



Yucca Schidigera Leaf Extracts as Emulsifiers in Oil-in-Water Systems

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Abstract

Emulsification ability of *Yucca schidigera* leaves extracts for oil-in-water phase was investigated with three different solvent extracts; ethanol, n-hexane, and distilled water. N-hexane, ethanol, and distilled water extracts of the leaves were prepared using soxhlet extractor. Phytochemical analysis of the different leaf extracts was done using a GC-MS spectrophotometer. The results obtained show the presence of many bioactive compounds such as: saponins, tannins, alkaloids, flavonoids, etc. Different concentrations of the oil-in-water with the extracts (1000, 2000, 3000 ppm) were made. The volume of water that separated from the solution was measured to determine the emulsification ability of the different solvent extracts. At 3000 ppm of the extracts, distilled water and ethanol extracts emulsified the oil in water, although the distilled water extract gave a better emulsification result than the ethanol extract. This is attributed to the presence of a greater percentage of rich surfactant-like compounds in the distilled water extract which aided the reduction of the surface tension between the two immiscible liquids. The hexane extract did not emulsify at 1000 ppm, but at 2000 ppm and 3000 ppm slight emulsion that was stable for about 30 minutes was formed. This implies that hexane may not have extracted a good amount of surfactant-like molecules that would have aided the emulsification process. The ability of a synthetic emulsifier was also investigated and it produced good results. The prepared emulsifiers: n-hexane, distilled water, and ethanol extracts of *Yucca schidigera* leaves are suitable alternatives to synthetic emulsifiers because they are available and eco-friendly but there is a need to find out the concentration for optimum.

Keywords: Ethanol, hexane, distilled, synthetic, natural, surfactants, phytochemicals.

Introduction

Emulsions are colloids of at least two immiscible liquids, in which one liquid contains a dispersion of the other. Hence, an emulsion is a mixture of two or more liquids that are immiscible. Emulsions exhibit turbidity and an opaque quality due to light scattering from the myriad of suspended droplets at the colloidal scale. The process of the formation of an emulsion is known as emulsification. Different forms of emulsions exist: oil and water form oil-in-water emulsion, where the oil droplets are dispersed in water, or water-in-oil (w/o) emulsion, with water dispersed in oil. They can also form multiple emulsions, such as water-in-oil-in-water (w/o/w) (Sugiura et al., 2004). This is a complex system where tiny water droplets are enclosed within larger oil droplets, which are then dispersed in a continuous outer water phase. Most emulsions are unstable, with components that cannot mix on their own. The droplets in immiscible solutions come in different sizes, ranging from large sizes that can be visible to the human eye to sub-micro sizes (Abdulrahman et al., 2007). Water-in-oil emulsions are more common than oil-in-water emulsions, thus oil-in-water emulsions are often seen as reversed emulsions (Abubakar & Aliyu, 2017). In the petroleum industry, the emulsions of water-in-oil or oil-in-water cause huge financial losses when not properly treated. Ali and Alqam (2000) investigated the role of asphaltenes, resins, and other solids in the stabilization of water in oil emulsions and their effect on oil production in Saudi oil and reported their useful emulsification effects. Johnson et al. (1986) reported that saponin molecules aid the transportation of nutrients around the body from their study on the influence of saponins on gut permeability and active nutrient transport in vitro.

The ability of surfactant molecules to form micelles (micellation) in solution aids in the reduction of surface tension in liquids. This was demonstrated in the study carried out by Shah et al. (2016), titled; Micellization of cationic surfactants in alcohol—water mixed solvent media.

Surfactants are surface-active agents with a hydrophilic head (polar, water-loving head), lipophilic (fat-loving), and hydrophobic tail (water-resistant or non-polar tail). They help to lower the surface tension between fluids. They sometimes act as wetting agents, detergents, emulsifying agents, foaming agents, demulsifying agents, or dispersants. A good example of natural plants that have surfactant is the *Yucca schidigera* leaves. It contains saponins, which are a major ingredient in the formation of emulsions. Biosurfactants, which are surface-active substances of natural origin, can be sourced directly from plants or produced by microbes fermenting various substrates, including alkanes, oils, and sugars (Shah et al., 2016). Ozturk and McClements (2016), revealed the usefulness of natural emulsifiers in food emulsions.

