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Determination of Sun Protection Factor (SPF) of Malaysian Fruit and Vegetable Extracts Using UV–Visible Spectroscopy

Emily Edna Anak Nigel[1], Nurul Shafiqah Mohamad Nasir[1], Amerul Afiq Aspa[2] and Nurhuda Manshoor[1,2]*

[1]Faculty of Pharmacy, Universiti Teknologi MARA Selangor, Kampus Puncak Alam, 42300 Selangor, Malaysia

[2]Atta-ur-Rahman Institute for Natural Products Discovery, Universiti Teknologi MARA Selangor, Kampus Puncak Alam, 42300 Selangor, Malaysia

*Corresponding author (e-mail: nurhuda15@uitm.edu.my)

Excessive exposure to ultraviolet (UV) radiation causes various skin problems, including skin cancer. Sunscreen, which contains UV filters, plays an important role in preventing sun damage. Sunscreen protects the skin from UV-induced damage as it absorbs or reflects UV radiation. Nevertheless, continuous exposure to chemical and physical UV filters can result in numerous adverse effects on the skin and the environment. An emphasis has been placed to incorporate natural components such as fruit and vegetable extracts in sunscreen due to their absorption in the UV region, and antioxidant properties. This study aims to evaluate the potential use of Malaysian fruits and vegetables as photoprotective agents by determining their sun protection factor (SPF), total phenolic contents, and antioxidant activity. Five fruit samples, guava, star fruit, sapodilla, dragon fruit, water apple, and five vegetable samples, tomato, brinjal, torch ginger, sweet potato, and onion were analysed for their SPF. The photoprotective activity was recorded using the spectrophotometric method and calculations were done using the Mansur equation. The phenolic content and antioxidant activity of all samples were assessed using the Folin-Ciocalteu method and DPPH radical scavenging assay, respectively. Among all fruit tested, the SPF of guava was found to be the highest, followed by star fruit, sapodilla, dragon fruit, and water apple. While among the vegetables, the onion had the highest SPF followed by torch ginger, brinjal, sweet potato, and tomato, at a concentration of 0.5-1.0 mg/ml. A strong correlation was found between SPF with concentration ($r = 0.95$-0.99, $p < 0.05$), a weak correlation between SPF with TPC ($r = 0.02$, $p > 0.05$), and a moderate correlation between TPC with DPPH ($r = 0.46$, $p > 0.05$). The study shows the possibility to incorporate several selected plant extracts into sunscreen in pharmaceutical preparations.

Keywords: SPF; plant extract; phenolic content; antioxidant activity; photoprotective agent

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Exposure to UV radiations (UVR) from sunlight is considered a major modifiable environmental risk factor for skin problems, including keratosis, sunburns, photoaging, induction of oxidative stress, malignant transformation, and cancer [1-3]. Established by their wavelengths, the ultraviolet (UV) spectrum of the radiation is categorised into UVA (320-400 nm), UVB (280-320 nm), and UVC (200-280 nm). Around 95% of the UVA and 5% of the UVB radiations can be found in the atmosphere, while no UVC radiation can penetrate the earth's atmosphere [4]. Both UVA and UVB can be absorbed by different cellular proteins present in skin cells, hence, exhibit significant effects on the skin health [5]. Despite only small percent present in the atmosphere, UVB accounts for most of the UVR damage on the skin. Exposure to UVR on the skin results in the activation of the cutaneous immune system, leading to an inflammatory response via different mechanisms, for example, production of UV photo-products, such as, cyclobutane-type pyrimidine dimers (CPD) and pyrimidine-pyrimidone, which play a role in skin carcinogenesis, and production of reactive oxygen species (ROS) [6,7]. Thus, primary skin disease prevention focuses on minimizing UVR exposure through sun protection behaviours. Sunscreen is regarded as a vital adjunct to other types of UVR radiation protection from sunlight. It is a key component of public health efforts for skin disease prevention [8].

Sunscreens are typically used to avoid the noxious effects of UV radiations. Recently, human's interest to incorporate plant extracts having antioxidant activity and the ability to absorb UV rays into sunscreens have considerably increased [9]. The effectiveness and quality of sunscreens are critically quantified by SPF. SPF value is defined as the ratio of the energy required to create a low erythema dosage (skin reddening or minor sunburn) with sunscreen usage, to the energy required to achieve the same reaction without sunscreen usage [10]. It is mainly against UVB radiation because

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it is measured as protection thought to have the highest incidence during the day, when people are exposed for a longer period [11,12]. Hence, sunscreen product is considered to be more effective in preventing sunburn when the SPF value is higher [13].

