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A SPECTROSCOPIC IN-VITRO METHOD FOR DETERMINING THE SUN PRODUCTION FACTOR (SPF)AND PHYSICAL PROPERTIES OF MARKETED SUNSCREEN FORMULATIONS

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ABSTRACT:
Applying sunscreen or lotion protects the skin from harmful ultraviolet rays, reducing the risk of sun exposure-related diseases such as skin cancer. The increasing awareness of these dangers has driven a demand for testing sunscreen formulations. This research utilizes ultraviolet-visible spectroscopy to measure the Sun Protection Factor (SPF) and the UVA/UVB ratio for several different sunscreens from various brands. The SPF values of the tested products range from 15 to 100. The spectroscopy method is simple, fast, and accurate in determining SPF values in a controlled environment. Notably, some sunscreen formulations in the Kurdistan market display SPF values 62.5% below the label amount, indicating that many people in Kurdistan may be using sunscreens with less protection than they believe. Besides evaluating SPF, the research also examines the tested sunscreens' optical band gap and refractive index.

KEYWORDS: SUNSCREEN, IN VİTRO SPF, UV-VİS SPECTROMETER.

1. INTRODUCTION

The sun emits ultraviolet (UV) rays, specifically UVA and UVB, a portion of the electromagnetic range. UVA wavelengths extend from 400 to 320 nm, while UVB wavelengths extend from 320 to 290 nm (D'Orazio *et al*., 2013). UVA beams can enter both the upper layer of skin (the epidermis) and the lower layer (the dermis), frequently harming keratinocytes within the epidermis where skin cancer ordinarily starts. Although UVB rays don't enter the dermis, they are more penetrating due to their shorter wavelengths. Both types of UV rays can harm humans, causing sunburns, skin cancer, and other skin damage (Cadet & Douki, 2018); (Sander *et al*., 2020) ; (Tang *et al*., 2024). More than 1 million people in the United States are diagnosed with skin cancer each year (Prakash *et al*., 2015). To mitigate these risks, the use of sunscreen is commended.

Sunscreen secures the skin by absorbing or reflecting harmful UV beams, preventing them from coming to it. Utilizing sunscreen during sun exposure can significantly reduce the risk of skin cell damage and cancer development. Sunscreens are designed to protect the skin from the harmful effects of the sun, including immediate effects like erythema (sunburn) and long-term effects like actinic photo-aging and skin cancers.

The efficacy of sunscreen against UVB in humans is evaluated based on the minimum erythemal dose (MED). This test involves applying sunscreen to a volunteer's skin, exposing protected and unprotected skin to UV rays from a solar simulator, and determining the doses necessary to cause minimal sunburn on each volunteer's protected and unprotected skin (MEDp and MEDu). The individual SPF is the ratio of these two doses (SPF = MEDp/MEDu). The product's SPF is the average of individual SPFs from multiple volunteers. Sunscreens are formulated to contain appropriate amounts of UV-absorbing substances. They are assigned sun protection factors (SPF) to indicate their level of protection against UV radiation (Sabzevari *et al*., 2021).

These measures are crucial for individuals' well-being, as exposure to UV radiation, particularly UVB, can lead to various health issues, including sunburn, skin cancer, immune system deficiencies, and eye damage (Behar-Cohen *et al*., 2013). Microfine metal oxides like zinc oxide and titanium dioxide have effectively protected against UV rays by activating electrons within their atomic structure and absorbing UV radiation (Singh & Nanda, 2014; Threes Smijs, 2011). Consequently, zinc oxide and titanium dioxide have become significant subjects of scientific research. Nanotechnology, which involves manipulating particles at the atomic and molecular levels, is already present in various products and is expected to become even more important (Fonseca & Rafaela, 2013).