Saponin-rich plants are eco-friendly and non-toxic, unlike the synthetic ones. They have good physicochemical and biological properties, for example is the *yucca* plant investigated in this study (Oleszek et al., 2001; Rai et al., 2021; Tenon et al., 2017). In addition, biosurfactants are amphiphilic compounds and are good alternative molecules for industrial and domestic applications due to their multi-functionality, environmental friendliness, and availability. The chemical compounds of bio-surfactants have gained much attention because they are considered suitable for remediation technology. The Mojave yucca (*Yucca schidigera*), or Spanish dagger, is a flowering plant indigenous to the southwestern deserts of North America. The plant identified, belongs to the family of *Asparagaceae*. Extracts of *Yucca* have been used as foaming agents in carbonated soft drinks (Oleszek et al., 2001).

Several researches have been carried out on the emulsification of oil – in –water. Amongst them is the study on the emulsification of heavy crude oil in water for pipeline transportation by Maier et al. (2014) and the studies by Maduelosi et al. (2024 & 2025). Their analysis reveals a dual effect: emulsification initially reduces the viscosity of the crude oil samples, but the final viscosity of the emulsion is positively correlated with several factors. These factors include the emulsion's oil content, surfactant concentration, mixing parameters (speed and time), salt concentration, and the pH of the aqueous phase. The effect of synthetic surfactants on the environment was studied by Tenon et al. (2017) and the results obtained showed that the use of synthetic emulsifiers has detrimental environmental impacts, including the degradation of aquatic ecosystems through the reduction of microbial populations, harm to aquatic fauna, decreased photochemical efficiency in plants, and compromised wastewater treatment processes.

This study aimed to investigate the emulsification potential of *Yucca schidigera* leaf extracts as natural emulsifiers in oil-in-water systems and to evaluate their suitability as eco-friendly alternatives to synthetic emulsifiers.

Materials and Methods

Yucca schidigera leaves were collected from the Chapel of Redemption compound, Rivers State University, Port Harcourt. A crude oil sample was gotten from Emohua Local Government Area, Rivers State. Dichloromethane (DCM), distilled water, n-hexane, and methanol were obtained from the laboratory of the Department of Chemistry, Rivers State University laboratory. The leaves of *Yucca schidigera* were plugged, washed using distilled water, air dried at room temperature, and ground into fine powder. The extraction was done using soxhlet apparatus with three different solvents; n-hexane, ethanol, and distilled water. A commercial synthetic emulsifier was used as a standard. The extracts were characterized using GC-MS. Plant emulsifiers were prepared by mixing 10 g of each of the solvent extracts with 20ml of dichloromethane. An emulsification test was conducted to evaluate the efficacy of various extracts and synthetic emulsifiers. A primary oil-in-water emulsion was prepared by homogenizing 300 mL of crude oil with 150 mL of water. From this emulsion, 10 mL aliquots were dispensed into six 15 mL centrifuge tubes. A 1 mL volume of each test solution, including ethanol, hexane, and distilled water extracts, as well as synthetic emulsifiers, was added to the individual tubes at a standardized concentration of 3000 ppm. The tubes were then placed in a rack and allowed to stand undisturbed for 60 minutes. The stability of the emulsion was quantified by measuring the volume of water separated (i.e., the volume of the resolved aqueous phase) from the emulsion in each tube at 10-minute intervals.

Results

Table 1: Components of Distilled Water Extract.

S/N	RT	COMPOUND NAME	MW	% COMP
1.	6.265	2-Piperidinone (C ₅ H ₉ NO)	99.13	13.17
2.	9.79	p-Cresol	108.81	2.52

C ₇ H ₈ O				
3.	10.002	4H-Chromene, 4a,5,6,7,8,8a-hexahydro-2,3,5,5,8a-pentamethyl (C ₁₄ H ₂₂ O)	206.32	4.94
4.	11.942	5,7-Dimethyloctahydrocoumarin (C ₁₁ H ₁₈ O ₂)	182.26	2.88
5.	12.199	Bicyclo[2.2.1]heptan-2-one, 5-brom-1,7,7-trimethyl-, (1R-exo)- (C ₁₀ H ₁₈ O)	154.5	8.80
6.	13.944	3-Undecen-5-yne, (Z)- (C ₁₁ H ₁₈)	150.6	4.16
7.	15.775	Hexadecanoic acid, ethyl ester (C ₁₈ H ₃₆ O ₂)	284.5	7.09
8.	20.553	Diisooctyl phthalate (C ₂₄ H ₃₄ O ₄)	390.6	7.09
9.	25.634	2-Ethylacridine (C ₁₅ H ₁₂ N ₄ O)	264.8	5.63
10	25.760	4 -tert-Amylphenol, TMS derivative (C ₁₁ H ₁₆ O)	164.4	21.42

Table 2: Components of Ethanol Extract.