Sunscreens, both physical and chemical, are products with photoprotective properties that can help protect the skin by absorbing, scattering, or blocking carcinogenic and skin damaging UVR [14,15]. Chemical sunscreens that contain active ingredients such as avobenzone, benzophenone, sulisobenzones, and para-aminobenzoic acid (PABA) work by absorbing UV radiations, causing them to be excited to a higher-energy state. As a result of their return to the ground state, the absorbed energy is converted into longer, lower-energy wavelengths, such as infrared radiation, therefore producing heat [16]. Meanwhile, physical sunscreens formulated with titanium dioxide (TiO_2) and zinc oxide (ZnO) shield the skin from UV light by physically reflecting or scattering the incident radiation. A combination of physical and chemical sunscreens is said to be effective at blocking both UVA and UVB exposure [17].

While such UV filters provide UV protection, the extensive use of these in sunscreen products may lead to adverse effects to the skin in the case of continuous application over a long period. Some chemical incorporated into the products, such as benzophenone-3, have been linked to side effects, toxicity, and even ecological issues with frequent exposure [18]. Such synthetic chemicals may interact with cutaneous cells, generating skin reactions like contact dermatitis, photo-irritation, and photosensitivity [19]. These side effects are caused by oxidative DNA damage, either due to overproduction of reactive oxygen species (ROS) or potential systemic toxicity [20-22]. Apart from that, UV-filters pose a great threat towards the environment. The presence of oxybenzone, ZnO and TiO2 in the sea causes harm towards the ecological system [23]. Thus, there has been an interest in finding other potential alternative UV filters to be used in sunscreens that could potentially give the same UV protection as other standard sunscreens. Studies have been conducted in the search for natural new active compounds with UVR filtering ability, which are expected to be as effective and much safer [24].

The effectiveness of sunscreens is critically quantified by the sun protection factor (SPF). The higher the SPF, the more effective the product is in preventing sunburn. The presence of phenolic compounds including flavonoids and phenolic acids, give these plants their significant antioxidant activities and ability to absorb UV radiation [25]. Plant extracts with high antioxidants could provide protection against free radicals by inactivating ROS which is the main cause of skin damage due to UVR exposure and provide the ability to absorb UV radiation [26]. As such, in recent years, there has been a focus on the use of natural components such as extracts from fruits to aid in the filtering function of multifunctional sunscreen formulations due to their ability to promote photo-protection 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 are thought to be beneficial. This is due to the presence of phenolic chromophores in fruits and vegetables, which possess antioxidant properties and the UV protection [18].

Thus, the objective of this study was to determine SPF values of selected Malaysia fruits and vegetables, which are commonly used in everyday diet. Analyses was carried out to measure UV absorption capacity of five vegetables, onion (*Allium cepa*) brinjal (*Solanum melongena*) tomato (*Solanum lycopersicum*), sweet potato (*Ipomoea batatas*) and torch ginger (*Etlingera elatior*), and five fruits guava (*Psidium guajava*), star fruit (*Averrhoa carambola*), sapodilla (*Manilkara zapota*), dragon fruit (*Hylocereus polyrhizus*) and water apple (*Syzygium aqueum*). In addition, assays were conducted to determine the total phenolic content and antioxidant potential of above mentioned fruits and vegetables.

The findings from this study provide possibilities for plant extracts to be used as alternatives to UV filters in the formulation of sunscreen products that elicit effective UV protective ability and may have less potential for adverse effects. Moreover, the increasing demand for use of natural and safe ingredients from plants in many cosmetics or beauty products presents remarkable economic growth for many related sectors in the future. Therefore, the results obtained from the present study open a wide opportunity for further research and studies to be done in the development of innovative, safe plant-based cosmetics or beauty products from local plants.

EXPERIMENTAL

Chemicals and Materials

Methanol (RCL Labscan) was purchased from Merck, Malaysia. The ultra-pure water was purified at 18 MΩ cm by ELGA PURELAB® Option water purification system from Veolia Water Technologies, Paris, France. Folin-ciocalteu reagent, gallic acid, ascorbic acid, 2,2-Diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich. Sodium carbonate is a common regent available in the laboratory.