Historically, SPF evaluation has been performed in vivo on human volunteers (Bendová *et al*., 2007), following the COLIPA method, is based on the minimal erythemal dose related primarily to the biological effects of UVB irradiation (Honari & Maibach, 2017). The effectiveness of sunscreen formulations and factors influencing sun protection were studied (Portilho *et al*., 2023). The actual SPF values of products body creams and lotions were calculated using Mansur's formula (Mbanga *et al*., 2014); (Andrea *et al*., 2022; Omar & Abdulrahman, 2015). Evaluation studies of the sunscreen cream like diffusion studies, and estimation of SPF were also carried out (Cedrick *et al*.), 2024) Some articles comprehensively review existing sunscreen testing standards, discussing challenges and opportunities in improving analytical methods (Zou *et al*., 2022). A key objective was to examine both in vitro and in vivo SPF values of natural 90% pterostilbene extracted from Pterocarpus marsupium (Majeed *et al*., 2020). The study further explores the comparison of UVA-PF measurement protocols, highlighting advancements in nanotechnology-based sunscreens, which enhance UV protection through improved safety and efficacy (Chavda *et al*., 2023).

This research aimed to determine the in vitro SPF values of several commercially available sunscreen markets in Erbil City by UV-Vis spectroscopy and compare the results with the label-claimed SPF values. Additionally, the study examined the UVA and UVB ratio, energy gap, and refractive index of these sunscreens.

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2. MATERIAL METHODS

The Materials And Specimens.

Analytical-grade ethanol (98%) was purchased from Fluka. Commercially available sunscreen formulations with SPF values of 15, 50, 60, 80, and 100 from various brands were acquired from pharmacies and other stores that sell these products.

The Instruments

UV measurements were carried out utilizing the Shimadzu UV-Vis mini 1240 spectrophotometer as shown in Figure 1(a). All samples were measured in 1 cm quartz cells.

Methods Of Sample Preparation

1.0 g of all samples were weighed, transferred to a 100 mL volumetric flask, diluted to volume with ethanol, followed by ultrasonication for 5 min, and then filtered through a cotton filter, rejecting the ten first mL. A 5.0 mL aliquot was transferred to a 50 mL volumetric flask and diluted to volume with ethanol. Then a 5.0 mL aliquot was transferred to a 25 mL volumetric flask and the volume was completed with ethanol. The final solutions were sealed in quartz vials.

UV Absorption Measurement And Physical Properties

After preparation, all samples were scanned at wavelengths between 200 and 400 nm. The Mansur equation was applied to calculate the SPF values at the end of all measurements.

After preparing, the sample solution's absorption spectrum was measured in the 200 to 400 nm region using a 1 cm quartz cell and ethanol as a blank. The absorption values were acquired in the range of 290 to 320 and every 5 nm, The samples' SPF was determined using the Mansur equation. (Mishra *et al*., 2011).

$$SPF = CF \times \sum_{290}^{320} \mathrm{EE}(\lambda) \times \mathrm{I}(\lambda) \times \mathrm{Abs}(\lambda) \ldots\ldots\ldots\ldots (1)$$

Here, CF = correction factor (10), EE (λ) = arrhythmogenic effect of radiation with wavelength λ, and Abs (λ) =spectrophotometric absorbance values at wavelength λ. The values of EE (λ) x I are constants. They were determined by Sayre et al and are given in Table 1(Das *et al*., 2017).

Table 1. Values of EE (λ) x I at a different wavelength

Wavelength	Value of EE x I
290	0.0150
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0837
320	0.0180

The UVA/UVB protection ratio is an essential metric for evaluating a sun protection product's ability to protect against UVA and UVB radiation. Our research testing service can reliably analyze the UVA to UVB protection ratios of various sunscreens and sunblocks. We carefully evaluate those products' UVA and UVB filters for their relative effectiveness. With this information, beauty firms may confidently sell their sun protection products, giving customers reliable evidence of their products' balanced protection against UVA and UVB rays. Recognizing the UVA to UVB protection ratio allows consumers to make informed decisions when choosing sun protection solutions that meet their needs. This knowledge empowers them to choose products that provide optimal protection against UVA-induced premature aging and UVB-induced sunburn and skin damage. The optimal protection ratio to assure adequate protection in both regions of the UV spectrum is about 1:1 UVA to UVB. To offer optimum protection, you want an SPF factor no more than three times higher than the UVA protection factor.

