grocery based on their comparable levels of development. The fruits' consistent size, color, and degree of exterior ripeness were taken into consideration when choosing them.

Preparation of Plant Samples

After being cleaned under running water, whole plant samples were split into smaller, comparable-sized pieces. For three days, the plant materials were kept frozen at -20°C. For seventy-two hours, the frozen samples were lyophilized in the Freeze Dry System. A Waring Commercial Blender was then used to grind the dried plant materials into fine powders until they were completely homogenized, and they were then stored in the refrigerator at 4°C for later usage.

One gram of the powdered dried plant material was dissolved in one hundred milliliters of 80% methanol for the TPC and DPPH free radical scavenging test. After an hour of stirring at 150 rpm with a magnetic stirrer, the mixtures were filtered through Whatman No. 1 filter paper. The clear solution obtained was kept at 4°C in an airtight bottle for further analysis.

To assess repeatability for the assays, three replicates of each plant sample were prepared, and assays were performed on the same day in a uniform environment. Acceptable repeatability for absorbance values is set at a mean SD of not higher than 1 for all replicates.

SPF Determination of Plant Samples

Using an analytical balance, five grams of each ground powder were weighed and then put into different beakers. For three days and seventy-two hours, the plant materials were immersed in 100 millilitres of 80% methanol at 4°C. After an hour of individual stirring at 150 rpm with a magnetic stirrer, the solutions were filtered through Whatman No. 1 filter paper to produce a clear solution. After that, each filtrate was 50 times diluted to create a stock solution that contained 1 mg/ml. Following this, serial dilutions were carried out to acquire various sample concentrations for SPF analysis (1, 0.50, 0.25, 0.125, and 0.0625 mg/ml). Using a BMG Labtech SPECTROstar® Nano spectrophotometer, the absorbance of each solution was measured in 5-nm increments within the UVB wavelength range (290–320 nm) kand 80% methanol as blank. The SPF of each sample was determined using the methodology and equation provided by Mansur et al.. The following Mansur equation was used to calculate the SPF:

$$= CF \sum_{290}^{320} EE(\lambda).I(\lambda).Abs(\lambda)$$

where:

CF = correction factor

EE = erythemogenic effect of radiation with wavelengths

I = solar intensity spectrum

Abs (λ) = spectrophotometric absorbance values at wavelength

As can be observed in Table 1, Sayre et al. established a link between the erythemogenic effect (EE) and the solar intensity spectrum (I) at each wavelength, stating that the values of EE (λ)

× I (λ) were constant at each wavelength. Sun protection factor (SPF) is calculated using the EE and I constants. [31-38]

Table 1; Erythemogenic effect of wavelength radiation, EE(λ) and Sun intensity at wavelength, I (λ)

Wavelength (mm)	EE(λ) × I(λ)
290	0.0150
295	0.0817
300	0.2985
305	0.3179
310	0.1894
315	0.0843
320	0.0185

Determination of Total Phenolic Content of Plant Samples

With a small modification, the Folin-Ciocalteu technique was used to determine the samples' total phenolic content. Gallic acid served as a standard for this experiment. To create the 0.5 mg/ml stock standard solution, 250 mg of dry gallic acid were dissolved in 1 ml of extracting solvent (80% methanol) and then diluted to 500 ml volume with ultra-pure water. Then, using ultra-pure water to dilute the previously made gallic acid stock solution, various concentrations of working standards (0.01, 0.02, 0.03, 0.04, and 0.05 mg/ml) were created. The concentration of the prepared sample was 1 mg/ml. In a test tube, 750 µl of the Folin-Ciocalteu reagent (which had been diluted ten times with ultra-pure water) was mixed with 100 µl of the sample solution. After five minutes of standing at room temperature, 750 µl of 6% (w/v) sodium carbonate was added, and the mixture was gently stirred. The absorbance was measured at 725 nm following 90 minutes of standing at room temperature. A plot of the gallic acid standard calibration curve (0.01-0.05 mg/ml) was made. The gallic acid equivalent (mg GAE) per g dry weight (DW) of the samples was used to express the total phenolic contents.

