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Antioxidant and Antistaphylococcal Activity of Topical Fucoidan Gel from *Sargassum oligocystum* Montagne

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ABSTRACT

Brown seaweed is one of the algal species that has been used as food, a source of nutritional supplements, and formulated for therapeutic and cosmetic purposes. This study evaluated the antioxidant and antistaphylococcal activities of topical fucoidan gel (TFG) from *Sargassum oligocystum*. A completely randomized design was used, and the experimental protocol includes extraction, lyophilization, and characterization, quality testing, and biological assay. Physicochemical tests suggested that the lyophilized fucoidan is comparable with the properties of pharmaceutical-grade fucoidan. FTIR characterization revealed that fucoidan spectra contain the key functional groups, the sulfate groups, and polysaccharide chains. The formulated topical fucoidan gel also conforms to the selected minimum standards conducted for semi-solid preparation. Analysis of variance of antioxidant and antistaphylococcal assays showed that there was a significant difference in the median inhibitory concentration (IC50) and inhibitory zone (IZ) among treatments at the $p<.01$ respectively. Scheffe

test confirmed that the IC50 of treatment pairs Ascorbic Acid (AA) -TGF, AA-Lyophilized Fucoidan (LF), and TFG-LF were insignificant, which means they are comparable. Consequently, the IZ of Mupirocin 15ug/ml and TFG 45ug/ml has no significant difference, and it's inhibitory zones on *S. aureus* are comparable. Thus, the results suggested that lyophilized fucoidan from *S. oligocystum* is a potential alternative antioxidant and antistaphylococcal agent.

Keywords – Applied Science, Antioxidant, Antistaphylococcal, DPPH Assay, Disc Diffusion Method, Philippines

INTRODUCTION

Cosmetic is a formulated product intended to be applied topically to the body for the enhancement and restoration of personal appearance. Its formulation involves knowledge of the physicochemical properties of active and inactive ingredients that need skills in the manufacturing process considering their delivery system. Cosmetic industries employ the formulation of antiaging topical preparations to combat the harmful free radicals that damage the cells. External factors can also lead to the formation of these free radicals like eating of processed foods, exposure to environmental pollutants, and even absorption of hazardous chemical compounds from topical preparations. The human body is capable of producing antioxidant compounds that can combat the harmful effect of these reactive oxygen species (ROS), but when this ROS outcasts the natural antioxidant of the body, then cellular and metabolic processes are affected. With such, the aging process of the cells becomes rapid than cellular regeneration.

Antibacterial resistance is recently a major health issue in society. The increase in the rate of antibacterial resistance dominates the rate of recovery from infection and the rate of discovery of new and effective medicines. A skin infection caused by *Staphylococcus aureus* can progress to the formation of furuncles, carbuncles, and skin abscesses. *S. aureus* is the commonly identified agent responsible for skin and soft tissue infections (McCaig, McDonald, Mandal, & Jernigan, 2006). It invades open wound, and when growth becomes uncontrollable, secondary complications may arise and will enter the systemic circulation that can lead to a serious condition like sepsis.

Plants, animal tissues, mollusks, and marine species have been used as a source of active compounds in the cosmetic industry. Interestingly, Seaweed or macro alga is one of the marine species with diverse biological activities and

are the rich source of phytochemical compounds with remarkable medicinal potential. (Dhargalkar & Pereira, 2005). Studies suggested that some bioactive compounds isolated from marine organisms had shown to exhibit anti-infective activity against bacteria (Ragupathu Raja Kannan, 2010), virus (Rowley et al., 2002) and fungus (Arumugam, Kannan, Arivuselvan, & Anantharaman, 2010). Likewise, some compounds have cellular activity in killing cancer cells (Numata, 1991) and protecting normal cells as an antioxidant (Athiperumalsamy, 2010). Also, it has an anti-inflammatory (Hua et al., 2004) and antidiabetic (Gokce & Haznedaroglu, 2008) properties. Macro algae consist of sulfated polysaccharides like fucoidan, which have a medicinal impact and valuable in developing new pharmaceutical alternatives (Menelo, Rayel, & Daisy, 2012). Fucoidan (Marudhupandi & Kuma, 2014 and 2013) from seaweeds exhibit antioxidant (Duan, Zhang, Li, & Wang, 2006; Kuda, Tsunekawa, Goto, & Araki, 2005; Lim, Cheung, Ooi, & Ang, 2002; Park *et al.,* 2004) and antibacterial (Demirel, Yilmaz-Koz, Karabay-Yavasoglu, Ozdemir, & Sukatar, 2009) activities. Thus, seaweeds can be a promising source of pharmaceutical and cosmetic alternatives.