Even with these benefits, there are potential drawbacks to using products with extremely high SPFs. After SPF 50, which blocks around 98 percent of UVB rays, the increase in UVB protection is minimal. Additionally, while UVA protection is crucial as it contributes to skin aging and may even cause skin cancers, SPFs primarily measure UVB protection. People who use high-SPF sunscreens might not get sunburned, since UVB is the main cause, but they may still be exposed to large amounts of skin-damaging radiation if the sunscreen lacks UVA-screening ingredients. The relative index UVA to UVB is calculated in equation (2):

$$\frac{\alpha UVA}{\alpha UVB} = \frac{\int_{320nm}^{400nm} A\lambda . d\lambda}{\int_{290nm}^{320nm} A\lambda . d\lambda} \ldots\ldots\ldots . . (2)$$

The refractive index of the samples was measured using a refractometer setup, as shown in Figure 1(b). The refractometer is an optical instrument to acquire a reflection spectrum over a visible wavelength range. It consists of two arms, or telescopes, whose axes lie in one plane. One telescope is stationary, while the other rotates around a central axis that intersects the two telescope axes perpendicularly. The angle between the two telescopes is read on a 360-degree graduated circle. A light source (He-Ne laser with a wavelength of 632.8 nm) provides the light for measurements. The light is depolarized, and a rotating polarizer allows the polarization of light to be selected. Another polarizer called the analyzer, is placed before the detector. The output from the PIN silicon detector is connected to a digital meter. This instrument was used to determine the variation of relative reflectance versus the angle of incidence, which was then used to determine the refractive index of the sunscreens.

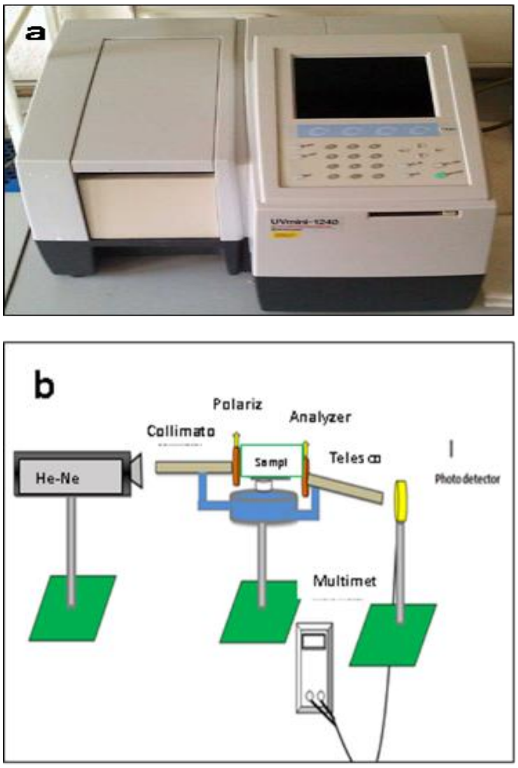

Figure 1: (a) Schematic of UV-visible spectroscopy setup and (b) Refractometer experimental setup used to measure the refractive index of samples.

3. CALCULATION AND RESULTS

Calculate SPF And UVA/UVB Ratio Of Sunscreens

SPF 15 (Sample S1)

Figure 2 demonstrates the absorbance spectrum for the S1 sample against wavelength. It clarifies that the high absorbance peaks occurred in the 300 nm and 200 UV regions. The SPF of sunscreens and relative indexes were calculated utilizing equations (1), and (2). This sample has a low SPF of 12 and a ratio of UVA to UVB 0.949, which sets it apart from the other samples

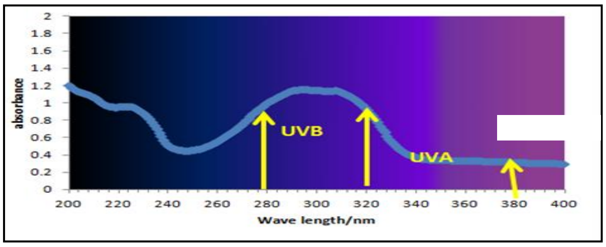

Figure 2: The absorbance spectrum for the S1 sample.