DPPH Free Radical Scavenging Assay of Plant Samples

With a few minor adjustments, the DPPH free radical scavenging assay was carried out by procedures. Ascorbic acid served as the standard reference for this experiment. To achieve various concentrations (0.01562, 0.03123, 0.06250, 0.12500, 0.25000, and 0.50000 mg/ml), the samples were prepared in serial dilutions. 5.0 mg of DPPH was dissolved in 100 mL of methanol to create a one mM DPPH solution. Then, a 96-well round-bottom microplate was filled with 25 µl of each sample solution and the standard. Each well was filled with 200 µl of a 1 mM DPPH solution, and the solutions were let to sit at room temperature in the dark for 30 minutes. The absorbance of each sample and ascorbic acid was measured at 517 nm following a 30-minute incubation period.

The control used in this assay was 25 µl of 80% methanol and 200 µl of 1 mM DPPH, while 80% methanol was used as blank. The antioxidant activity, which is the ability of the standards and sample to scavenge DPPH free radical was calculated using the following equation:

$Scavenging\ activity$ (%) = (1- absorbance of sample/absorbance of control) × 100

Higher scavenging activity was indicated by lower absorbance, which was followed by a decrease in the intensity of the purple to yellow colour of the solutions. The DPPH radical scavenging activity of each sample was expressed in percentage.

Statistical Analysis

Pearson test and regression analyses were used to correlate SPF with concentration, SPF with TPC, and TPC with DPPH. All these analyses were determined using Microsoft Excel with its Data Analysis add-in whereby the significant difference was set at $p < 0.05$.

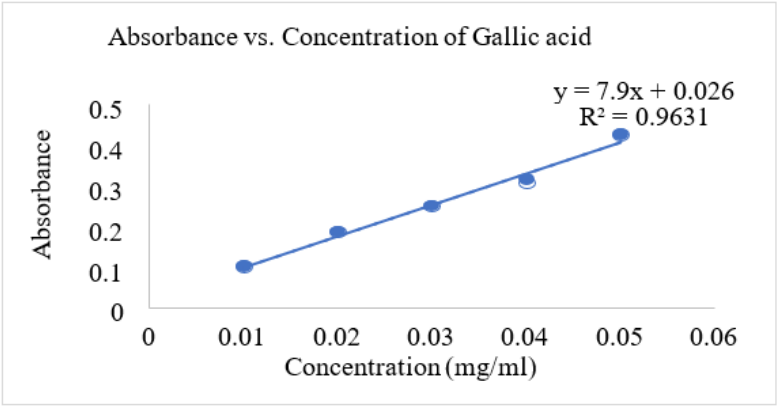

Table 2. TPC of fruits and vegetables at 725 nm

Sample	Total Phenolic Content (mg GAE/g DW)
Guava	4.66
Mango	7.57
Sapodilla	5.43
Dragon fruit	4.03
Apple	6.71
Onion	4.29
Brinjal	4.07
Sweet potato	2.70
Tomato	3.19
Ginger	14.92