FRAMEWORK

Fucoidan is composed of fucose-sulfated polysaccharide with a high molecular weight, which is freely soluble in water. The high molecular weight and water-solubility properties of fucoidan were considered to be responsible for delaying cell aging, suppressing cancer cell growth (Lemieszek and Rzeski, 2012), counteracting the oxidizing effects of free radicals and inhibiting bacterial growth. Physicochemical testing and FTIR characterization were employed to identify the presence of essential functional groups like sulfate and polysaccharides. These structure combinations were known to exert the antioxidant effect on harmful free radicals.

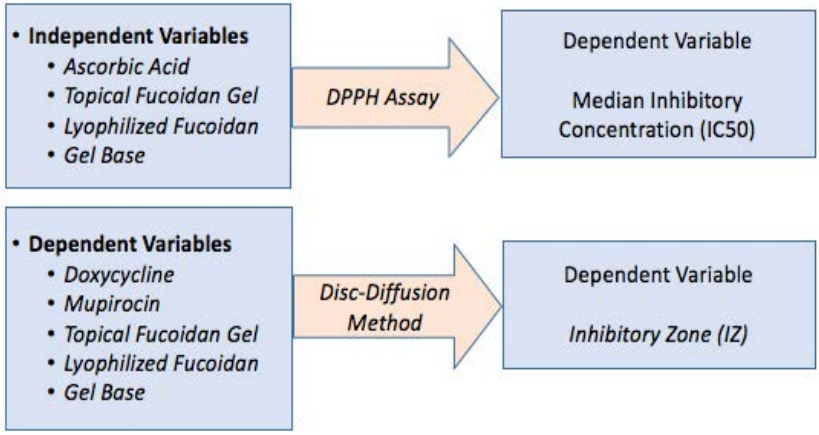

Figure 1. Conceptual Framework of the Study

OBJECTIVES OF THE STUDY

This study evaluates the antioxidant and antistaphylococcal activities of fucoidan topical gel from *Sargassum oligocystum*. Specifically, this study aims to evaluate: (1) the percentage yield of fucoidan; (2) the physicochemical properties of fucoidan; (3) the functional groups present in fucoidan under Fourier transform infrared (FITR) spectroscopy; (4) the characteristics of topical fucoidan gel based on the selected minimum test requirements for semi-solid pharmaceutical preparation; (5) the median inhibitory concentration (IC50) of the control and treatments using DPPH free radical scavenging assay; (6) the extent on the inhibition zone (IZ) of the control and treatments on the growth of *S. aureus* using paper-disc diffusion method; and (7) the significant difference between the IC50 and IZ of topical fucoidan gel and the positive control.

METHODOLOGY

Research Design

This study utilized an experimental and completely randomized design for antioxidants and an antistaphylococcal assay of fucoidan topical gel from *S. oligocystum*. In post-test, the only control group was used in assessing the free radical scavenging capacity and inhibition of *S. aureus* growth of different treatments.

Sample Collection

Mature and fresh *S. oligocystum* were collected from the subtidal zone of Brgy. Basiao, Ivisan, Capiz, through the assistance of fisherman. The whole plant was stored in a clear, wide-mouth glass bottle for macroscopic analysis and specific algal authentication through the guidance of aqua culturist of the Aquaculture Department of Southeast Asian Fisheries and Development Center, (AQD/SEAFDEC) Region VI. The authentication of algae was based on physical characterization using the following parameters: holdfast discoid, stem, primary to secondary branches, vesicles, and receptacles.