SPF 50 (Samples S2, S3, S4, and S5)

Figure 3 demonstrates the absorbance spectra for the S2, S3, S4, and S5 samples. The calculated SPF factors were 36.86, 43.84, 50.76, and 49.76. The calculated relative index UVA/UVB ratios are 2.715, 2.620, 2.469, and 2.470 respectively. they show that each sample's relative ratio is roughly equal.

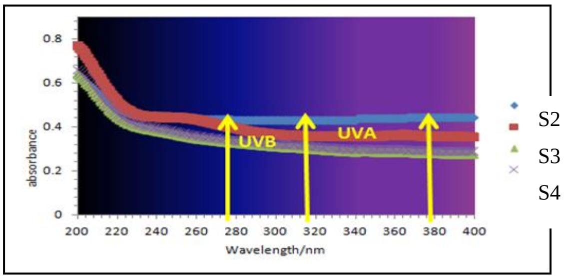

Figure 3: The absorbance spectra for S2, S3, S4, and S5 samples.

Spf 60 (Sample S6)

Figure 4 demonstrates the absorbance spectrum of S6. It indicates that the S6 sample has a high ultraviolet absorbance. The calculated SPF factor was 50.25. The calculated relative indexes UVA/UVB ratio was 0.775 indicating that the sample has a lower SPF than the label SPF.

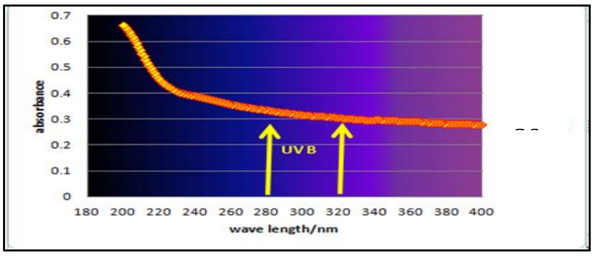

Figure 4: The absorbance spectrum for the S6 sample.

Spf 80 (Sample S7)

Figure 5 demonstrates the absorbance spectrum versus wavelength. Based on this figure, it was determined that sample S2 had a high absorbance in the UVB and UVA regions. The calculated SPF factor was 60 lower than what is stated on the label. The relative index of UVA to UVB ratio is 1.88.

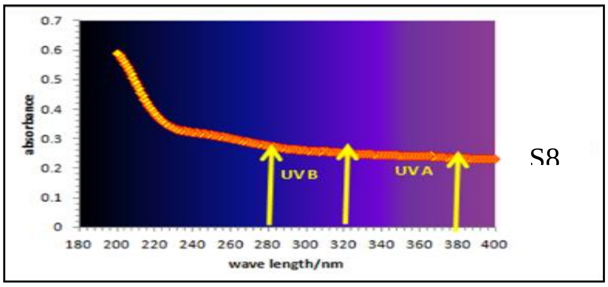

Figure 5: The absorbance spectrum for the S7 sample.

Spf 100 (Sample S8)

Figure 6 demonstrates the absorbance spectrum as a function of wavelength. It clarifies that the S8 sample has a very low absorbance of 0.25 for UVA and UVB regions. The computed SPF of this sample is very low at 80 compared with the label SPF factor is 100. The relative UVA / UVB ratio is 2.48.

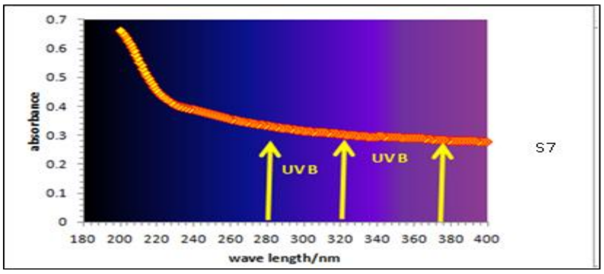

Figure 6: The absorbance spectrum for the S8 sample.