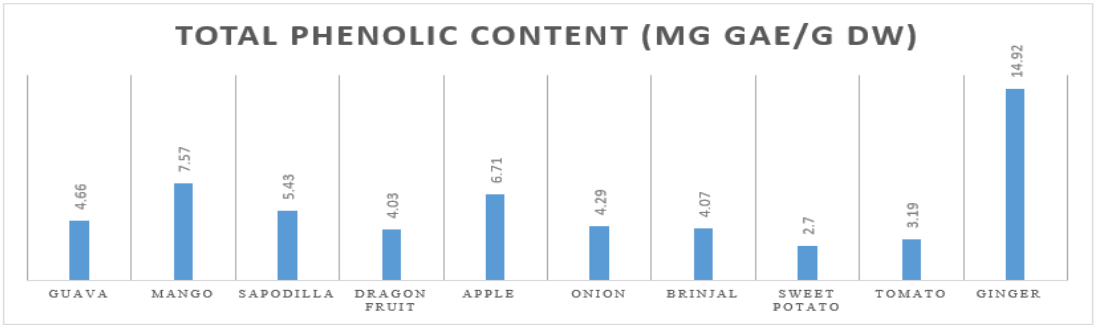

Table 3. Radical scavenging activity at different concentration of fruits

Fruit	0.5000 (mg/ml)	0.2500 (mg/ml)	0.1250 (mg/ml)	0.0625 (mg/ml)	0.0313 (mg/ml)	0.0156 (mg/ml)
Standard	92.25	89.81	88.87	88.27	51.02	30.69
Guava	20.62	13.12	10.75	10.27	10.22	8.99
Mango	22.67	22.46	14.83	12.61	9.46	5.63
Sapodilla	9.68	7.89	4.53	4.39	2.37	1.97
Dragon fruit	9.97	5.76	5.75	1.93	1.39	0.48
Apple	6.68	6.63	5.27	4.79	3.95	3.58

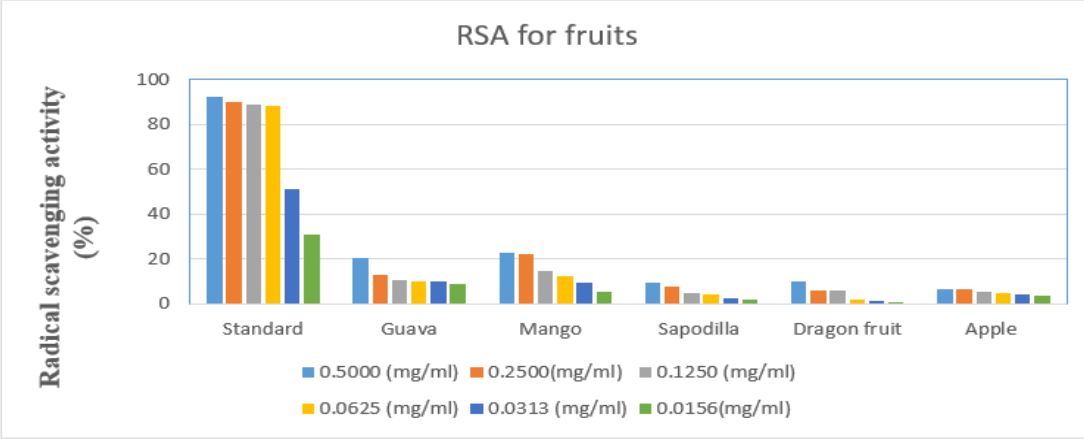

Table 4. Radical scavenging activity at different concentrations of vegetables

Vegetable	0.5000 (mg/ml)	0.2500 (mg/ml)	0.1250 (mg/ml)	0.0625 (mg/ml)	0.0313 (mg/ml)	0.0156 (mg/ml)
Standard	92.25	89.81	88.87	88.27	51.02	30.69
Ginger	42.28	25.37	10.12	9.06	8.34	5.7
Onion	13.93	12.47	9.11	6.62	3.76	2.4
Brinjal	14.29	9.97	6.11	3.44	0.88	0.64
Tomato	14.11	7.15	4.87	4.25	2.4	1.99
Sweet potato	12.19	5.85	4.6	2.33	2.17	1.89

