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Review on Saponin a Natural Surfactant

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ABSTRACT:
Natural plant-based surfactants are increasingly taking the place of synthetic ones in response to rising demand for natural surfactants and environmental concerns. Due to their natural nature and biodegradability, they are environmentally friendly. The surface action of numerous plant-based saponins has been researched up to this point. In this article, a summary of saponins is given, with a special emphasis on their surface-active characteristics. A category of substances known as saponins is found in many different types of plants. Saponins are capable of self-assembly and have high surface activity as a result of their amphiphilic characteristic structure, making them suitable for usage as natural biosurfactants. Many scientists are interested in saponin since it has emerged as a possible drug delivery system (DDS) carrier. According to a growing number of researches, medicines' solubility or bioavailability is increased when they combine with saponins. This result might be caused by a synergistic mechanism and offers a potentially ground-breaking idea for DDS: saponins might also be used as carrier substances. Saponins have been found to have a variety of biological properties, including antibacterial, antidiabetic, adjuvant, and anticancer properties. In this review, we focused on the morphological study on saponin carriers as well as their molecular properties and mechanisms as carriers. Additionally, the essay discussed saponins' function in DDS and how it is used.

Keywords: Saponin, Natural surfactant, Drug delivery system, Carrier, Synergistic effect.

I. INTRODUCTION:

One of the major existential a worldwide responsibility that has diminished is environmental pollution, harmed the environment of the earth's and its life [1]. Typically, a trend can be environmental considerations have been considered as favouringthe usage of natural products over synthetic concerns [2-4]. Surface active agents, often known as surfactants, are ampipathiccompounds with the capacity to forms micelles. Surfactants are effective emulsifiers, dispersing and foaming agents due to their surface activity properties [5].

Surfactants help polar substances dissolve in organic solvents. Surfactants which are the main components of soaps and detergents are frequently employed to remove oil-based material from a particular media. Surfactants are used in numerous industrial processes as a result of these qualities. Surfactants can be biological or synthetic in origin [6]. The capacity of a surfactant to minimize surface tension is primarily governs its effectiveness [7]. Lower critical micelle concentrations (CMC) are associated with more effective surfactants. In industrial, food, agricultural, cosmetic and pharmaceutical applications, surfactants are widely employed [8].Most synthetic surfactants are made from unprocessed petrochemicals [9]. These chemicals are usually hazardous and non-biodegradable due to their petrochemical nature, which results in significant environmental harm [10-11].

Alternative environmentally friendly methods for producing various kinds of natural surfactants or biosurfactants are currently the focus of research [12].

On basis of origin, natural surfactants are divided into two categories:-

A) Natural surfactants are produced by the plants and

B) Substances produced by fermentation of alkanes, oils, sugars and waste in the presence of microbes (also called biosurfactants) [13-14].

The primary source of natural surfactants are plants. Consequently, research should concentrate on discovering, obtaining and isolating natural surfactants from plants that are present in all ecosystem. There is no limit to the number of bioactive, biodegradable compounds that plants may produce and they are less poisonous and destructive than synthetic chemicals [15]. Out of all the bioactive chemical compounds, plant

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saponinshave the most surfactant capabilities [16]. They produce a soapy lather when combined with water, therefore the term "Saponins" [17]. Due to their natural origin, they are non-toxic, biodegradable and eco-friendly all of which are essential from an environmental and health aspect. Previous studies have demonstrated that saponins have superior physicochemical capabilities than synthetic ones in addition to being bioactive. Excellent physical, chemical and biological characteristics of saponin-rich plants make them an attractive source of natural surfactants for both academic and industrial use [18].

In this review, we provide a brief overview of the molecular and physicochemical properties of plant based natural surfactant, saponins emphasizing surfactant properties similar to those of conventional surfactants along with their potential application. Here we also discuss about how saponin surfactants used in drug delivery system.

MOLECULAR STRUCTURE OF SAPONINS:

Natural saponins are amphiphilic glycosides, which contain polar glycone structure moieties (sugar part) separated from non-polar aglycone structure moieties (also known as sapogenins) [19].