4. DISCUSSIONS

The SPF And UVA/UVB Ratio Of Sunscreens

The Spectral absorption of sunscreens S1, S2, S3, S4, S5 S6, S7, and S8 samples are presented in Figures 2, 3, 4, 5, and 6 respectively. The investigation of spectra designated as products for UVA and UVB protection. Since UVA radiation is in the range 320- 400 nm and UVB in the 290-320 nm range it is obvious from the given results that sunscreen S1 gave good results, since they showed absorption peaks, both in UVA and UVB region, nearly equal to 1. Product S1 has one good pronounced peak in the UVA range and is less pronounced in UVB in contrast, The other samples did not show absorption in the UVA and UVB spectrum. Table 2 indicates the computed value and the labels SPF with relative index UVA/UVB ratio for S1, S2, S3, S4, S5, S6, S7, and S8 samples. The results showed that 25% of the analyzed samples closely matched the labeled SPF, 12.5% had SPF values higher than labeled, and 62.5% had SPF values lower than labeled.

The UVA/UVB ratio helps determine if a sunscreen offers broad-spectrum protection, effectively shielding against both types of rays. Broad-spectrum sunscreens reduce the risks of both immediate sunburn (from UVB) and long-term aging or cancer risk (from UVA). The ratio is particularly relevant in ensuring that UVA protection is not neglected in formulations. Sunscreens with a high SPF often primarily target UVB protection (since SPF mainly measures UVB effectiveness). However, without adequate UVA protection, users may be at risk for photoaging and deeper skin damage. By ensuring a balanced UVA/UVB ratio, sunscreens provide comprehensive protection. In a standard defined by dermatology and photobiology experts, a UVA/UVB ratio of around 1/3 is often used as a guideline to balance the potential damage from both types of radiation. This ratio attempts to limit UVA exposure while still allowing some level of UVB for benefits like Vitamin D production. the exceeds our results of UVA/UVB ratio from this standard, primarily due to utilizing the artificial light source in the UV-spectrometer device.

Table 2: The labels and computed SPF with relative index ratio of samples.

Samples		**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
SPF	**Label**	**15**	**50**	**50**	**50**	**50**	**60**	**80**	**100**
	computed	**12**	**36.86**	**43.84**	**50.76**	**49.76**	**50.25**	**65**	**60**
Computed relative index UVA/UVB ratio		**0.949**	**2.715**	**2.620**	**2.469**	**2.470**	**0.755**	**1.88**	**2.48**

Figure 7 illustrates the larger discrepancies between label and computed SPF values for branded sunscreens. The results demonstrated that the SPF of sunscreen products on the market is higher than real compared to SPF computations, especially in S2, S7, and S8 samples. The relative index UVA/UVB ratio of samples is less than 3. Numerous clinical studies showed that well-balanced sunscreen, with an SPF to UVA ratio ≤ 3, provides the most effective protection against pigmentation (especially on dark skin), DNA damage, UV-induced skin immunosuppression, and photodermatoses it gives clear evidence that the SPF value alone is not sufficient to evaluate the efficacy of sunscreen. A UV level of 2 or below is considered low risk, and sun protection is not generally considered crucial. However, when the UV Index reaches 3 or above (Moderate), sun protection is recommended (Kollias *et al*., 2011). This means a high-protection, broad-spectrum sunscreen should be worn 365 days a year. Even on those days you're just running errands or going to work.

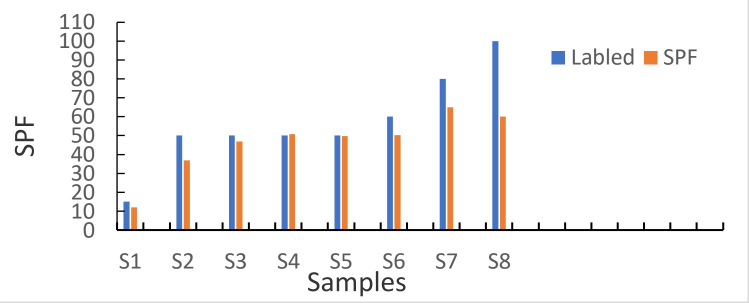

Figure 7: Differences between the label and calculated SPF values against samples.

