

Determination of the Sun Protection Factor of Red Ochre, various Namibian Seed Oils, and the Subsequent Development of a Lip Balm

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Abstract

The research aim was to formulate a novel lip balm, using natural products from Namibia. Samples were formulated containing red ochre at different concentrations in either a petroleum jelly base or a zinc oxide (15%) ointment base and assessed for Sun Protection Factor (SPF) activity. The SPF absorbance values of various Namibian seed oils such as ximenia, marula, Kalahari melon, and baobab oil were also determined by UV spectrophotometry. The absorbance values were recorded and substituted into the Mansur equation to calculate the SPF of each sample. The SPF of the standards, zinc oxide ointment British Pharmacopoeia (BP) base and petroleum jelly were 24.0 and 0.6 respectively. The sample with 5% red ochre in petroleum jelly had an SPF of 1.6 and the sample with 10% red ochre in petroleum jelly had an SPF of 3.4. The sample with 20% red ochre in petroleum jelly had an SPF of 12.7, while the sample with 50% red ochre in petroleum jelly had an SPF of 13.2. The 10% red ochre in zinc ointment BP base had an SPF of 11.4, while the 20% red ochre in zinc ointment BP base had an SPF of 28.7. Ximenia oil had the highest SPF of 11.5. Marula oil had an SPF of 0.5, Kalahari melon oil 2.9, and baobab oil 2.7. Therefore, the optimal formulation to use was 20% red ochre and 20% ximenia oil in a zinc ointment BP base.

1 Introduction

The importance of protection from sunlight has unfortunately not been given a high priority in our busy lifestyles. The lack of protection of the skin, hair, eyes, and the overall human body from prolonged UV (ultraviolet) ray exposure is concerning. More and more synthetic chemicals are being applied to the skin to beautify the external appearance, but an increase in the application of UV protection is not seen, as stated by the 2020 RealSelf Sun Safety Report done in America ([Practical Dermatology 2020](#)). Approximately 67 per cent of the population relies on anti-aging products to improve their outer appearance, but only 11 per cent apply sun protection daily ([Paul 2020](#)). Of the study population, 46 per cent reported that they had never used sun protection ([Paul 2020](#)). However, sun exposure is an important factor in contributing to overall health, such as

regulating the body's circadian rhythms and improving mood. It is vital for the functioning of the immune system, and of course soaking up the sun increases vitamin D production in the body ([Mead 2008](#)). However, frequent and prolonged sun exposure can have many negative effects on health. Sunlight reaches the earth either as long or short waves. The longer waves, such as ultraviolet A (UVA) rays, are not harmful to the skin, but shorter waves, such as ultraviolet B (UVB) rays, can cause skin damage. Sunburn is caused by overexposure to UVB rays. These rays can travel deep into the skin where they interfere with vital processes dedicated to the growth and healthy appearance of skin. Repetitive exposure to UVB rays causes the skin to become less elastic, wrinkled, and thinner. Increased sun exposure leads to earlier skin aging, according to Dr Barnett S. Kramer, a cancer prevention expert at the National Institutes of Health (NIH) ([Hoel et al. 2016](#)).

Namibia is a hot and sunny African country. Protection from the sun and UV rays is a real concern for some of the citizens in Namibia. Skin cancer remains the most prevalent form of cancer in Namibia, with an average of 812 new cases of skin cancer per annum recorded during the period 2014 to 2016 (Wells 2023).

The red ochre is indigenous to Namibia. The use of the red ochre as a skin and hair sunblock dates back approximately 285 000 years at a site of *Homo erectus* in Kenya (Havenga et al. 2022). Red ochre is a rock-like mass made up of clay, which acquires its red colour from hematite, a mineral containing ferric oxide (Geggel 2018). The Ovahimba are a seminomadic tribe residing in the northern part of Namibia and numbering about 50,000 people. Since 1500 AD the Ovahimba tribes have made use of 'Otjize', a mixture of finely ground red ochre mixed with butter and fat, to protect their skin and hair from the harmful rays of the sun (Gandhi & Trivedi 2018).