Five vegetable samples, onion, brinjal, tomatoes, orange-fleshed sweet potato, and torch ginger, and fruit samples, guava, star fruit, sapodilla, dragon fruit, and water apple were purchased from local supermarket and were collected based on similarities in maturity. The fruits were selected based on their uniform size, colour, and level of external ripeness.

Preparation of Plant Samples

Whole plant samples were washed under running water, then cut into smaller pieces of similar size. The plant materials were stored to frozen at -20°C for 3 days. The frozen samples were lyophilized in Labconco Freeze Dry System for 72 hours. The dried plant materials were then ground using Waring Commercial Blender into fine powders until fully homogenized and kept at 4°C in the refrigerator for future use.

For TPC and DPPH free radical scavenging assay, 1 g of the powdered dried plant materials were dissolved in 100 ml of 80% methanol. The mixtures were then stirred at 150 rpm using a magnetic stirrer for 1 hour before filtration using 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 uniformed environment. Acceptable repeatability for absorbance values is set at mean SD of not higher than 1 for all replicates.

SPF Determination of Plant Samples

Five grams from each ground powder was weighed with analytical balance and transferred into separate beakers. The plant materials were soaked in 100 ml of 80% methanol for 3 days at 4°C for 72 hours. The solutions were then individually stirred at 150 rpm using a magnetic stirrer for 1 hour before filtration using Whatman No. 1 filter paper to obtain a clear solution. Each filtrate was then diluted 50-fold to obtain a 1 mg/ml stock solution. From this, serial dilutions were performed to obtain different concentrations of samples (1, 0.50, 0.25, 0.125, and 0.0625 mg/ml) to be analysed for SPF. The absorbance of each solution was measured within the range of UVB wavelength (290–320 nm) with 5-nm increments using BMG Labtech SPECTROstar® Nano spectrophotometer and 80% methanol as blank. The SPF of each sample was determined using the methodology and equation provided by Mansur et al. [26]. The following Mansur equation was used to calculate the SPF:

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

where:

CF = *correction factor*
EE = *erythemogenic effect of radiation with wavelengths*
I = *solar intensity spectrum*
Abs (λ) = *spectrophotometric absorbance values at wavelength*

The relationship between the erythemogenic effect (EE) and the solar intensity spectrum (I) at each wavelength was determined by Sayre et al. [27] whereby the values of EE (λ) × I (λ) were stated to be constant at each wavelength as seen in Table 1.

Table 1. EE and I constants for the calculation of sun protection factor (SPF) [26].

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

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

Determination of Total Phenolic Content of Plant Samples

Determination of the total phenolic content of the samples was performed using the Folin-Ciocalteu method [28], with slight modification. For this assay, gallic acid was used as a standard. Briefly, 250 mg of dry gallic acid was dissolved in 1 ml extracting solvent (80% methanol), and then diluted to 500 ml volume with ultra-pure water to prepare for 0.5 mg/ml stock standard solution. Then different concentrations of working standards (0.01, 0.02, 0.03, 0.04, and 0.05 mg/ml) were prepared by diluting previously prepared gallic acid stock solution with ultra-pure water. The sample was prepared at 1mg/ml concentration. 100 µl of the sample solution was added to 750 µl Folin-Ciocalteu reagent (previously diluted 10-fold with ultra-pure water) in a test tube. The mixture was allowed to stand at room temperature for five minutes before adding 750 µl of 6% (w/v) sodium carbonate and mixed gently. After standing for 90 minutes at room temperature, the absorbance was read at 725 nm. The standard calibration curve of gallic acid (0.01-0.05 mg/ml) was plotted. The total phenolic contents were expressed as mg of gallic acid equivalent (mg GAE) per g dry weight (DW) of samples.

DPPH Free Radical Scavenging Assay of Plant Samples

The DPPH free radical scavenging assay was performed according to methods [29], with slight modification. For this assay, ascorbic acid was used as the standard reference. The samples were prepared in serial dilutions to obtain different concentrations (0.01562, 0.03123, 0.06250, 0.12500, 0.25000, and 0.50000 mg/ml). One mM DPPH solution was prepared by dissolving 5.0 mg DPPH in 100 mL methanol. Then, 25 µl of standard and each sample solution were added into a 96-well round bottom microplate. 200 µl of 1mM DPPH solution was mixed

into each well, and the mixtures were incubated for 30 minutes at room temperature in the dark. After 30 minutes incubation period, the absorbance of each sample and ascorbic acid was read at 517 nm. 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:

$$Scavenging\ activity\ (\%) = \left(1 - \frac{Absorbance\ of\ sample}{Absorbance\ of\ control}\right) \times 100\%$$

A 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 $p < 0.05$.