The comparison of calculated percentage protection for estimated and labeled SPF factors is shown in Table 3. This relationship(100-100/SPF) was used to estimate percentage protection SPF factors. The findings showed that the estimated percentage of protection SPF factors is 25% closely matched, while 75% is low compared to the label products in stores and markets. For this reason, the recommendation for Physicians (pharmacists) is to avoid not branded companies that manufacture sun products and evidence the patients and quality controls in the Kurdistan region check them before approving these cosmetic and sun products.

There are several recommendations for physicians and pharmacists who believe that store-bought sunscreens are generally sufficient for patients. While many over-the-counter (OTC) sunscreens offer adequate protection, healthcare providers can guide patients in making informed choices based on individual needs. Here are some recommendations to enhance the effectiveness of recommending OTC sunscreens: *(i)* Emphasize the importance of broad-spectrum sunscreens that protect against UVA and UVB rays. *(ii)*Recommend sunscreens with an SPF of at least 30, as they block around 97% of UVB rays. For patients with fair skin or higher sun sensitivity, suggest an SPF of 50 or above. By providing these additional tips, physicians and pharmacists can help patients use store-bought sunscreens more effectively, ensuring they get the best protection.

Table 3: Estimated and label percentage protection of SPF factors for sun products

Samples&	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
SPF	**15**	**50**	**50**	**50**	**50**	**60**	**80**	**100**
Label percentage %	93.33	98	98	98	98	98.33	98.75	99
Estimated percentage %	91.66	97.28	97.71	98	97.99	98	98.46	98.33

The Energy Gap Of Sunscreens.

The energy gap in sunscreens refers to the wavelengths of light that the active ingredients of sunscreens can absorb to protect the skin from harmful ultraviolet (UV) radiation. Sunscreens typically contain organic or inorganic compounds that absorb UV light, converting it into less harmful energy, such as heat, it prevents the UV radiation from penetrating the skin and causing damage. Figure 13 illustrates the absorbance spectrum for the samples. The collected data were utilized to determine the band gap energy of the sunscreens. Tauc plots were used to calculate the energy gap of samples. There are many methods for calculating the energy gap, and the subsequent conventional relationship for semiconductor near-edge optical absorption(Haryński *et al*., 2022):

$$\alpha h\nu = A(h\nu - E_g)^n \dots\dots\dots\dots(3)$$

Where A is a constant, Eg is the material band gap, and n is a quantity equal to 1/2 for a direct band gap and 2 for an indirect band gap compound. Plotting $(\alpha h\upsilon)^2$ vs. hυ yields the energy band gap from absorption spectra. The band gap energy is calculated by extrapolating the straight line to the $(\alpha h\upsilon)^2 = 0$ axis. Figure 8 shows the calculated direct band gap values for all sunscreen samples. The data is tabulated in Table 4. These findings indicated that samples S2, S3, S5, and S6 have a maximum absorption for UV spectrum at corresponding wavelengths 353 nm, 339 nm, 371 nm, and 316 nm, while the samples S1, S4, S7, and S8 have high absorption at corresponding wavelengths 424 nm,454 nm, 402 nm, and (476, 576 nm) that lays the visible spectrum radiation. According to U.S. Food and Drug Administration (FDA) rules, to be labeled as broad spectrum, a product must have a critical wavelength of at least 370 nm, meaning 90 percent of the product's total absorbance must be at or above this value when measuring from 290 to 400 nm.

The energy gap of a sunscreen typically refers to the energy range within which sunscreen molecules can absorb ultraviolet (UV) radiation effectively, preventing it from penetrating the skin and causing damage. Sunscreens primarily absorb UV radiation in the UVA (320–400 nm) and UVB (290–320 nm) ranges to protect skin from sunburn, premature aging, and skin cancer. When UV photons hit these molecules, they provide just enough energy to bridge this energy gap, causing the molecules to absorb the UV radiation and enter an excited state instead of allowing the energy to reach the skin. Sunscreens are formulated to maintain the stability of the energy gap, as repeated exposure to UV light can degrade certain molecules, reducing their effectiveness. Stabilizers and additional antioxidants are often added to formulas to preserve this energy gap and ensure prolonged protection.