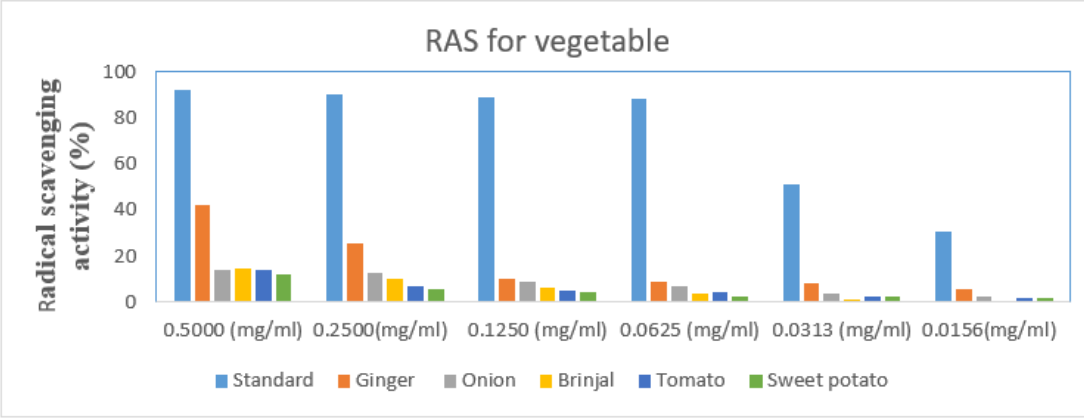

Table 5. SPF values of fruits at different concentrations

Fruit name	1.00mg/ml	0.50mg/ml	0.25mg/ml	0.125mg/ml	0.0625mg/ml
Guava	11.05 ±0.05	5.05 ±0.03	3.80 ±0.12	3.65 ±0.21	3.28 ±0.15
Mango	5.02 ±0.02	4.17 ±0.06	4.09 ±0.05	3.96 ±0.15	3.52 ±0.45
Sapodilla	4.14 ±0.11	3.77 ±0.32	3.37 ±0.21	3.29 ±0.15	3.14 ±0.05
Dragon fruit	3.73 ±0.12	3.24 ±0.25	3.18 ±0.06	3.02 ±0.05	2.98 ±0.55
Apple	3.46 ±0.23	3.27 ±0.26	3.16 ±0.05	3.09 ±0.09	3.05 ±0.12

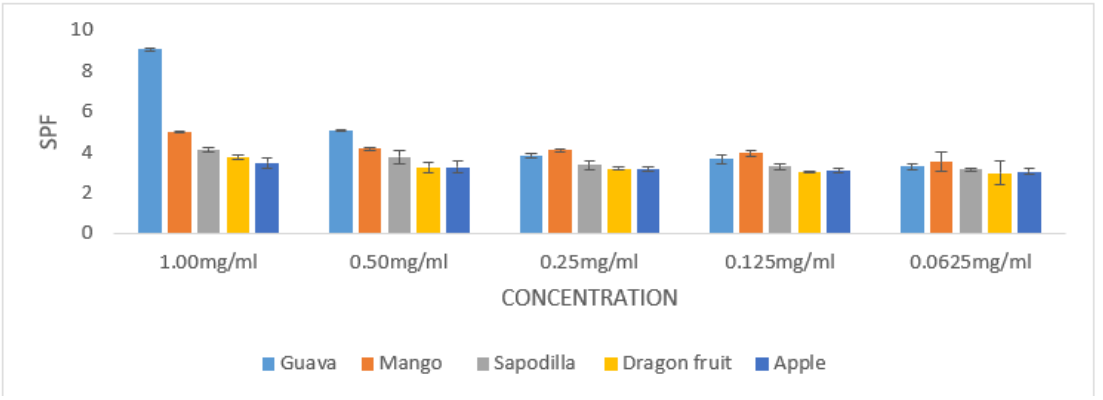

Table 6. SPF values of vegetables at different concentrations

Vegetable name	1.00mg/ml	0.50mg/ml	0.25mg/ml	0.125mg/ml	0.0625mg/ml
Ginger	5.01 ±0.05	4.02 ±0.08	2.96 ±0.33	2.76 ±0.12	2.68 ±0.43
Onion	5.42±0.15	4.53 ±0.55	2.95 ±0.46	2.63 ±0.25	2.59 ±0.50
Brinjal	4.87±0.22	3.94 ±0.76	3.47 ±0.27	3.07 ±0.15	2.80 ±0.32
Tomato	4.11 ±0.15	3.63 ±0.56	2.98 ±0.08	2.97 ±0.22	2.73 ±0.09
Sweet potato	4.56 ±0.33	3.82 ±0.44	3.33 ±0.22	2.79 ±0.37	2.73 ±0.10

3. Results

Total Phenolic Contents (TPC) Assay

By considering the relationship between absorbance and concentration, a linear regression equation with R2=0.9831 was derived from the gallic acid standard calibration curve. Table displays the milligrams of gallic acid equivalents (GAE) per gram of dry weight (mg GAE/g DW), which is the total phenolic content of the samples as evaluated at a concentration of 1 mg/ml. Mango, sapodilla, guava, dragon fruit, and apple had the highest TPC for fruit extracts. In contrast, ginger had the highest TPC for vegetable samples, followed by onion, brinjal, tomato, and sweet potato.