RESULTS

Total Phenolic Contents (TPC) Assay

A linear regression equation with R^2=0.9831 was obtained from the standard calibration curve of gallic acid (Figure 1) by taking into consideration the relationship between absorbance and concentration. The total phenolic content of the samples was determined at a concentration of 1 mg/ml and expressed as milligrams of gallic acid equivalents (GAE) per gram of dried weight (mg GAE/ g DW) as shown in Table 2. Figure 2 shows the highest TPC for fruit extracts was exhibited by star fruit, followed by sapodilla, guava, dragon fruit, and water apple, whereas in vegetable samples, torch ginger had the highest TPC followed by onion, brinjal, tomato, and sweet potato.

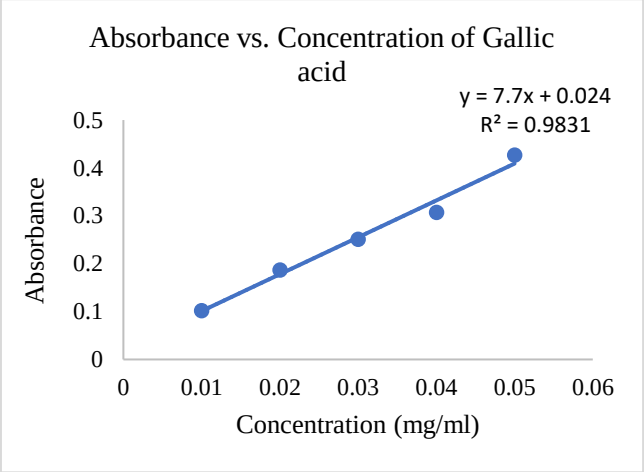

Figure 1. Gallic acid standard calibration curve.

Table 2. TPC of fruits and vegetables at 725 nm

Sample	Total Phenolic Content (mg GAE/g DW)
Guava	4.46
Star fruit	6.57
Sapodilla	6.43
Dragon fruit	3.03
Water apple	3.71
Onion	4.09
Brinjal	3.97
Sweet potato	2.40
Tomato	3.19
Torch ginger	16.92

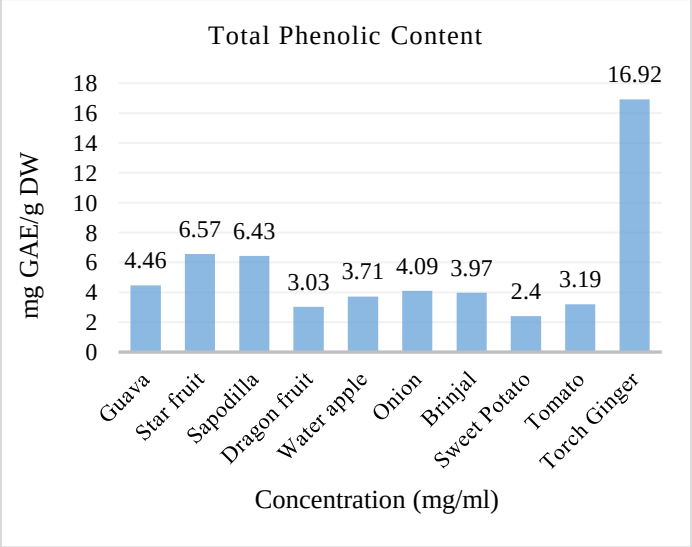

Figure 2. Total phenolic content (TPC) of plant samples

Antioxidant Activity (DPPH Free Radical Scavenging Assay)

DPPH radical values were assayed to assess the anti-oxidant potential of the selected fruits and vegetables. The results (Table 3) showed a significantly low percentage of DPPH radical scavenging activity compared to the standard for every concentration. Among the vegetable samples, torch ginger generally indicated a high percentage of DPPH radical scavenging activity compared to other samples (Figure 3). At the highest concentration (0.5 mg/ml), star fruit obtained the highest scavenging activity of 22.67% whereas water apple demonstrated the lowest scavenging activity of 6.68% (Figure 4). Although the order of highest to lowest percentage of DPPH radical scavenging activity among the samples varied for all concentrations, the samples overall follow the trend of increasing percentage of DPPH radical scavenging activity with concentration.