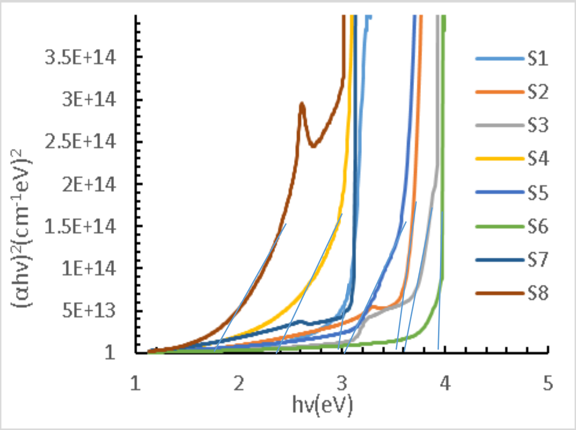

Figure 8: The band gap energy (Eg) of the samples.

Table 4: Energy gap (Eg) for S1, S2, S3, S4, S5, S6, S6, and S7 of Sunscreens.

SPF	SPF15	SPF50				SPF60	SPF80	SPF100
samples	S1	S2	S3	S4	S5	S6	S7	S8
Energy gap/eV	2.92	3.52	3.65	2.73	3.34	3.92	3.08	2.6 2.15

The Refractive Index Of Sunscreens

When the light incident on the surface of a dielectric matter (sunscreen) a portion of incident light is reflected and the other transmitted in the materials. The reflected part of the incident light depends on (*i*) the angle of the incident and (*ii*) the polarization direction of the incident light. The function that describes the reflection of the light polarized parallel as perpendicular to the plane of the incident is called the Fresnel equation.

$$\mathrm{r} = \frac{\mathrm{ni}\cos\theta i - \mathrm{nt}\cos\theta t}{\mathrm{ni}\cos\theta i + \mathrm{nt}\cos\theta t} \dots\dots\dots(4)$$

Where ni and nt are the refractive indices of the two media. The θi and θt are the incident and transmitted angles. The variation of reflectance for the polarization beam parallel to the plan of the incident with the angle of the incident is shown in Figure 9. This illustrates how the reflectance changes with angle incident and how the Brewster angle is determined, it's observed that for the lower angle, reflectance is a constant change, that it's decreased and approaches zero at a certain angle called Brewster angle which equals 65 for S1. The reflected light is polarized perpendicular to plane incidence at the Brewster angle. The transmitted ray contains all the parallel components. Brewster angle(θi) depends on the indices of the refraction of the incident medium air (n_o) and the reflecting medium glass(n_g)which are given by:

$$\tan\theta i = \frac{ng}{no} \dots\dots\dots\dots(5)$$

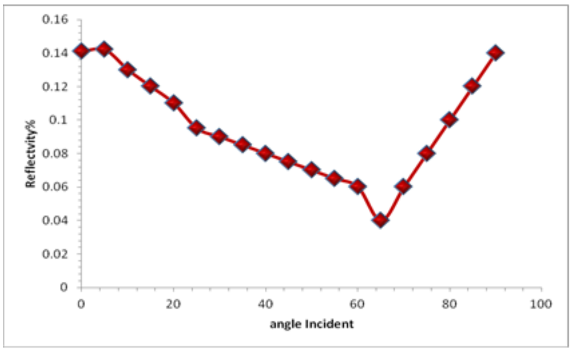

Figure 9: The reflectance (R) for parallel polarization versus angle incident of the S1 sample

Table 5 shows the refractive index for S1, S2, S3, S4, S5, S6, S7, and S8. Sunscreens sample. Sample S2 has a low refractive index of 1.064; in contrast, S3 and S4 have higher refractive indexes of 2.142 and 2.144. These finding indicates that the S2 sunscreen is more transparent than other sunscreen samples, and has a greater extent of a UV radiation beam. The refractive index affects how visible sunscreen appears on the skin. For mineral-based sunscreens (like those with TiO_2 or ZnO), the goal is to create a product that provides effective UV protection while remaining transparent. By optimizing the refractive index of the ingredients, manufacturers can minimize the whitening effect that occurs when light reflects off the particles, making the sunscreen appear more transparent and cosmetically acceptable. Sunscreens often contain ingredients like titanium dioxide (TiO_2) and zinc oxide (ZnO) that scatter and absorb UV light. The refractive index of these particles influences how effectively they scatter light, enhancing the sunscreen's ability to block harmful UV radiation. A higher refractive index in these particles can improve their scattering efficiency, particularly in the UV range, contributing to better protection.