It has also been discovered that many plant based oils have characteristics that offer some form of sun protection. In addition to the red ochre, Namibia also has many natural seed oils found in local indigenous plants; however, literature is lacking regarding the SPF factors associated with these oils.

Ximenia americana is an indigenous plant found in northern Namibia. The oil is extracted from the seeds of the plant by roasting, crushing, and boiling (NANCI 2020). The oil contains 80% mono-unsaturated fatty acids and is therefore very stable. It contains several long chain fatty acids such as, ximeninic, ximenic, and nervonic acid, which carry bioactive properties (NANCI 2020). As a cosmetic, ximenia oil is also believed to have anti-aging, as well as anti-inflammatory properties. An increase in the activity of the sebaceous glands has also been noted (NANCI 2020).

Marula oil is well known in the rural settlements of Northern Namibia. It is a seed oil from the fruit of the *Sclerocarya birrea* tree (NANCI, 2020). Marula has important traditional, social, economic, and nutritional value. The oil is traditionally named 'Ondjove' and is well known for skin and hair care. It consists of 70 to 78% of the mono-unsaturated fatty acid called oleic acid and is high in antioxidants (Mariod et al. 2004). Marula oil hydrates the skin and is quickly absorbed (Houghton 1999).

The Kalahari melon (*Citrullus lanatus*) is also popular in rural Namibia. The oil has a long history in the northern region as a cosmetic oil, and the seeds are stored as a source of energy and protein (NANCI 2020). The seeds of the fruit are roasted and boiled to extract the oil, which is used traditionally as a skin moisturiser and massage oil (NANCI 2020).

The bark and fruit of the *Adansonia digitata* tree are used as traditional medicine in Namibia. The fruit pulp is cooked with porridge. The seeds of the fruit are pressed to produce baobab oil, which is well known for its use in cosmetic products (NANCI 2020).

Namibian seed oils provide high moisturising effects as well as emollient properties; therefore it would be advantageous to formulate a red ochre lip balm sample with a selected Namibian plant-based oil to deliver a product having the highest possible SPF properties. To this end, knowledge of the various SPF values of the Namibian seed oils of interest would be helpful in the

formulation process. For example, according to one study consulted, the SPF values of eucalyptus oil and lemon grass oil were found to be 2.625 and 6.282 respectively (Saraf & Kaur 2010).

The higher the SPF, the higher the efficiency of a product in preventing sunburn. A sunscreen with an SPF of 2 protects the skin against 50% of UV rays, an SPF of 15 protects against 93% of sun damage, and an SPF of 50 blocks 98% UV rays (Rifkin et al. 2015).

This research project aimed to assess the photoprotective properties and SPF of Namibian red ochre as well as various Namibian natural seed oils at different concentrations and in different bases (w/w%) by means of UV spectrophotometry, as well as to formulate a novel lip balm with the best of these sun protective agents.

2 Materials and Methods

2.1 Reagents and Materials

The Namibian seed oils and red ochre were purchased from established suppliers in Windhoek. The petroleum jelly BP and zinc ointment BP bases were purchased from Nampharm® (based in Windhoek). Three solvents were tested, namely: ethanol, diethyl ether, and hydrochloric acid. Petroleum jelly base and zinc oxide (15%) ointment base did not dissolve in ethanol. Petroleum jelly dissolved in hydrochloric acid, but zinc oxide ointment did not. Both bases fully dissolved in diethyl ether, which therefore was proven to be the most suitable solvent. The reference samples used were zinc ointment BP, eucalyptus oil, and lemon grass oil. UV spectrophotometry was carried out using the Genesys10S UV-VIS Spectrophotometer (Thermo Scientific, Massachusetts, USA). The ultrasonic bath was the S10(H) Elmasonic model, manufactured by Elma GmbH in Germany.

2.2 Experimental Procedure

Various samples of lip balm were formulated using the red ochre and either petroleum jelly or zinc ointment as the base. Red ochre rock was ground to a fine powder using a mortar and pestle. Four different concentrations of lip balm were formulated: 5%, 10%, 20%, and 50%, mixed into each of the two different bases.