Experimental Procedure

Extraction of Fucoidan. S. oligocystum samples were washed thoroughly using a continuous stream of tap water to remove dirt and sands, followed by washing of distilled water and were air-dried for one week. Algae were milled into a fine powder using an electric granulator. Four kilograms of powdered samples were soaked in 8000 mL distilled water and heated over the electro thermostatic automated water-bath for 4 hours at 80°C (Jehan *et al.,* 2010 and Guevarra, 2004). Suction filtration was applied to separate the algal residues, and the filtrate was transferred to a glass container. The samples were kept at 2-8°C inside the ice-jacketed thermostat box and transported to AQD/SEAFDEC for lyophilization.

Percentage Yield Determination. The weight of the lyophilized powder, which was previously measured using an analytical balance, was divided by the weight of algae samples and multiplied by 100.

Physicochemical Evaluation of Fucoidan. The color, odor, taste, form, pH of 1% solution, and solubility in polar and nonpolar solvents of lyophilized powder were enumerated under physical tests. Carbohydrate, sulfate, and polysaccharide tests were identified under chemical properties.

FTIR Characterization. Characterization of lyophilized powder was performed using Fourier Transform Infrared Spectroscopy and compared with the reference standard fucoidan (pharmaceutical and food grade) at 650-4000cm^{-1} frequency range. (Soehono *et al.,* 2014). The quality of the lyophilized powder, including the reference standard, was compared against Agilent pectin internal standard in the Attenuated Total Reflection Library of the FTIR Spectrometer (Agilent Technologies).

Formulation of Fucoidan Gel. Distilled water was heated over the thermostat mechanical stirrer at a temperature of 80°C (Soehono *et al.,* 2014) with 100 revolutions per minute (rpm) stirring for five minutes. Xanthan gum was gradually

sprinkled over the stirring water and allowed to swell until a homogenous gel-like mixture formed. In a mortar, fucoidan was levigated with distilled water until a paste-like consistency developed. Titanium dioxide was added to the fucoidan paste and triturated continuously until homogenously mixed. The fucoidan-titanium dioxide mixture was then added to the xanthan gum gel. Lemon-tea tree oil mixture was added to the gel and stirred for one minute. The prepared gel was transferred to a filling machine and dispensed to a gel container. The finished product was labeled accordingly.

Minimum Tests for the Quality of Fucoidan Topical Gel. The color, odor, taste, form, pH of 1% fucoidan topical gel solution, miscibility in polar and nonpolar solvents, bacterial count, spreadability, and viscosity were tested.

Antioxidant Assay. The free radical scavenging activity was based on the inhibition of the stable 1, 1-diphenyl-2-picrylhydrazyl (DPPH) free radical. One (1) ml of 0.1 mmol/L solution of DPPH in ethanol solution was added to 3 mL solution of lyophilized fucoidan (LF) and topical fucoidan gel (TFG) at concentrations of 5, 10, 25 and 50 αg/mL). These solutions were incubated further at room temperature, and after 30 minutes, the absorbance of each solution was recorded at 517 nm. Ascorbic acid (vitamin C) was used as a reference standard following the same concentration of the LF and TFG for comparing the extent of the free radical scavenging capacity of the treatments. The percentage inhibition activity was calculated using the formula [(A0–A1)/A0] x 100, where A0 is the absorbance of the DPPH solution as the control, and A1 is the absorbance of the treatment/ standard. Median inhibitory concentration (IC_{50}) value was calculated from the equation of line obtained by plotting a graph of concentration (αg/ml) versus % inhibition (Nasrin, 2013) using Microsoft Excel.

Ethical Consideration. Prior to the collection of *S. aureus* from human skin, the researchers sought approval from the Institution of Ethics Research Committee through the completion of the ethics form for a faculty research project.