The more transparent in terms of refractive index, its components are designed to minimize the scattering and reflection of visible light, allowing more light to pass through the product. The refractive index measures how much a material bends or refracts, light as it passes through it. The closer the refractive index of the sunscreen is to the refractive index of the skin (around 1.4-1.5), the more light can pass through without being noticeably reflected or scattered. This similarity results in less visible residue and gives the sunscreen a more "invisible" or transparent look when applied. Traditional sunscreens often use larger particles or ingredients that have a higher refractive index, leading to a "white cast" or visible layer on the skin. Transparent sunscreens may use smaller particles, such as nano-sized zinc oxide or titanium dioxide, which tend to have a refractive index closer to that of skin and thus blend more seamlessly. People often prefer more transparent sunscreens, especially for everyday use, as they avoid the chalky or greasy look some sunscreens can have, especially on darker skin tones.

Additionally, the refractive index of ingredients contributes to the SPF by enhancing the scattering and absorption properties. An increased refractive index can boost the SPF by improving how UV light is managed by the sunscreen film on the skin. The refractive index also plays a role in ensuring that the sunscreen formulation remains stable and homogenous. Differences in refractive index between ingredients can sometimes lead to phase separation, reducing the product's effectiveness and appearance. Sunscreen formulations are often designed to balance the refractive index between the active ingredients and the base to maintain a stable and consistent mixture.

Table 5: Refractive index for S1, S2, S3, S4, S5, S6, S7, and S8 samples.

SPF	**SPF15**	**SPF50**				**SPF60**	**SPF80**	**SPF100**
Samples	S1	S2	S3	S4	S5	S6	S7	S8
Refractive index	2.1	1.064	2.142	2.144	1.648	1.955, 1.351	1.954	1.412

CONCLUSION

The UV spectrophotometry method is proposed for the in vitro determination of SPF values and physical properties in cosmetic formulations, particularly sunscreens. This method is simple, fast, and cost-effective, utilizing inexpensive reagents. It measures the spectral transmittance and absorbance of sunscreens in the UV region. The resulting spectral absorbance data predict in vitro SPF values based on standard erythema and solar exposure data. In this study, the calculated SPF values for several sunscreen formulations available in Kurdistan were compared with their labeled SPF values. The results showed that 25% of the analyzed samples closely matched the labeled SPF, 12.5% had SPF values higher than labeled, and 62.5% had SPF values lower than labeled. These findings suggest that a significant proportion of sunscreens used in Kurdistan may offer less protection than claimed, possibly due to the lower cost of these products. Additionally, the UVA/UVB ratio was calculated for all samples, revealing values below 3. This ratio is essential in determining whether sunscreen provides broad-spectrum protection, effectively shielding against UVA and UVB radiation. Broad-spectrum sunscreens help reduce the risk of immediate sunburn (from UVB rays) and long-term skin aging and cancer (from UVA rays). The study also evaluated the energy gap of the sunscreen samples, showing that some exhibited high absorption in the UV spectrum (<400 nm), others absorbed more in the visible spectrum (>400 nm). These wavelengths correspond to the active ingredients in sunscreens, which absorb and protect the skin from harmful UV radiation. The percentage protection factors of products were also compared. The estimated percentage protection SPF factors of tested products is low. A refractive index of products was investigated. The finding was close to one suggesting a transparent appearance and the highest refractive indexes observed were 2.142 for sample S3 and 2.144 for sample S4. This parameter contributes to the SPF by enhancing the scattering and absorption properties and is crucial in ensuring that the sunscreen formulation remains stable and homogenous. Overall, the proposed UV spectrophotometry method proves to be an effective and efficient way to assess SPF values in sunscreen products. These findings hold significant public health implications, particularly given the discrepancies between labeled and actual SPF values.

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