Table 3. Radical scavenging activity at different concentration

	Radical scavenging activity (%)					
Conc. (mg/ml)	0.5000	0.2500	0.1250	0.0625	0.0313	0.0156
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
Star fruit	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
Water apple	6.68	6.63	5.27	4.79	3.95	3.58
Torch ginger	42.28	25.37	10.12	9.06	8.34	5.70
Onion	13.93	12.47	9.11	6.62	3.76	2.40
Brinjal	14.29	9.97	6.11	3.44	0.88	0.64
Tomato	14.11	7.15	4.87	4.25	2.40	1.99
Sweet potato	12.19	5.85	4.60	2.33	2.17	1.89

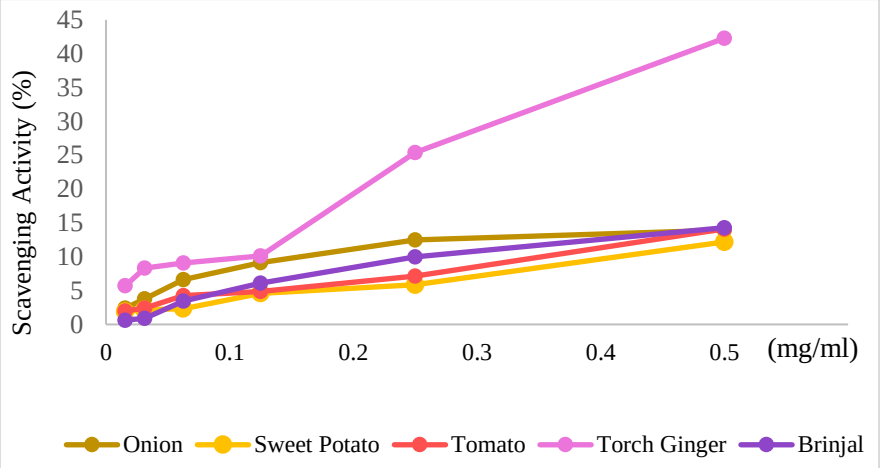

Figure 3. DPPH radical scavenging activity of vegetable extracts

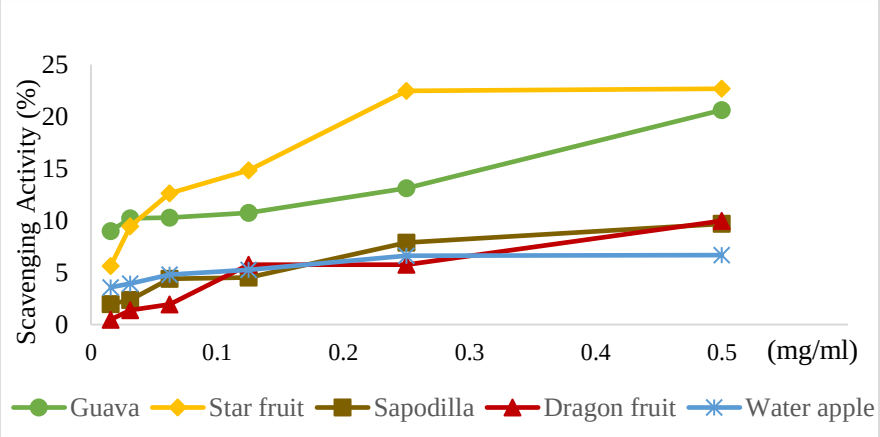

Figure 4. DPPH radical scavenging activity of fruit extracts

SPF Determination of Plant Samples

To provide effective protection against UV-induced skin damage, the plant samples should have a wide range of absorbance in the UVB region, which is between 290 nm to 320 nm. Therefore, in vitro sun protection factor (SPF) determination was conducted for each sample at different concentrations. In Figure 5, the SPF values of the fruit sample ranged from 11.05 (highest) to 2.98 (lowest). At 1 mg/ml, the SPF values of the fruits were in the decreasing order of guava > star fruit > sapodilla > dragon fruit > water apple. However, starting from concentrations of 0.50 to 0.0625 mg/ml, this pattern was not closely followed as the order of fruits from highest SPF value to lowest SPF values varied at each concentration. SPF values for vegetable samples are shown in Figure 6. 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 SPF of each sample were significantly different ($p < 0.05$).