Collection, Culture, Isolation, Identification, and Confirmation of S. aureus. The test microorganism, *S. aureus* was obtained from human skin through the wet swabbing method. The swabbed microorganism was cultured, isolated, and identified by inoculating in the Mannitol Salt Agar (MSA). The MSA is a selective agar medium, and the formation of yellow isolates (Sharp and Searcy, 2006) confirmed the identity of the *S. aureus*. Gram staining was also used to reconfirm the identity of *S. aureus*. The yellow isolates were then suspended in a Trypticase Soy Broth (TSB) and incubated to 18 hours before testing. The 18-hour *S. aureus* culture was standardized using the McFarland standard, which

is equivalent to 10^6 uCFU/mL of 0.5 McFarland standard (Akinpelu, Abioye, Aiyegoro, Akinpelu, & Okoh, 2015).

Antistaphylococcal assay. The paper disc diffusion method was used to measure the antibacterial activity (Rasmavar *et al.,* 2014 and Guevarra, 2005). Doxycycline disc (30ug/disc) and Mupirocin cream (2%w/w) were the positive antibiotic disc, and commercial cream used respectively. The cream was diluted with water to quantify the equivalent amount of active ingredient parallel to the three treatments of LF and FFH (15ug/disc, 30ug/disc, and 45ug/disc) by using ratio-proportion and dilution technique. Ten microliters of treatments and mupirocin cream dilutions were used to wet the standardized and sterilized 6-mm Whatman filter paper discs, whereas ten microliters of topical gel base were used as a negative control. The paper discs were applied on the surface of the inoculated plates, not closer than 15 mm from the edge of the agar plate, and far enough from each other to prevent overlapping of zones of inhibition using a sterile forceps. The agar plates were inverted and placed in an incubator at 36.5°C and incubated for 24 hours (Guevara, 2005). Antibacterial assay was performed by measuring the diameter of the inhibition zone (IZ) around the discs. The assay was repeated trice. Antibacterial activity was expressed in terms of the mean inhibition zone in diameters (mm) produced by different treatments with positive and negative controls. The zones of inhibition were determined using a digital vernier caliper with the corresponding inferences: <10mm (inactive), 10-13mm (partially active), 14-19mm (active), and >19mm (very active).

Data Analysis

The median inhibitory concentration for antioxidant assay and zone of inhibition for antistaphylococcal assay were analyzed using Statistical Package for Social Science (SPSS) version 23.0.0.0 through Analysis of Variance to compare the significant difference. Post-hoc Scheffe test was used to confirm further where the differences occurred between treatments. Statistical significance was set at p-value ≤ .01.

RESULTS AND DISCUSSION

There were 263.20 grams of lyophilized fucoidan obtained from 4000 grams of *S. oligocystum* samples equivalent to 6.58% w/w yield. The amount of fucoidan depends on the habitat, type of species, and method extraction. Fucoidan is a sulfated polysaccharide that is soluble in water and remains stable up to 80°C (Soehono *et al.,* 2014).

Physicochemical tests in table 1 show that the color of pharmaceutical-grade fucoidan and lyophilized fucoidan differs in terms of color and pH. *S. oligocystum* is a highly pigmented alga with dark spots. The pH difference depends on the type of algal source since the pharmaceutical grade was extracted from kelp.

Table 1. Physical Properties of Lyophilized Fucoidan

Physical Test	Pharmaceutical Grade Fucoidan	Lyophilized Fucoidan
Color	Light brown	Brown
Odor	Fishy	Fishy
Taste	Salty	Salty
Form	Powder	Powder
pH	7.67	7.05
Solubility in water	Freely-soluble (1:10)	Freely-soluble (1:10)
Solubility in ethanol	Insoluble	Insoluble

Chemical identification tests in table 2 reflect that fucoidan is composed of sulfate and polysaccharides. It reveals that fucoidan is a carbohydrate by nature, and it contains glycosidic linkages that stabilize the key functional groups responsible for its bioactivity. The physical and chemical properties of fucoidan obtained from *S. oligocystum* played a significant role in the formulation of topical gel. Fucoidan possessed polar characteristics, and it can be incorporated in a hydrogel base to ensure good delivery.