On the basis of nature of aglycone skeleton present in saponins structure they are classified as two main groups

A) Steroidal saponins:- which are almost exclusively present in monocotyledonous angiosperms. It contains a steroid aglycone, a C27 spirostane skeleton, generally comprising of 6-ring structure.

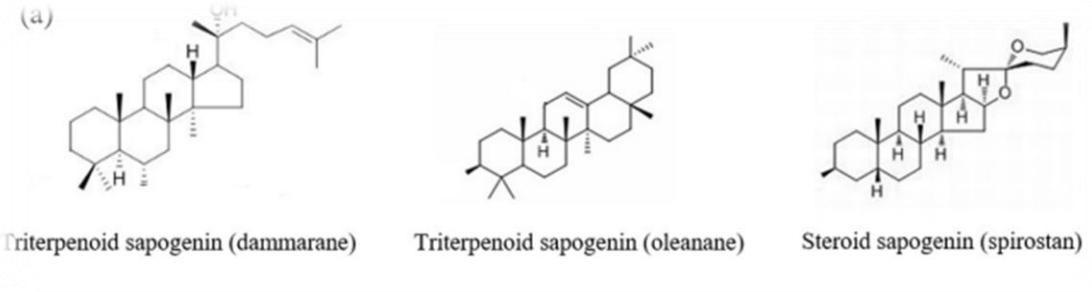
B) Triterpenoidsaponins:- It consist of Triterpenoidaglycone, which consists of a C30 skeleton, comprising of a pentocyclic structure [20].

According to the number of sugar units, saponins are classified into –

A) Monodesmosidicsaponins:- It contain a single sugar unit attached to C3.

B) Bidesmosidicsaponins:- It contain two sugar units attached to C3 and C26 or C28 and

C) Tridesmosidicsaponins:- It contain three sugar units attached [21-22].



Triterpenoid sapogenin (dammarane) Triterpenoid sapogenin (oleanane) Steroid sapogenin (spirostan)

SOURCES OF SAPONINS:

Saponins are a wide set of secondary metabolites that are primarily found in over 100 types of vascular plants, including some marine sources. Families including Fabaceae, Araliaceae, and Caryophyllaceae are examples of dicotyledonous plants, which are the main producers of Triterpenoidsaponins. The majority of steroidal saponins are produced by monocotyledonous plants, which include members of the Agavaceae, Liliaceae and Dioscoreaceae families [23].

TABLE NO.1 LIST OF SOME SAPONIN-RICH PLANTS ACTS AS NATURAL SURFACTANTS

Scientific Name	Common Name	Parts Used
Acacia cancinna	Shikakai	Pods and bark
Albiziaprocera	SetoSiris	Leaves
Acorusgramineus	Grass-leaved Sweet Rush, Japanese Sweet Flag.	Leaves
Aesculusassamica	Horse Chestnut	Leaves

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Aesculusindica	Kanor, Indian horse chestnut, Barkhor	Fruits
Asparagus racemosus	Shatavari	Roots
Camellia oleifera	Tea	Seeds
Chiococca alba	West Indian milkberry	Roots
Chlorogalumpomeridianum	Soap plant	Bulbs
Chlorophytumborivilianum	Safedmusli	Leaves
Discorea composite	Yams	Rhizomes and roots
Glinuslotoides	Soap Jacob	Roots, leaves and seeds
Glycine max	Soya bean	Sprouts and seeds
Oryza sativa	Asian rice	Peels
Phaseolus vulgaris	Kidney beans	Seeds
Pisumsativum	Green pea	Seeds
Quillajasaponaria	Soap bark	Inner bark
Tribulusterrestris	Puncture vine	Fruits
Trigonellafaenumgraecum	Fenugreek	Seeds and leaves

Surfactant Properties of Saponins:

The lipophilic non-polar aglycone and hydrophilic polar glycone moieties that make up saponins' amphiphilic structure are what give them their surfactant capabilities in aqueous solutions [24].This saponin structural characteristic is similar to a synthetic surfactant molecule [25].The hydrophilic portion of a saponin molecule is composed of water-soluble sugar chains, whereas the hydrophobic portion could be a steroid or triterpenoid that is not water-soluble [26]. Since they are non-ionic surfactants, saponins have a variety of qualities that are significant to surfactants, such as surface activity, micellization; foaming, detergency, wetting, and emulsification [27].These are extremely importantproperties to investigate for the use of saponins as surfactants.