One gram of each of the eight prepared lip balm samples was weighed on an analytical balance and placed separately into eight small beakers. Sixteen millilitres of diethyl ether was added to each beaker using a pipette. The solution was stirred with a glass rod until completely dissolved. Each beaker was then placed in the ultrasonic bath for 60 seconds (at a room temperature of 25 degrees Celsius). Thereafter, 3ml of the solvent (diethyl ether) was added to the first cuvette using a pipette and the cuvette was placed in the UV spectrophotometer as a blank, followed by 3ml of a sample solution being added to the second cuvette using a pipette, and the cuvette was placed into the UV spectrophotometer as sample 1 (Dutra et al. 2014). The test was run and the highest absorbance as well as the exact wavelength (between 290–320nm) where the absorbance occurred was recorded. The tests were run in triplicate for all eight samples, keeping the blank the

same throughout; and for each sample the absorbance, along with its corresponding lambda max (λ_{max}) wavelength, were recorded (Dutra et al. 2014). These results were then used to calculate the SPF of each lip balm sample, using the Mansur equation (Zaid et al. 2018).

The second part of this experiment pertained to determining the SPF of various Namibian seed oils for the first time, as well as that of various known essential oils, which were used as reference standards (such as lemon grass and eucalyptus). Using six beakers, 20ml of diethyl ether was added to each using a pipette. Thereafter, 4ml of each oil of interest was added to the separate beakers using a pipette. The solutions were stirred using a glass rod until the oils were completely dissolved. The beakers were each placed into the ultrasonic bath for 60 seconds (at a room temperature of 25 degrees Celsius), then 3ml of each oil sample was separately added to the cuvette (Dutra et al. 2014). The UV spectrophotometry test was conducted in exactly the same way (in triplicate) as with the red ochre samples (using diethyl ether in the first cuvette as a blank). The corresponding wavelength and the absorbance values were recorded for each formulation and oil (Table 3 and Table 4). The SPF of the red ochre and various Namibian fixed oil samples was determined using the Mansur equation and constant $EE \times I$ values as seen below (Table 1):

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

CF = correction factor (10)

$EE(\lambda)$ = erythematous effect of radiation of wavelength λ

$I(\lambda)$ = intensity of sunlight at wavelength λ

$Abs(\lambda)$ = spectrophotometric absorbance values at wavelength λ .

(The values of $EE \times I$ are constant)

A subjective assessment of all the creams was conducted by a fourth year pharmacy student with a strong interest in cosmetics (Table 6).

2.3 Data Analysis

All samples were run in triplicate on the UV spectrophotometer and the average of each sample's absorbance results was calculated. The correction factor was determined after the absorbance data of the samples, which had a known SPF, were obtained. The correction factor used in the already well-established Mansur equation was 10 (Dutra et al. 2014). This was to account for the systemic errors. When multiplying the absorbance of these samples by their respective $EE \times I$ value (Table 1) (Naik 2019), the calculated SPF was consistently one tenth of the SPF values known from literature (Saraf & Kaur 2010). Therefore, the correction factor was determined to be 10. As shown in Table 1, the erythematous effect of radiation of wavelength λ (EE) multiplied by the intensity of sunlight at wavelength λ (I) are given as constant values for each wavelength between 290nm and 320nm (Naik 2019). The absorbance values used in the Mansur equation are the obtained absorbance values from running each sample in the UV spectrophotometer. For example, a sample that showed its highest absorbance at a wavelength of 305nm will have the constant $EE \times I$ value of 0.3278. To obtain the SPF of the

Table 1: Multiplication of the EE (erythematous effect of radiation) and the I (intensity of sunlight) were given as a constant value for each wavelength.

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

sample, the correction factor of 10 is multiplied by the $EE \times I$ value and multiplied by the absorbance recorded from the UV spectrophotometer.