S/N	RT	COMPOUND NAME	MW	% COMP.
1.	9.561	Eicosyl isopropyl ether (C ₂₃ H ₄₈ O)	3406	1.17
2.	10.168	1-Octadecanesulphonyl chloride	353	1.30
3.	11.152	Dodecanoic acid (C ₁₂ H ₂₄ O ₂)	20032	3.17
4.	11.284	1-Octadecanesulphonyl chloride (C ₁₈ H ₃₇ ClO ₂ S)	3530	1.57
5.	11.787	Oxirane, hexadecyl- (C ₁₈ H ₃₆ O)	268.5	1.86
6.	15.438	n-Hexadecanoic acid (C ₁₆ H ₃₂ O ₂)	25642	10.23
7.	16.897	Neophytadiene (C ₁₆ H ₃₂ O ₂)	25642	8.89
8.	17.114	9,12-Octadecadienoic acid (Z,Z)- (C ₁₈ H ₃₂ O ₂)	282	23.62
9.	20.256	Palmitic acid vinyl ester (C ₁₈ H ₃₄ O ₂)	282	4.57
10.	22.885	Sesquirosefuran (C ₁₅ H ₂₂ O)	218	2.98

Table 3: Components of N- Hexane Extract.

S/N	RT	COMPOUND NAME	MW	% COMP.
1.	3.945	Cyclotetrasiloxane,-octamethyl- (C ₈ H ₂₄ O ₄ Si ₄)	296.61	0.93
2.	14.022	Cholesta-3,5-diene (C ₂₇ H ₄₄)	368.63	0.97
3.	21.157	1H-Indole -5-methyl-2-phenyl- (C ₁₅ H ₁₃ N)	372.5	5.59
4.	21.340	2-methyl-7-phenylindole (C ₁₅ H ₁₃ N)	207.27	1.11
5.	24.510	Ethyl5-(furan-2-yl)-1,2-oxazole -3-carboxamide (C ₁₈ H ₁₄ N ₂ O ₅)	338.3	4.29
6.	25.975	6-Octadecenoic acide(z)- (C ₁₈ H ₃₄ O ₂)	282.5	8.55
7.		2,3-Dihydroxypropyl elaidate (C ₂₁ H ₄₀ O ₄)	356.5	4.50
8.	19.168	1H-Indole -5-methyl-2-phenyl- (C ₁₅ H ₁₃ N)	207.27	1.44
9.	17.953	Benz[b]-1,4-oxazepine-4(5H)-thione,2,3-dihydro-2,8- dimethyl- (C ₁₁ H ₁₃ NOS)	207.29	1.96
10.	16.396	2-(n- propyl) oxybenzylidene acetophenone (C ₁₅ H ₁₂ O)	208.25	3.13

Table 4: Volume of Water That Separated With the Distilled Water Extract Emulsifier at Different Times.

Extract conc. (ppm)	10 minutes (mL)	20 minutes (mL)	30 minutes (mL)	40 minutes (mL)	50 minutes (mL)	60 minutes (mL)
1000	0.00	0.00	0.00	1.50	2.00	2.00
2000	0.00	0.00	0.00	0.00	1.00	1.00
3000	0.00	0.00	0.00	0.00	0.00	0.00
Blank	0.50	2.50	3.00	3.50	4.00	5.00

Table 5: Volume of Water That Separated With the Ethanol Extract Emulsifier at Different Times.

Extract conc. (ppm)	10 minutes (mL)	20 minutes (mL)	30 minutes (mL)	40 minutes (mL)	50 minutes (mL)	60 minutes (mL)
1000	0.00	9.50	8.50	8.00	8.00	8.00
2000	0.00	2.50	4.80	5.50	5.60	6.00
3000	0.00	0.00	0.00	0.00	0.00	0.00
Blank	1.00	2.00	3.00	3.50	4.00	4.50

Table 6: Volume of Water that Separated With the N-Hexane Extract Emulsifier at Different Times.