1) Micellization Behavior and Reduction of Surface Tension:

Due to their amphiphilic structure, which is depicted with a schematic in Figure 2, the surfactant molecules in an aqueous solution display intriguing behavior with the hydrophilic head pointing toward and the hydrophobic head away from water molecules, they tend to congregate on the surface at low surfactant concentrations as shown in fig.2A [4].

Surface activity is increased and water's surface tension is decreased by this phenomena. Until they reach a concentration known as critical micelle concentration, the surfactant molecules are shown in Figure 2B to be dissociated (CMC).A cluster known as a micelle is formed when extra surfactant molecules collect above CMC. When an aqueous solution containing a surfactant reaches CMC, its stable surface tension value decreases to its lowest level [28]. The adsorption of surfactants at the surface is unaffected after micelles have formed.

The formation of micelles is therefore aided by any further rise in surfactant concentration, as seen in Figure 2C, rather than surface tension [29]. Since the creation of micelles and the phenomenon of surface tension decrease by surfactant molecules are clearly depicted in Figure 2, water molecules are not present in the illustration. Due to their amphiphilic nature, saponins exhibit surface-active capabilities in aqueous solutions just like any other surfactants. Additionally, they create micelles over CMC, which lower the surface tension of water [30].

The surface-active characteristics of surfactants can be determined using the CMC, a crucial physical parameter.Surface tension, electrical conductivity, refractive index, light scattering, and other measurable physicochemical

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properties of the surfactant solution exhibit abrupt changes at CMC. As a result, a sharp breakpoint is found in the curve when the concentration of the surfactant is plotted against it, or its logarithm in the case of surface tension.The intersection of the two fitted straight lines yields the CMC values [31]. The experimental determination of the CMC of a surfactant solution has made considerable use of this property [25].

The distinguishing characteristics of all surfactants, which include detergents, foaming agents, emulsifiers, solubilizers, and other diverse industrial applications, are the formation of micelles in aqueous solutions and the lowering of surface tension [27].