3 Results

The absorbance results and calculated SPF values for the eight formulated lip balm samples as well as that of the pure bases used can be seen in Table 2. The absorbance results and calculated SPF values for Namibian seed oils can be seen in Table 3 and Table 4. The subjective assessment of the lip balm formulated with petroleum jelly is found in Table 6.

Eucalyptus oil had an absorbance of 3.378 at wavelength 295nm, which produced an SPF of 2.8 versus 2.6 from the literature (Saraf & Kaur 2010). Lemon grass oil had an absorbance of 3.805 at wavelength 310nm which, produced an SPF of 7.0 versus 6.3 from the literature (Saraf & Kaur 2010).

The calculated SPF result of the 20% red ochre in petroleum jelly with 20% ximenia oil was found to be 14.7. This was based on an absorbance of 4.488 at wavelength 305nm (Table 5).

4 Discussion

The SPF value is indicative of the extent to which the product protects the skin from UVB rays, the harmful rays of the sun. The higher the SPF value, the greater degree of protection it offers against the sun. A total of eight novel lip balms were formulated using Namibian red ochre and various Namibian seed oils. The idea of initially using petroleum jelly as a base, was simply to optimise the formulation of red ochre and ximenia oil which was required for an optimal SPF. Once the optimal formulation of red ochre and ximenia was established, zinc ointment BP was used as a base (at it had a much higher SPF than petroleum jelly). The samples formulated with zinc ointment BP as the base showed higher SPF values, as zinc ointment BP alone provides an SPF of 24 (Table 2) (Zickerman 2022). Petroleum jelly as a base alone had an SPF of 0.6 (Table 2). There was a clear increase in the SPF values as the concentration of red ochre in the formulations increased. For example, in the lip balm samples formulated with

Table 2: The absorbance results and calculated SPF values for the 8 formulated lip balm samples as well as the pure bases used.

Lip Balm Sample	Absorbance	Wavelength	Calculated SPF
0% Red Ochre in Petroleum Jelly	4.048	290nm	0.6
5% Red Ochre in Petroleum Jelly	4.909	305nm	1.6
10% Red Ochre in Petroleum Jelly	4.156	295nm	3.4
20% Red Ochre in Petroleum Jelly	4.419	300nm	12.7
50% Red Ochre in Petroleum Jelly	4.577	300nm	13.2
0% Red Ochre in Zinc Ointment	-	-	24.0
10% Red Ochre in Zinc Ointment	3.974	300nm	11.4
20% Red Ochre in Zinc Ointment	4.125	305nm	28.7

Table 3: The absorbance results and calculated SPF values for the commercial essential oils used as references, as well as their respective SPF values according to literature.

Commercial essential oil	Absorbance	Wavelength	SPF	Literature
Eucalyptus	3.378	295nm	2.7	2.6 (Saraf and Kaur, 2010)
Lemon Grass	3.805	310nm	7.0	6.3 (Saraf and Kaur, 2010)

Table 4: The absorbance results and calculated SPF values for the indigenous Namibian oils.

Namibian oil	Absorbance	Wavelength	SPF
Ximenia	4.000	300nm	11.5
Marula	3.006	290nm	0.5
Kalahari Melon	3.552	295nm	2.9
Baobab	3.354	295nm	2.7

Table 5: The absorbance and calculated SPF result of the 20% red ochre in petroleum jelly with 20% Ximenia oil.

Lip Balm Sample with Ximenia oil	Absorbance	Wavelength	SPF
20% red ochre in petroleum jelly with 20% Ximenia oil	4.488	305nm	14.7*

petroleum jelly as the base, there was an SPF increase from 1.6 in the 5% sample up to 13.2 in the 50% samples (Figure 1 and Table 2). The lip balm samples formulated with zinc ointment as the base also indicated a clear increase in SPF as the concentration of red ochre increased. Zinc ointment BP (15% zinc oxide) base has an SPF of 24, and the 20% red ochre in the

zinc ointment BP sample was found to have an SPF of 28.7 (Table 2), while the 20% red ochre in the petroleum jelly sample had an SPF of 12.7 (Figure 2); the SPF of petroleum jelly alone was negligible (SPF=0.6). One study assessed various samples of ochre from various locations in the Kunene Region of Namibia and found the *in vitro* SPF of the ochre samples was between