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

The regression value and significance between SPF with concentration were strong ($r = 0.95$-0.99, $p < 0.05$), whereas the correlation of SPF with TPC ($r = 0.02$, $p > 0.05$) was weak. The correlation of TPC with DPPH radical scavenging activity of the fruit samples was moderate ($r = 0.46$, $p > 0.05$). Meanwhile, in vegetable samples, regression analysis showed the SPF value for onion, torch ginger, brinjal, sweet potato, and tomato strongly correlates with the concentration ($r = 0.92$-0.99, $p < 0.05$). The correlation of TPC with DPPH radical scavenging activity of the vegetable samples was moderate ($r = 0.44$, $p > 0.05$).

Table 4. SPF values at different concentration

	Sun Protection Factor				
Conc. (mg/ml)	1.00	0.50	0.25	0.125	0.0625
Guava	11.05 ±0.05	5.05 ±0.03	3.80 ±0.12	3.65 ±0.21	3.28 ±0.15
Star fruit	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
Water apple	3.46 ±0.23	3.27 ±0.26	3.16 ±0.05	3.09 ±0.09	3.05 ±0.12
Torch 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

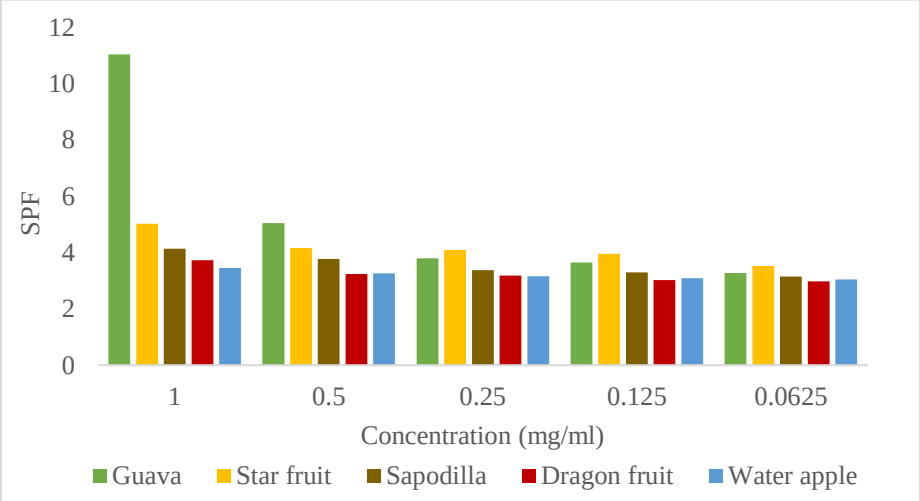

Figure 5. SPF values of fruit samples at different concentration

Figure 6: SPF values of vegetable samples at different concentrations

DISCUSSION

SPF values are considered high when SPF ≥30, moderate from 12-30, and minimal when they are ranging from 2–12 [30]. Based on this grading, the SPF values of all the study samples fall in the category of low SPF. The result showed that torch ginger, onion, brinjal, tomato, and sweet potato contain natural compounds that can provide UV blockage of at least 50%. In the present study, onion obtained the highest SPF value among other plants. Phenolics such as apigenin and flavonoids, mainly flavonol and quercetin were found in onion [31,32]. Apigenin presented an absorption spectrum in the UVB range and could accelerate the reversal of UVB-induced

CPD [33]. Comparably, quercetin provides a photoprotective effect against both UVA and UVB by increasing antioxidant enzymes and effectively scavenging intracellular UVB-induced ROS respectively [34,35]. Anthocyanins are flavonoids that can absorb sections of the UV-A (315–400 nm) and UV-B (280–315 nm) spectra [36]. Anthocyanins exhibit photoprotective roles in plants by acting as scavengers of ROS [37]. As such, these components in onions may have contributed to their photoprotective ability against UV radiation which gives its high SPF value.

