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syrup (concentrated juice; *Yucca* extract), and dried and finely powdered logs (*Yucca* powder) are of particular interest to cosmetic, pharmaceutical and beverage industries as well as animal nutrition [77]. These products possess foaming features that are of particular interest in cosmetic, soft drinks (root beer), food and feed industries [78].

In the United States, *Yucca* is listed in The Code of Federal Regulation [79]. In Japan, *Yucca* extract (extract of whole plant of *Yucca arborescens* or *Y. schidigera*) is listed in the List of Existing Food Additives [80]. Because steroidal saponins in *Yucca* exhibit antifungal activities, *Yucca* extract has been added to food as a ‘shelf life extender’ in the Japanese market. *Yucca* powder water extracts can be successfully used in confectionery/food industries for improving both product quality and shelf stability. Sucharzewska and co-workers documented that *Yucca* extract contains two groups of beneficial substances. One group is formed by steroidal saponins, which may improve product quality (porosity, density, and hardness), and the second one is created by antioxidants that are able to reduce fat oxidation and extend food quality during shelf-life time [81]. It is also worth to note that *Yucca* extracts may be used as natural, non-toxic deodorizers. The studies conducted in Poland show that combined treatment with microbial preparations and *Yucca* extract can significantly reduce the concentration of odorants in poultry manure [82]. Natural saponin extracts, namely those that may be obtained by steam treating the pulp of *Yucca* with water, in combination with proteins exhibit a synergistic effect, eliminating odors from the breath and oral cavity of humans, as well as from other environments [83].

Tenon and co-workers used HPLC/ELSD technique for *Yucca* steroidal saponin quantification. This method is effective for routine industrial analyses for saponin fingerprints and capable of distinguishing saponin profiles from taxonomically distant species [78].

The second saponin source of commercial value is *Quillaja*. The term ‘quillaia’ refers to the dried inner bark of the tree, which is a large evergreen with shiny, leathery leaves and a thick bark, native to China and several South American countries, principally Bolivia, Chile, and Peru [84, 85]. The bark of this tree was used as shampoo in for hundreds of years. *Quillaja* extracts contain over 100 triterpenoid saponins. The basic structure of them is the hydrophobic triterpenoid quillaic acid known as sapogenin, and the hydrophilic sugar moieties are attached at two positions: di- or trisaccharide at C3 and oligosaccharide at C28 [85]. Young plants usually exhibit less heterogeneous saponin profiles than those obtained from mature extracts [87].

A large amount of *Quillaja* saponin is mainly utilized as a surfactant. It is also used in beverages, food ingredients, shampoos, liquid detergents, toothpastes and extinguishers as an emulsifier and long-lasting foaming agent. Additionally, a saponin mixture possessing immune-adjuvant properties was given a pharmaceutical application, as a suspension stabilizer [88].

The beneficial effects of extracts from *Yucca* and *Quillaja* are well documented. The extracts from these plants may influence microbial fermentation. Inhibition of gut microbes, particularly *Streptococcus bovis*, *Butyrivibrio fibrisolvens*, *Escherichia coli* and rumen protozoa has been reported [74]. Extracts of *Y. schidigera* and *Q. saponaria* have been used as ‘food grade’ sapo‐nins. This term is widely used by manufacturers, and it is defined as any grade or preparation of saponin which is approved for use in food and beverages under the United States Food and Drug Administration (FDA).
According to the Codex Alimentarius Commission, extracts from *Q. saponaria* may be used as a foaming agent in ‘water-based flavored drinks’, including ‘sport’ or ‘electrolyte’ drinks and particulate drinks (GSFA category 14.1.4, 500 mg/kg maximum use level). In soft drinks, unpurified *Quillaja* extracts are used at dose up to 200 mg/kg. However, in syrups intended for dispensable frozen beverages (FCBs) or frozen lemonades, *Quillaja* extracts may be up to 500 mg/kg on dry solid basis [87].

Although *Quillaja* and *Yucca* saponins are not considered Generally Recognized As Safe (GRAS) by FDA, they have been assigned as GRAS by Flavor and Extract Manufacturers’ Association of the United States (FEMA) with FEMA number 2973 [21, 87]. *Quillaja* extracts are classified as type 1 and type 2 based on their saponin content, 20–26% and 75–90%. *Quillaja* extract, type 2, is used in Japan as an emulsifier for preparations containing lipophilic colors or flavors that are added to soft drinks, fermented vegetables, and dressing [87]. Other saponins used food additives include enzymatically modified soybean saponin, *Pfaffia* and *Yucca* extracts, and tea seed saponins [80].

In the European Union, *Quillaja* extract is classified as the foaming agent for use in water-based, flavored non-alcoholic drinks and labeled as E999 (200 mg/l calculated as anhydrous extract) [87].

The physiochemical properties of saponins can also be utilized in food processing applications, thus, while complex formation of saponins with cholesterol has been used for the removal of cholesterol from dairy products such as butter oil [89–91]. It was documented that the natural food-grade surfactant isolated from the bark of the *Q. saponaria* Q-Naturale® may be able to replace synthetic surfactants in food and beverages [92]. The interaction of saponins with cell membranes has been considered for the selective precipitation of fat globule membranes from cheese whey. In this application, saponins are used to increase the hydrophobicity of the fat membrane to facilitate flocculation and precipitation of the formed complexes.

As a natural surfactant, *Q. saponaria* saponins demonstrated good performance in manufacturing orange oil nanoemulsions. This fact may permit the manufacture of good quality orange oil-based nanoemulsions in beverage and alcohol-free mouthwash applications [93, 94]. *Quillaja* saponins show a high surface activity and functionality to solubilize a lutein ester extract for its incorporation in food matrices [86]. Additionally, it was documented that the mixtures containing *Quillaja* saponins and lecithins were rather unaffected upon heating from 25 to 75°C. Therefore, these results provide important insights into selecting surfactants to be used in specific food applications, for example, whether the food will be heat treated or not. This type of structure modulation through different environmental conditions and heating may also be useful for structure design in pharmaceutical applications [95].

Dried roots of licorice represent an important agricultural product. The name ‘glycyrrhiza’ originates from the Greek words ‘glykosrhiza,’ which mean ‘sweet root.’ Licorice is used as a sweetener and a flavor enhancer for foods in China and other countries. It is approved by Food and Drug Administration USA as a food additive, regarded with the ‘GRAS’ label and registered as CFR 184.1408 [33].