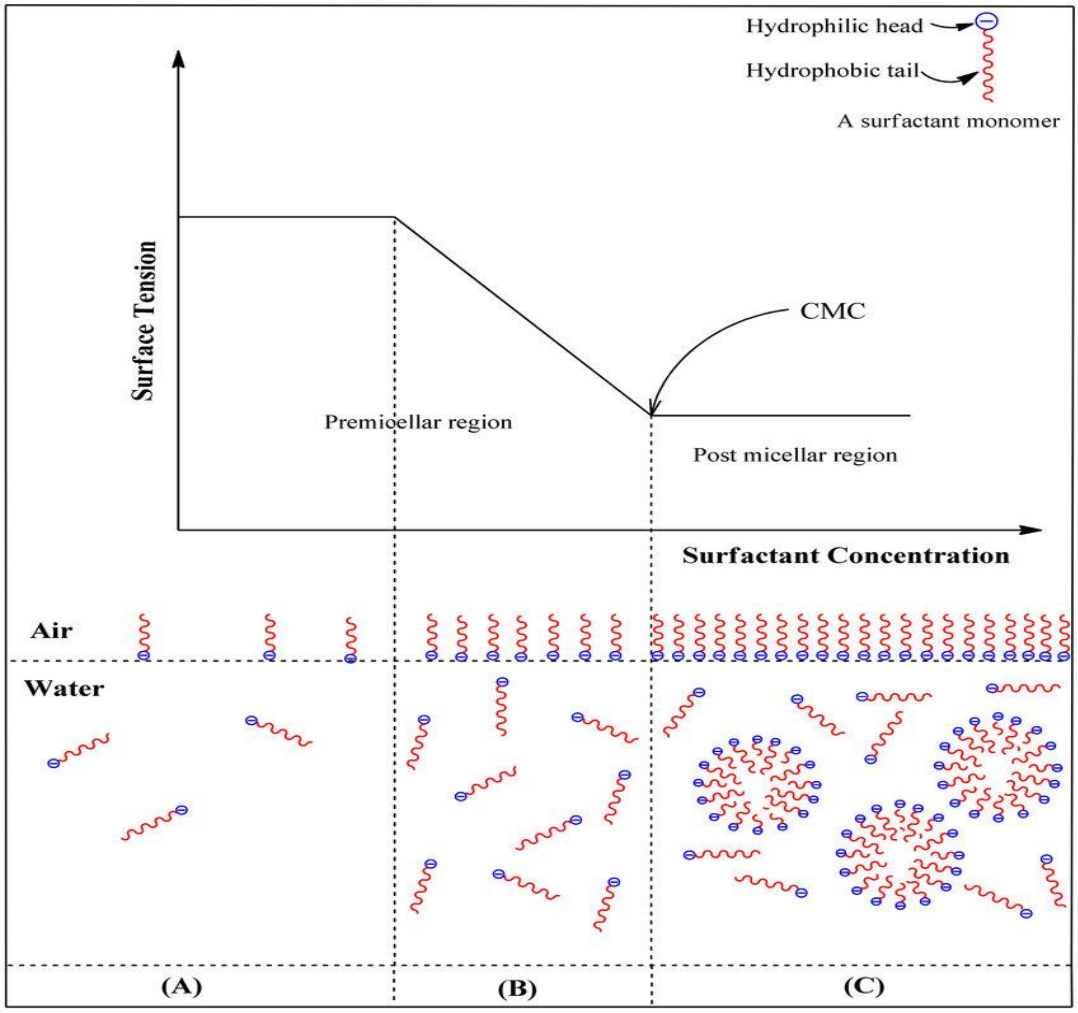

Figure 2. Diagrammatic illustration of micellization behavior of surfactants in aqueous solution. (**A**) At low surfactantconcentration, a very less reduction in surface tension is observed. (**B**) With the increased surfactant concentration, surfacetension reduces steadily till CMC is reached. (**C**) Beyond CMC, no more changes in surface tension are observed

2) Saponins as Cleaning and Wetting Agents:

Surfactants have the power to remove grease, filth, and dirt from the substrate [4]. Because of this, they are included as a cleaning component in a number of detergents for the home and personal care items. A cleaning chemical like this makes it easier to remove debris from a surface that would otherwise be difficult to wash with water. Reduced surface tension and the formation of micelles in aqueous media are both connected with a surfactant's cleaning activity [32].Wetting is a complicated phenomena brought on by the

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surfactant's adsorption at the solid-liquid interface. This process causes the interfacial tension to decrease, enhancing the wetting behaviour. Since soil, dye, lubricant, and printing can all be removed by washing, the use of surfactants as wetting agents has generated more economic interest. Additionally, they help with industrial and medical applications by limiting the dispersal of drips on solid surfaces [33].For their potential to replace traditional surfactants in cleaning and wetting applications, saponins have frequently been studied. According to Chen et al., Camellia oleiferasaponins have a moderate detergency when compared to Tween 80, SLS, and crude saponins from Sapindusmukorossi [34].