Table 2. Chemical Properties of Lyophilized Fucoidan

Chemical Test	Constituent Detected	Standard Result	Experimental Result
Molisch	Carbohydrate	Purple ring	Purple ring
$BaCl_2$	Sulfate	White precipitate	White precipitate
Lugol	Polysaccharide	Blue-black solution	Blue-black coloration

Figure 2 detects the specific vibrations and stretch of different functional groups of fucoidan under the FTIR spectrometer through the reference sensing of the pectin library internal standard observed at wavenumber 3400-3500cm^{-1}. The spectra of standard fucoidan and lyophilized fucoidan are identical.

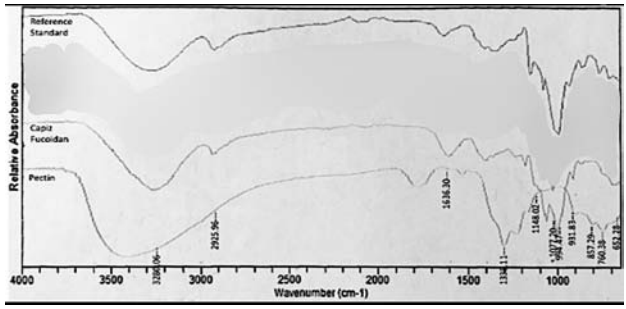

Figure 2. FTIR Spectra of Standard Fucoidan, Lyophilized Fucoidan, and Internal Standard

Based on the FTIR spectra, the different functional groups present in fucoidan under the FTIR spectrum. The presence of OH group in the monosaccharide monomer is observed at 3300-3400cm^{-1}, an aliphatic C–H at 2900cm^{-1}, a C=O stretch for acetate at 1700cm^{-1} (Zayed *et al.,* 2016). The C-O-C bending vibrations in the glycosidic linkage is observed at the region 700-1000cm^{-1} (Fernando et al., 2017). The glycosidic linkage stretch C–O–C and C–O–H are distinct between 1600 cm^{-1}and 1000 cm^{-1}. The signals near to 1600 cm^{-1}and 1500 cm^{-1}are produced by the asymmetric and symmetric stretch vibration of C-O-O of uronic acid (Marques, Vilanova, Mourão, & Fernàndez-Busquets, 2016, Cuib *et al.,* 2004). The presence of S=O stretching of the sulfate group is noted as a weak band at 1000cm^{-1} (Peranginangin & Saepudin, 2016). Therefore, the distinct band stretch of polysaccharide at 1000–3400cm^{-1} and sulfate at 1000 cm^{-1} is an indication that it is a sulfated polysaccharide. These are the essential functional moieties that can affect cell division and blood vessel formation (Lemieszek and Rzeski, 2012).

Minimum test requirements for topical fucoidan gel as a semi-solid pharmaceutical preparation in table 3 shows that TFG has a white-opaque viscid gel-like property, which was miscible both in water and alcohol.

Table 3. Minimum Test Requirements for Topical Fucoidan Gel (TFG)

Parameter	Result
Color	White
Odor	Citrus
Transparency	Opaque
Form	Gel
Consistency	Viscous
Bacterial count	Not detected
Miscibility in water	Miscible with small globules on the surface of the liquid
Miscibility in ethanol	Miscible
Spreadability	6.02 cm ± 0.05
% spreadability difference	5.64% (mupirocin ointment) ; 9.06% (vitamin E cream)
Viscosity	1342.67 mPa.s ± 0.33
% viscosity difference	14.22% mupirocin ointment) ; 18.06% (vitamin E cream)

Figure 3 shows that 5.64% and 9.06% are the spreadability difference of TFG (topical fucoidan gel) compared to MUP (mupirocin) and VITE (vitamin E), respectively. This shows that the ability of TFG to spread is closely related to MUP. This relationship can also be attributed to the spreadability comparison of the mupirocin-topical gel base (MUP-TGB) since the consistency of TFG depends entirely on the characteristic flow of TGB.