Antioxidant Activity (DPPH Free Radical Scavenging Assay)

To evaluate the antioxidant capacity of the chosen fruits and vegetables, DPPH radical levels were measured. For each concentration, the results (Table) demonstrated a noticeably lower

percentage of DPPH radical scavenging activity than the norm. When compared to other vegetable samples, torch ginger often showed a higher percentage of DPPH radical scavenging activity. Mangos had the highest scavenging activity (22.67%) at the maximum concentration (0.5 mg/ml), while water apples had the lowest scavenging activity (6.68%). The samples generally follow the pattern of rising percentage of DPPH radical scavenging activity with concentration, even though the order of highest to lowest percentage of DPPH radical scavenging activity varied for all concentrations.

SPF Determination of Plant Samples

The UVB zone, which spans from 290 to 320 nm, is where the plant samples should have a broad range of absorbance to effectively defend against UV-induced skin damage. Consequently, each sample was subjected to an in vitro sun protection factor (SPF) assessment at varying doses. The fruit sample's SPF values ranged from 11.05 (highest) to 2.98 (lowest) in Figure. The fruits' SPF values at 1 mg/ml were as follows: guava > mango > sapodilla > dragon fruit > apple. However, because the sequence of fruits from highest to lowest SPF values altered at each dose, this pattern was not closely followed starting at concentrations of 0.50 to 0.0625 mg/ml. The figure displays the SPF values for vegetable samples. At concentrations, 0.0625 to 0.2500 mg/ml, the SPF values for all samples were negligible, because they do not follow the trend in which onion is the highest and tomato is the lowest. All reported SPFs of each sample were significantly different ($p < 0.05$).

Correlation between SPF with concentration, SPF with TPC, and TPC with DPPH

SPF and concentration had a substantial regression value and significance ($r = 0.95$-0.99, $p < 0.05$), while SPF and TPC had a poor connection ($r = 0.02$, $p > 0.05$). TPC and the fruit samples' DPPH radical scavenging activity showed a moderate connection ($r = 0.46$, $p > 0.05$). Regression research revealed that the SPF value for tomato, sweet potato, ginger, onion, and brinjal in vegetable samples closely corresponds with the concentration ($r = 0.92$-0.99, $p < 0.05$). TPC and the vegetable samples' DPPH radical scavenging activity showed a moderate connection ($r = 0.44$, $p > 0.05$).

4. Discussion

SPF levels are classified as minimum when they fall between 2 and 12, moderate between 12 and 30, and high when they are ≥30 [30]. All of the study samples' SPF values fell into the low SPF group according to this grade. The findings indicated that natural chemicals found in sweet potatoes, tomatoes, brinjal, ginger, and onions can offer at least 50% UV protection. Out of all the plants in the current study, onions had the highest SPF rating. Onions contain phenols such apigenin and flavonoids, primarily flavonol and quercetin. Apigenin could hasten the reversal of UVB-induced CPD and showed an absorption spectrum in the UVB range. Similarly, quercetin increases antioxidant enzymes and has a photoprotective impact against UVA and UVB, efficiently scavenging ROS produced by intracellular UVB. Sections of the UV-A (315–400 nm) and UV-B (280–315 nm) spectra can be absorbed by anthocyanins, which are flavonoids. By scavenging ROS, anthocyanins in plants demonstrate photo-protective functions. As a result, these ingredients in onions might have helped them achieve their high SPF value by providing photoprotection against UV rays.

Guava showed the highest SPF of any fruit sample, with an SPF value of 11.05 at a concentration of 1 mg/ml. Guava contains phenolic compounds, specifically anthocyanin and ellagic acid. Ellagic acid inhibits UV-A-induced apoptosis, reactive oxygen species (ROS), malondialdehyde, and DNA damage. The photosynthetic apparatus is protected by anthocyanins from the harmful effects of photooxidative stress and excessive visible or UVB radiation. They are potent antioxidants and scavengers of reactive oxygen species, and they absorb both visible and ultraviolet light. While coumarins are absent from guava, flavonoids and tannins are present.