3) Saponins as Foaming Agents and Stabilizers:

An essential quality of a surfactant solution is foaming [29]. When surfactant molecules partially occupy the liquid surface, foaming results. In this process, foamy, spherical liquid films with a greater surface tension emerge from parts of the surface that are not occupied by the surfactant. However, the ability of the surfactant to clean has very little to do with foam generation, which is typically a feature desired by customers. Foams are particularly preferred for biomedical and personal care applications because of their huge specific surface area, low specific weight, and capacity to develop a variety of mechanical characteristics ranging from liquid to solid [35]. Along with quick foam creation, a consistent and acceptable foaming level is also required. As a result, dangerous alkanol amide foam stabilizersare routinely used in commercial formulations. As a result, alternatives to products that include alkanol amide are needed. Most saponins have water solubility and have the ability to froth in an aqueous solution [30]. Bidesmosidic or Tridesmosidicsaponins have not been shown to have the best foaming properties as compared to Monodesmosidicsaponins for the qualitative investigation of saponins in plant extracts; the foaming property has been exploited. Its existence is indicated by the height and duration of the froth that forms when distilled water is agitated in a test tube [17]. Saponins produce foam that is stable and in an acceptable quantity [36].Saponin is a strong option for the creation of innovative stable foams for use in biomedicine due to its great surface activity and foaming capabilities. A surfactant's foaming capacity serves as a gauge of its foaming power. It is calculated as the foam's height at the time of its immediate measurement after foam formation. The durability of the foam is gauged by its stability [37].Sapindusmukorossi has a strong foaming capacity with an R5 value of more than 60%, according to Pradhan et al [4].

4) Saponins as Emulsifiers:

Because of their ability to emulsify, surfactants are frequently used in the food, pharmaceutical, cosmetic, and other sectors to create and stabilise products that are emulsion-based [38].Because surfactants are amphiphilic, they can bind to oil-water surfaces during homogenization, reducing interfacial tension and producing stable emulsions.Previous studies have shown that natural emulsifiers can produce an effective and stable emulsion. This study led to the usage of saponins as surfactants in the creation of oil-in-water emulsions. According to Tmáková et al., saponin extracts from Sapindusmukorossi, Verbascumdensiflorum, and E. arvense are superior than synthetic surfactants (SLS and Tween 80) [27]. Saxena et al. discovered that an emulsion with the greatest stability formed at the CMC after studying the emulsification characteristics of Sapinduslaurifolius (fruit) [39].Saponins' surfactant ability is used as an emulsifier in beverages. Quillajasaponins are utilised to make beverage emulsions [40].

5) Saponins as Solubilizers:

Surfactants have a hydrophobic core that can solubilize organic non-polar substances like petroleum, dye, soil, etc [32]. Vinarov et al. examined the solubilization of hydrophobic pharmaceuticals by 13 different saponin extracts and discovered that the presence of Quillajasaponaria and Camellia oleifera improved the solubilization of danazol and fenofibrate over Brij-35 [36].

The Job of Saponinsin DDS:

The conventional effects of saponins in DDS include better bioavailability, less side effects, slow-release, and targeting. In addition, due to their biological action, saponins have a synergistic effect with medications.

1) More Enhanced Bioavailability:

The fact that many naturally occurring active chemicals have a range of possible pharmacological effects but have limited oral bioavailability due to low solubility, instability, and low permeability makes it difficult to test new medications in the beginning phases of

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research.Asper studies, saponins can bind with the several medicines to considerably boost their oral bioavailability.For instance, Cur (curcumin) was encapsulated into nanoparticles by Peng and Zhang using various saponins. Its bioavailability was roughly 8.9 to 19 times greater than that of free Curcumin in an oral dosing experiment in rats [41-42]. Additionally, when creating mixed micelles with other carrier substances like lecithin and glycocholic acid, saponins can contribute to the stability of micelles and boost bioavailability [43].The two basic explanations for how saponins increase a drug's bioavailability are covered below.

A) Enhanced Drug Solubility:

Incorporating hydrophobic medicines into DDS is a traditional technique for increasing the solubility of such pharmaceuticals in water.Some weakly water-soluble medications can be dissolved in the hydrophobic region of the carrier to increase their solubility and thus their bioavailability. Saponins can form micelles and vesicles, which are carriers that can be used to deliver pharmaceuticals. for example, Vit.K [43], Curcumin [42], Atorvastatin Calcium [44], and Praziquantel [45] saponins can encapsulate them, greatly increasing their solubility.