Relationship Between Red Ochre Concentration in Petroleum Jelly Base and SPF of the Lip Balm Sample

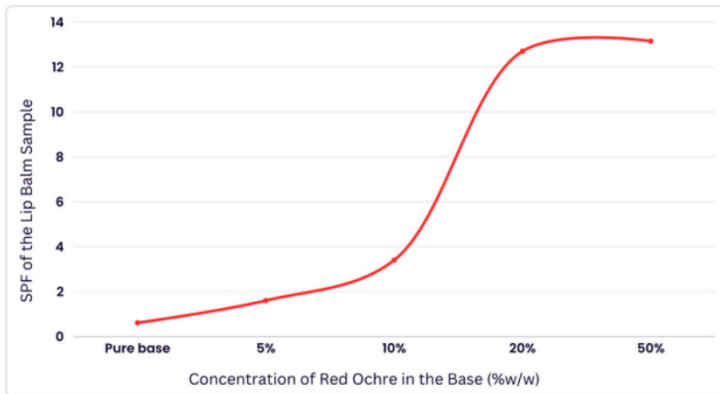


Figure 1: Red ochre in petroleum jelly – concentration *versus* SPF

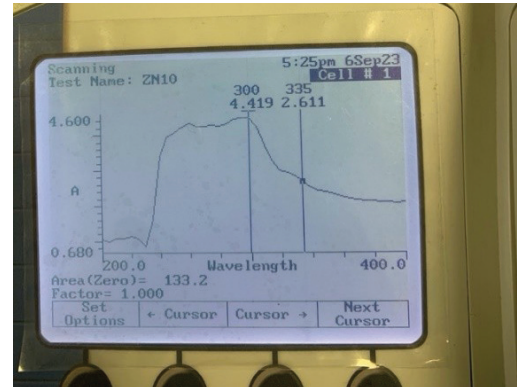


Figure 2: Showing the UV Spectrophotometry absorbance results of the 20% red ochre in petroleum jelly base sample. Absorbance = 4.419 (SPF = 12.7)

Table 6: The subjective assessment of the lip balm formulated with petroleum jelly.

Color	Dark red/ brown color with a glossy effect.
Texture	The 5%, 10% and 20% red ochre samples felt smooth on the lips. The 50% red ochre lip balm had a gritty feel on the lips.
Smell	Odorless.
Safe & causes no irritation	Yes. The lip balm was applied to the lips and left on for one hour. No reactions or irritations were caused.
Uniform color on applied area	Yes. The same color was well distributed over the lips and provides solid color coverage when using the 20% sample. The higher the red ochre concentration, the more solid the color appears on the lips. The 5% and 10% red ochre sample did not fully cover the lips with a solid color.
Stable under environmental conditions	Yes. The lip balm was stored indoor in Namibian climate without cooling and did not undergo any physical or chemical changes.
Moisturizes lips	Yes. Approximately an hour after application, the lips remained feeling moisturized.

1.9 and 13 after being mixed with butter (Rifkin et al. 2015). The SPF values in the study closely agree with the results found in this research project. However, in this study we recorded the concentration of red ochre in the base (for a particular SPF value) which has not previously been done.

The second part of this research experiment was focused on determining the SPF values of known commercially available essential oils (lemon grass and eucalyptus). Two reference standards were used to confirm the accuracy of the UV spectrophotometer results. According to literature, the SPF of eucalyptus oil is 2.6 and that of lemon grass oil 6.3 (Dutra et al. 2004). In this experiment the SPF of eucalyptus oil and of lemon grass oil was determined to be 2.8 and 7.0 respectively, which values correlated closely with literature and confirmed the credibility of the experiment. Subsequently, the SPF of four pure Namibian seed oils was determined as follows: ximenia 11.5, marula 0.5, Kalahari melon 2.9, and baobab 2.7 (Table 4). Using the above information, a final lip balm sample was formulated containing 20% red ochre in petroleum jelly to which was added 20% ximenia pure oil, as ximenia oil had the best SPF potential. The SPF of this combination sample was 14.7. This concentration was also chosen

because of the unique and appealing colour it delivers, as well as the smooth texture felt on the lips after application. Subjective assessments of this formulation were also favourable (Table 6).