When the UV spectrum absorption profile is being evaluated, tannin can absorb UV radiation. In comparison to gallic acid, it has a significantly higher molar absorptivity coefficient and a broader wavelength range of absorption, which encompasses the full UVB range (280-315 nm). This implies that tannin might partially prevent UV rays from interacting with biological materials. Because coumarins increase the risk of photodermatitis, melanomas, and burns, they should not be used for extended periods of sun exposure. Because their inclusion in cosmetic compositions can cause hyperchromic spots on the skin after exposure to UV light, their absence is significant when characterizing plant extracts. Guava's high SPF rating can therefore be attributed to these characteristics. The addition of guava to a 7.5% 2-ethyl-hexyl methoxycinnamate cream formulation increased the cream's photoprotective capacity by 134%. This is because extract ingredients work in concert with manufactured sunscreens. Accordingly, this research showed that fewer synthetic filters could be used, product toxicity could be decreased, and the final cost of a sunscreen product could be decreased.

The presence of polyphenolic components such as flavonols, flavone, and isoflavones is responsible for torch ginger extract's exceptional antioxidant activity. This could account for the antioxidant activity and TPC values of torch ginger found in this investigation. Other than that, sweet potatoes exhibited inadequate antioxidant activity, with the lowest TPC among the samples. However, as demonstrated by tomatoes and brinjal, they had stronger antioxidant activity even though their TPC was lower than that of onions. It is possible to ascribe the antioxidant to substances other than phenolic compounds. According to one study, the high quantities of α-tocopherol, β-carotene, and ferulic acid in spinach and swamp cabbage were the cause of their strong antioxidant activity. Although tomatoes are the primary source of lycopene, they also include other significant antioxidants such as α-tocopherol and ascorbic acid. This could thus explain why, despite having a lower TPC value than onions, tomatoes exhibited higher antioxidant activity. The presence of polyphenols is not entirely responsible for their ability to scavenge free radicals. The presence of additional non-phenolic substances that react with the Folin-Ciocalteu reagent, such as vitamins, amino acids, organic acids, metal complexes, and inorganic acids, may be the cause of the antioxidant activity and cause an overestimation of TPC value. The link between phenolics' structure and antioxidant activity may also contribute to variances, as flavonoids are thought to be more potent antioxidants than phenolic acids.

There was a moderate association between TPC and DPPH ($r = 0.46$, $p > 0.05$) and a weak link between SPF and TPC ($r = 0.02$, $p > 0.05$), according to correlation studies between the two. Because the Folin-Ciocalteu assay only provided a rough estimate of the quantity of TPC in the samples, its polyphenols were not specifically credited with the free radical scavenging action. The moderate connection between TPC and DPPH could be explained by the fact that

TPC might not contain all of the antioxidants that could be present in an extract. Furthermore, because non-phenolic compounds react with the Folin-Ciocalteu reagent, their presence can lead to an overestimation of TPC. These substances include vitamins, ketones, aldehydes, amines, nucleotides, unsaturated fatty acids, thiols, proteins, amino acids, and carbohydrates. As a result, it is difficult to anticipate the fruits' antioxidant capability just based on their phenolic content only. Antioxidant activity can also be caused by non-phenolic compounds.

5. Conclusion

This study does not support the widely held notion that phenolic levels and their scavenging effects on DPPH are the cause of high SPF values. According to published research, a wide variety of chemical substances, including anthranilates, cinnamates, salicylates, benzophenones, and others, can filter UVA and UVB rays. Guava had the highest SPF value in this study, although its phenolic content and DPPH radical value were lower than those of torch ginger. In contrast, the photo-protective properties of other samples were comparatively low. Vegetable extract analysis shows a moderate association between TPC and SPF values, although all samples showed substantial correlations between TPC and antioxidant activity. There was no discernible relationship between TPC and DPPH or SPF and TPC among the fruit samples. Numerous factors, such as variations in the phenolic content and other non-phenolic chemicals, could be to blame for this. The results of this study demonstrated the potential of fruits and vegetables as sun protection agents, to be utilized as substitutes for the synthetic photoprotective agents already on the market, even though they have modest photo-protective qualities. These extracts can be employed in sunscreen compositions and may be more important in reducing the negative effects of UV radiation. The effectiveness and safety of the products to be utilized as an alternative photo-protective agent in sunscreen need to be further investigated. Determining the form in which the formulation will be stable and exhibit the optimal effects is also crucial.

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