According to studies, QS enhances the solubility of cholesterol in aqueous solutions by 103 fold, outperforming the common surfactants Tween 20 and Triton X-100 [46].

B) Enhanced Membrane Permeability:

Saponins have various ways by which they can improve the penetration of biological membranes. For instance, the cell membrane and -hederin interact in a certain way. When its concentration exceeds CMC, it interacts with membrane cholesterol and aggregates, creating temporary holes in the cell membrane and entering the membrane when its concentration is higher than CMC [47]. Saponins can also improve transdermal penetration for medicines applied topically. Carvedilol was loaded onto rat skin and then worked on by the GA-chitosan mixture. Under an electron microscope, changes in the lipid structure, separation of the keratinocytes, and an increase in the space between epidermal cells were seen after delivery, which may have aided carvedilol's transdermal absorption [48].

2) Reduced side effects:

When used with DDS, saponins can exhibit "attenuation" effects. The saponin-drug complexes demonstrated reduced cytotoxicity than the original medicines in a variety of in vitro toxicity tests [49].The antidepressant fluoxetine (FL) has a limited therapeutic index, which results in severe toxicity and impairs liver and kidney function.The LD50 was dramatically enhanced by the 4:1 combination of GA:FL while the dosage of FL was decreased, lessening its adverse effects. The substance was given the trade name "fluoglyzin" in a patent (FG) [50].

3) Synergistic Effects:

The beneficial pharmacological actions of saponins, particularly in cancer, are what cause the synergistic interaction between medicines and saponins. As a result, it is particularly clear how saponins and anticancer medications interact.More than 150 different forms of saponins have been proven in studies to have anticancer properties, particularly for colon, liver, breast, and lung cancer [51]. Malignant glioma, colon cancer, lung cancer, and liver cancer can all be inhibited by the saponin GA, which has a broad-spectrum anticancer effect [52-54]. Multi-drug resistance may play a role in how saponin-anticancer medicines can enhance the therapeutic impact after building a complex (MDR). P-gp is a multi-drug resistant protein that functions as a key drug transporter on the membrane of MDR tumour cells. It can mediate drug efflux. It has been demonstrated that ginsenosides and diammoniumglycyrrhizinate both inhibit P-gp, potentially lowering anticancer drug resistance [55-56]. In addition to greatly raising the intracellular drug concentration of anticancer medications, using GA as a carrier material can also lessen the tissue damage and anti-multidrug resistance brought on by chemotherapy and radiotherapy. Additionally, it has a synergistic impact on medications, enhancing the effectiveness of the combination drug over the individual drug [54]. The studies indicate that saponin is a promising anticancer drug carrier material.

II. CONCLUSION:

More and more natural products are being adopted worldwide as alternatives to synthetic ones as environmental consciousness rises. Petrochemicals make up the majority of the raw ingredients used to make synthetic surfactants. Most of these items are poisonous and non-biodegradable due to their petrochemical nature, harming the environment. Natural surfactants, as opposed to synthetic ones, are obtained directly from nature, specifically from

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plants**.**Utilizingnatural surfactants aids in minimising environmental degradation brought on by the over use of synthetic surfactants in numerous industries. Therefore, further research should be done on natural surfactants that are widely dispersed in nature. Therefore, future research should concentrate on finding additional naturally occurring surfactants derived from plants.One important focus has switched toward using saponins instead of synthetic ones in a variety of domains of application as they have grown in favour among scientists as a sustainable alternative source of natural surfactants. In addition, it has received support from tighter environmental regulations and rising consumer demands. The development of more herbal products has been promoted as aresult.Natural surfactants with saponin bases are important in DDS and can be employed as drug carriers with outcomes that are sometimes superior to those of conventional surfactants. Additionally, unlike typical surfactants, distinct saponins have unique biological properties and can interact synergistically with medications. Further study is required to fully grasp the mechanisms and enhance the effects of saponins in order to maximize their application in the near future. It is thought that saponins play a more significant role in DDS.

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