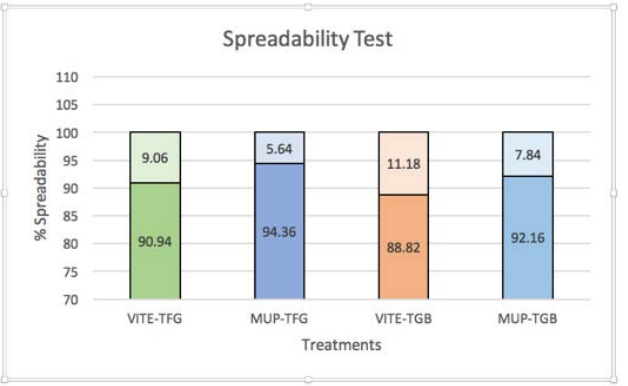

Figure 3. Spreadability of Mupirocin Ointment, Vitamin E Cream, Topical Fucoidan Gel, and Topical Gel Base

Figure 4 reveals that 14.22% and 18.06% are the viscosity difference of TFG (topical fucoidan gel) compared to MUP (mupirocin) and VITE (vitamin E), respectively. This reveals that the consistency of TFG is closely related to MUP. This relationship can also be attributed to the viscosity comparison of the mupirocin-topical gel base (MUP-TGB) since the consistency of TFG depends entirely on the characteristic flow of TGB. Consequently, no bacterial growth was detected when subjected to microbial count analysis.

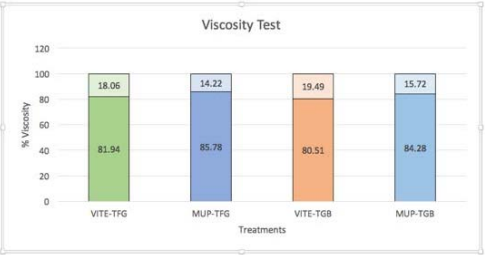

Figure 4. The Viscosity of treatment pair VITE-TFG (vitamin E cream vs. topical fucoidan gel), MUP-TFG (mupirocin vs. topical fucoidan gel), VITE-TGB (vitamin E cream vs. topical gel base) and MUP-TGB (mupirocin vs. topical gel base)

Figure 5 reveals the average median inhibitory concentration (IC50) of different treatments which was evaluated using 1, 1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assay. It shows that AA ($\bar{x}$=19.00±0.02) has the lowest IC50, followed by TFG ($\bar{x}$=20.73±0.07), LF ($\bar{x}$=22.48±0.02) and TGB ($\bar{x}$=38.86±1.36).

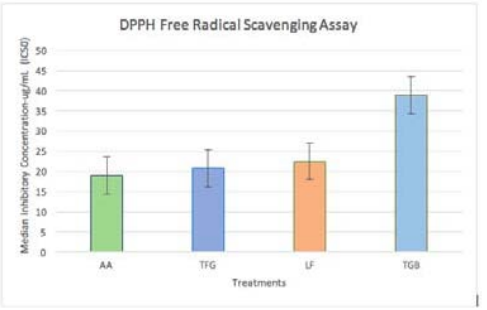

Figure 5: Average median inhibitory concentration (ug/mL) of AA (ascorbic acid), TFG (topical fucoidan gel), LF (lyophilized fucoidan) and TGB (topical gel base) on DPPH free radical

One-way analysis of variance in Table 4 reveals that there was a significant difference in the IC50 among treatments at the p<.01 level [F(3, 8) = 182.3406, p = 1.05e-7]. Post-hoc Scheffe test reveals that the IC50 of treatment pair AA-TGF, AA-LF and TFG-LF are insignificant, which means they are comparable.