The highest SPF obtained from the fruit samples was that of guava, which demonstrated an SPF value of 11.05 at 1 mg/ml concentration. Phenolic substances, which are ellagic acid and anthocyanin are present in guava [38]. Ellagic acid prevents DNA damage, malondialdehyde, reactive oxygen species (ROS), and apoptosis brought on by UV-A [39]. Anthocyanins shield the photosynthetic apparatus from the detrimental effects of excessive visible or UVB light as well as photooxidative stress. They absorb both visible and UV light and are strong antioxidants and scavengers of reactive oxygen species [40]. Guava also contains flavonoids and tannins, but an absence of coumarins [41]. Tannin is able to absorb UV light during an evaluation of the UV spectrum absorption profile. It has a substantially greater molar absorptivity coefficient and a wider wavelength range of absorption that includes the entire UVB range (280-315 nm) compared to gallic acid. This suggests that tannin may, to some extent, block UV photons from interacting with biological components [42]. Coumarins are contraindicated in prolonged exposure to the sun as there is a risk of photodermatitis, melanomas, and burns. This makes their absence crucial when characterising plant extracts as their presence in cosmetic formulations can induce hyperchromic patches on the skin after exposure to UV light. Hence, guava's high SPF value can be contributed to these properties it possesses. Guava supplementation in 7.5% 2-ethyl-hexyl methoxycinnamate cream formulation improved the photoprotective ability of the cream by 134%. It is due to the synergistic effect between extract components and synthetic sunscreens. As such, this finding revealed that it is possible to utilize fewer synthetic filters, reduce product toxicity, and lower the end cost of a sunscreen product [41].

The remarkable antioxidant activity of torch ginger extract is attributed to the presence of polyphenolic compounds such as flavonols, flavone, and isoflavanones [43]. This could explain the values for TPC, and antioxidant activity of torch ginger obtained in the present study. Otherwise, sweet potatoes in which the TPC was the lowest among other samples showed poor antioxidant activity. However, as seen in brinjal and tomato, although their TPC was lower than that of onion, their antioxidant activity was higher. The antioxidant can be attributed to other chemicals than phenolic compounds. A study showed that the high antioxidant activity of spinach and swamp cabbage was due to high levels of α-tocopherol, β-carotene, and ferulic acid [44]. Tomato is the main source of lycopene, but it also contains other important antioxidants such as ascorbic acid and α-tocopherol [45,46]. Thus, this could explain why tomatoes had high antioxidant activity than onions despite their lower TPC value. Free radical scavenging activity is not fully attributed to the presence of polyphenols [47]. The antioxidant activity could be due to the presence of other non-phenolic compounds such as vitamins, amino acids, organic acids, metal complexes, and inorganic acids that are reactive to Folin-Ciocalteu reagent, leading to overestimation of TPC measurement [48,49]. Additionally, variations may also be due in part, to the structure-antioxidant activity relationship of phenolics, whereby flavonoids are considered stronger antioxidants than those phenolic acids [50].

Correlation analyses between SPF with TPC and TPC with DPPH revealed a weak correlation between SPF with TPC ($r = 0.02$, $p > 0.05$) and a moderate correlation between TPC with DPPH ($r = 0.46$, $p > 0.05$). The free radical scavenging activity was not specially attributed to their polyphenols because the Folin-Ciocalteu assay only gave a rough estimation of the presence of TPC in the samples [47]. TPC may not necessarily include all of the anti-oxidants that may be present in an extract, which would explain the moderate correlation between TPC and DPPH [50]. Besides, the presence of non-phenolic substances (vitamins, ketones, aldehydes, amines, nucleotides, unsaturated fatty acids, thiols, proteins, amino acids, and carbohydrates) can cause overestimation of TPC as they are also reactive to the Folin-Ciocalteu reagent [51]. 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.

CONCLUSION

The conventional belief that high SPF value is due to their phenolic contents and their scavenging effects on DPPH is not demonstrated in this study. Literatures showed that there are many types of organic compounds that can filter either UVA or UVB (eg. Anthranilates, cinnamates, salicylates, benzophenones etc). In this study, guava showed the highest SPF value, but relatively low phenolic content and DPPH radical value as compared to torch ginger. whereas other samples showed the relatively low photoprotective property. Analysis of vegetable extracts indicates a weak correlation between TPC and SPF values, however, significant correlations were observed between TPC and antioxidant activity of all samples. Among the fruit samples, no significant correlation between SPF and TPC as well as TPC and DPPH. This could be due to various reasons including variation in phenolic content, and other non-phenolic compounds. Despite having low photoprotection properties, the findings of this study showed the potential of Malaysian fruits and vegetables as sun protection agents, to be used as alternatives to the

currently available synthetic photoprotective agent. These extracts could be of greater significance in preventing the harmful effects of UV radiation and can be used in sunscreen formulations. Further research is to establish the efficacy and safety of the products to be used as an alternative photoprotective agent in sunscreen. It is also important to find out in which form the formulation will be stable and shows the best effects.

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