Natural compounds are increasingly being investigated in cosmetic and pharmaceutical sunscreens as they are often widely available, non-toxic, safer for use, and have considerable UV protective properties and fewer side effects when compared to synthetic alternatives (Milutinov et al. 2024). Plant extracts with aromatic rings in their structures, for example flavonoids or polyphenols, are able to absorb UV to reduce sunburn by acting as a natural UV filter. In addition, they might also demonstrate antioxidant and/or anti-inflammatory activity (Li et al. 2023). It is known that many herbal sunscreens are able to absorb light preferentially over the range of 280 to 320nm without causing any harm to sensitive skin and eyes (as compared to synthetic chemical-based sunscreens) (Balkrishna et al. 2023). Although the photoprotective effects of many natural components have been established, such as rutin, ferulic acid, caffeine, shea butter, and various plant extracts (Morocho-Jácome et al. 2021), caution should still be exercised, as in many cases their negative side effects are not yet known (He et al. 2021).

Cosmetic formulations using *Melaleuca alternifolia* essential oil for improvement in photoaged skin have also proved to be successful (Hugo Infante et al. 2023). As a result, the SPF of the four cosmetically most used Namibian seed oils was determined for the first time, and it was found that ximenia oil had an impressive SPF of 11.5. This SPF result was slightly lower than that of a study of the plant extract *Baccharis antioquiensis* in Colombia, which demonstrated an SPF of 15 (Mejía-Giraldo et al. 2022).

Studying the SPF of red ochre (Figure 3) at various concentrations is vital for determining how much is needed for a specific SPF. In this study it was concluded that a 20% red ochre and 20% ximenia oil mixture combined with zinc oxide ointment BP would have the highest SPF; in addition, this formulation also felt appealing and had a favourable light purple colour (Figure 4).

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Figure 3: Red ochre rock found in Northern Namibia



Figure 4: 20% red ochre and 20% Ximenia oil mixture combined with zinc oxide 15% ointment B.P.

Conflict of Interest

The authors declare no conflict of interest.

Ethical considerations

The red ochre and Namibian seed oil products used in these experiments were obtained from various well-established retail outlets in Windhoek. It is known that IKS-Community Rights permits/agreements would already have been established with these various outlets in Windhoek. As a result, for the purpose of this research, purchasing these products was exempt from IKS-Community Rights permits/agreements.

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About the Author

Michael Knott completed his B.Pharm. degree at Rhodes University in 1999, his M.Sc. (Pharmacy) with distinction in 2002, and later finished a Ph.D. at Rhodes University in 2012. He is a registered pharmacist in South Africa, Namibia and Malta (EU). Michael moved to Namibia in 2014 to assist with setting up the first and only School of Pharmacy in the country. Since then, he has obtained Namibian permanent residence and has played a key role in lecturing and researching Pharmaceutical Sciences in Namibia. He is currently an associate professor in the Department of Pharmaceutical Sciences at the School of Pharmacy. In addition, Michael lectures psychopharmacology to psychology master's students at the University of Namibia. He is passionate about psychopharmacology, natural products, travelling and loves to explore remote parts of Namibia and learn more about natural products from the San and Damara people. He is well published in the field of natural product drug discovery. (<https://scholar.google.com/citations?user=omDl2d8AAAAJ&hl=en>) In 2020, he got his PhD from Rhodes University nostrificated (or recognised) in Poland (EU) by the Medical University of Gdansk, and in 2018 he completed his Postgraduate Diploma in Higher Education with distinction at the University of Namibia. He is married to Harriet (a clinical psychologist) and has a 12-year-old daughter named Annabelle.