Table 4. Analysis Of Variance of Median Inhibitory Concentration (IC50) of Four Treatments (ascorbic acid, topical fucoidan gel, lyophilized fucoidan and topical gel base)

	SS	df	MS	F	Sig
Between groups	757.1555	3	252.3852	182.3406	1.05e-7
Within groups	11.0731	8	1.3841		
Total	768.2286	11			

p<0.01

DPPH is a free radical and popularly used as a model to assess the antioxidant capacity in a relatively short time-frame compared with other methods. The DPPH radical is scavenged through the donation of hydrogen by the antioxidant to form a stable DPPH-H molecule. The DPPH carries similar key functional groups such as -OH and -OSO_3H groups. The excess -OH groups are replaced by the -OSO_3H groups, thus scavenging effect or inhibition of oxidation is exhibited. In the present study, it showed that lyophilized fucoidan and topical fucoidan gel have strong scavenging activities on DPPH radicals at a dosage of 22.48ug/mL±0.02 and 20.73ug/mL±0.07 which may be attributed due to the high sulfate content interlinked in the polysaccharide backbone. In relation to the present study, Zhang *et al.* (2003) and Athiperumalsami *et al.* (2010) relate the antioxidant activity and the sulfated polysaccharide content from *Porphyra haitanesis* extract, the higher the sulfated polysaccharide contents, the stronger the antioxidant activity. In this study, part of the chemical identification test was the detection of the presence of sulfate and polysaccharides, then further reconfirmed through FTIR characterization where sulfate and polysaccharides formed vibration stretch detected within wavenumber 3400-3500cm^{-1}.

Figure 6 shows the average inhibition zone on *S. aureus* growth of doxycycline, mupirocin, TGF, TGB and distilled water which were evaluated using a paper-disc diffusion assay. The highest to lowest IZs were observed from doxycycline ($\bar{x}$=24.48±0.13), MUP45ug/disc ($\bar{x}$=22.69±0.37), MUP30ug/disc ($\bar{x}$=20.83±0.09), MUP15ug/disc ($\bar{x}$=19.18±0.19), followed by TFG45ug/disc ($\bar{x}$=19.43±0.08), TFG 30ug/disc ($\bar{x}$=15.84±0.20), TFG 15ug/disc ($\bar{x}$=12.83±0.32),

TGB ($\bar{x}$=7.95±0.03) and distilled water 0.01ml/disc ($\bar{x}$=6.04±0.01).

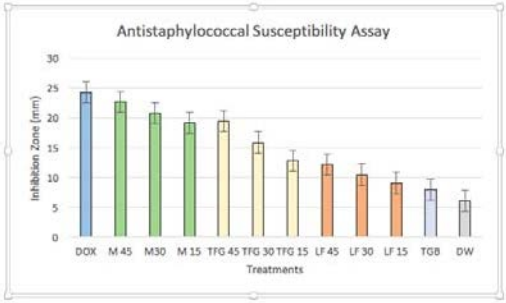

Figure 6: Average inhibition zone (mm) of DOX (doxycycline), M (mupirocin) 45-30-15ug/disc, TFG (topical fucoidan gel) 45-30-15ug/disc, LF (lyophilized fucoidan) 45-30-15ug/disc, TGB (topical gel base) and DW (distilled water)

One-way analysis of variance in Table 5 reveals that there was a significant difference in the IZ among nine treatments at the p<.01 level [F(8, 18) = 2099.9222, p = 1.11e-16]. Post-hoc Scheffe test in table 11 explains that the IZ of mupirocin 15ug/ml and topical fucoidan gel 45ug/ml has no significant difference. Thus, the inhibitory zones on *S. aureus* between MUP15ug/ml and TFG45ug/ml are comparable. However, TFG45ug/disc has the least significant difference when compared to MUP30ug/disc.