Extract conc. (ppm)	10 minutes (mL)	20 minutes (mL)	30 minutes (mL)	40 minutes (mL)	50 minutes (mL)	60 minutes (mL)
1000	8.00	8.50	8.50	8.50	8.30	8.00
2000	0.00	1.50	1.80	1.70	1.90	2.00
3000	0.00	0.00	0.00	2.00	2.00	2.00
Blank	1.00	2.00	3.00	3.50	4.00	4.50

Discussion

The phytochemical analysis of ethanolic, n-hexane, and distilled water extracts of *Yucca schidigera* showed the presence of notable phytochemical compounds, such as: 2-Piperidinone- (C_5H_9NO), 4-tert-Amylphenol, TMS derivative ($C_{11}H_{16}O$), n-Hexadecanoic acid- ($C_{16}H_{32}O_2$), 9,12-Octadecadienoic acid (Z,Z)-($C_{18}H_{32}O_2$), 1H-Indole-5-methyl-2-phenyl- ($C_{15}H_{13}N$), 6-Octadecenoic acid(z)-($C_{18}H_{34}O_2$). etc as shown in Tables 1 to 3. This is similar to the findings made by some earlier researchers, Abubakar and Aliyu (2017), Maduelosi et al. (2024 & 2025), and Maier et al. (2014). Distilled water extract yielded a measurable amount of saponins while other solvent extracts yielded moderate to little amounts of saponins.

The emulsification test carried out with the different solvent extracts at the same time interval and different concentrations (1000 ppm, 2000 ppm, and 3000 ppm) presented in Tables 4 and 5, showed a trend in the emulsifying ability of the distilled water extract emulsifier and the ethanol extract emulsifier. The distilled water extract emulsifier at 1000 ppm concentration emulsified the liquids homogeneously while the ethanol extract emulsifier did not completely emulsify the liquids. There were traces of emulsion breakage in the solution. This may be as a result of the absolute amount of saponin present at a higher percentage and the surfactant-like compounds present in the distilled water extract, which was able to reduce the interfacial tension of the liquids thereby increasing the solubility of the hydrophobic molecule of the oil in water interfaces. Some earlier researchers made a similar observation in their studies (Ralla et al., 2017; Maduelosi et al., 2004 & 2025). The ethanol extract emulsifier may not have a sufficient amount of saponin and other surfactant likely compound for complete emulsification. With an increase in volume of the extracts (2000 ppm and 3000ppm), the ethanol extract emulsifier was enriched thereby gaining the ability to reduce the interfacial tension of the liquids and increasing the emulsifying ability. The ethanol extract emulsifier (at 2000 ppm) separated the liquids with an increase in concentration. This may be because surfactants can also act as demulsifying agents. When there is an unequal amount of polar and non-polar components in the solution it makes the system unstable. For an emulsion to occur successfully the solution system must be in equilibrium with an equal amount of polar molecule from the extract and the water, and an equal amount of non-polar molecule from the extract and the oil. This is in accordance with the studies by Maduelosi et al. (2024 & 2025) and Yaqoob et al. (2006), which revealed that the dispersed oil droplets inside the water field emulsion have films that surround them which help stabilize the emulsion, and the films are believed to be formed by the adsorption of high molecular polar molecules.

The result of the n-hexane extract emulsifier presented in Table 6 shows that the extract did not emulsify the solution completely, both at 2000 ppm and 3000 ppm concentration. This may be as a result of the hexane not being able to extract a sufficient amount of surfactant-like compounds which would have aided the emulsification process and reduced the interfacial tension between the oil and water interfaces. This report is in agreement with the study, which revealed that the efficiency of a surfactant is determined by its ability to reduce surface/interfacial tensions which is a mechanical energy required to create a unit new area of the liquid surface. The synthetic emulsifier employed in this research emulsified the solution and the blank was used as a control to certify the fact that water and oil are two immiscible liquids that remain naturally separated from each other.

Conclusion

Distilled water extract yielded a good amount of saponin while other solvent extracts yielded moderate to little amounts of saponin. It was observed that the distilled water extract emulsifier and the ethanol extract emulsifier were effective in forming an emulsion of oil in water. The distilled water extract emulsifier was also observed to be the best solvent extract emulsifier as it required a small amount to emulsify compared to ethanol and hexane extract emulsifiers. At 3000 ppm, the distilled water extract and ethanol extract emulsified oil in water without separation but the distilled water extract gave a better emulsification. However, at 2000 ppm the ethanol extract did not emulsify completely because there was an observed separation though not as clear as the blank, but distilled water emulsified completely without separation. The hexane extract did not emulsify at both 1000 ppm and 2000

ppm concentrations because the hexane may not have extracted a sufficient amount of surfactant-like compounds which would have aided the emulsification process.

Recommendation

The demulsification ability of *Yucca schidigera* Leaf extract should be investigated

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