Table 5. Analysis of variance of the inhibitory zone (IZ) of nine treatments (doxycycline, mupirocin 45-30-15ug/disc, topical fucoidan gel 45-30-15ug/disc, topical gel base and distilled water)

	SS	df	MS	F	Sig
Between groups	989.2101	8	123.6513	1091.3076	1.11e-16
Within groups	2.0395	18	0.1133		
Total	991.2496	26			

p<0.01

One-way analysis of variance in Table 6 reveals that there was a significant difference in the IZ among nine treatments at the p<.01 level [F(8, 18) = 1091.3076, p = 1.11e-16]. Post-hoc Scheffe test in Table 13 depicts that the IZ of three LF treatments has a significant difference when compared to DOX and MUP. Thus, the results in the antistaphyloccocal activity of lyophilized fucoidan

are not comparable to the positive control. However, LF15ug/disc has the least significant difference when compared to the TGB.

Table 6: Analysis of variance of the inhibitory zone (IZ) of nine treatments (doxycycline, mupirocin 45-30-15ug/disc, lyophilized fucoidan 45-30-15ug/disc, topical gel base, and distilled water)

	SS	df	MS	F	Sig
Between groups	1169.6193	8	146.2024	2,099.9222	1.11e-16
Within groups	1.2532	18	0.0696		
Total	1170.8725	26			

$p<0.01$

Fucoidan is a complex sulfated polysaccharide that is found in the cell walls of several edible brown algae like *Fucus vesiculosus* (Choi, Jang, & Cha, 2015)*, Sargassum fulvellum, S. kjellmanianum, L. angustata, L. angustata var. longissima, L. japonica, Ecklonia cava*, and *Eisenia bicyclis*. Ale *et al.* (2011) tested sulfated polysaccharide brown algal species its bioactivities and noted that the high concentration of polysaccharides in these species is responsible for its antimicrobial properties (Choi, Jang, & Cha, 2015, Qin *et al.,* 2013 and Horikawa, Noro, & Kamei, 1999).

TFG formula contains a mixture of lemon-tea tree oil as odor enhancing agents and known to exert antioxidant and antibacterial activities (Frassinetti *et al.,* 2011 and Kim *et al.,* 2004). Lemon-tea tree oil and fucoidan co-synergized each other when in the formulation as reflected in their average IC50: TFG ($\bar{x}$=20.73) lyophilized fucoidan ($\bar{x}$=22.48) and topical gel base ($\bar{x}$=38.86). Numerically, the combined lyophilized and topical gel base in the topical fucoidan gel has a lower IC50, which means that the lower the concentration of IC50, the stronger is the free radical scavenging activity. Consequently, the addition of methylparaben which was used as a preservative enhances the antistaphylococcal activity of lyophilized fucoidan, as seen in the IZ of TFG 45ug/disc ($\bar{x}$=19.43) which is comparable to MUP15ug/disc. Pharmaceutical additives or excipients are needed to improve the aesthetic appeal of the formulated product. Citrus scent was considered because it is the scent of choice in masking the fishy smell of fucoidan (Robbins, 2018). Therefore, the topical gel base served as the reference for evaluating the influence of these additives in the activity of fucoidan as a component of base formulation and finished product, respectively.

CONCLUSIONS

Based on the gathered findings and results of the study, topical fucoidan gel is a potential antioxidant agent at a dose of 20.73ug/ml based on free radical scavenging activity and as an antistaphylococcal agent at a dose of 45ug/disc on *S. aureus*.

TRANSLATIONAL RESEARCH

The findings of this research is helpful in the realization of the preservation of brown algae and its habitat because the results showed that the fucoidan from *S. oligocystum* is a potential antioxidant and antistaphylococcal alternative. Likewise, the results must be forwarded to relevant health research agencies for them to perform different replicates utilizing different bacterial strains and conduct molecular rearrangement of fucoidan to enhance its biological activities better.

RECOMMENDATIONS

The researcher would like to recommend the use of other free radicals for antioxidant assay and other skin pathogenic bacteria for antibacterial assay to establish an additional scope of biological and bacteriological activities using the local algal source which is *S. oligocystum*.

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