Egyptian Opuntia ficus-indica (OFI) Residues: Recovery and Characterization of Fresh Mucilage from Cladodes

Abstract

The utilization of biopolymers gained recent attention worldwide due to their effective role in producing eco-friendly and economical products. Mucilage from Opuntia ficus-indica (OFI, and other succulent plants) has the capacity to absorb huge amounts of water, forming a viscous colloid with interesting rheological properties. It also had the potential ability for use as food additives or food technological products. We, therefore, aimed at extracting and characterizing pure liquid mucilage from the cladodes of OFI (Egyptian variety) using multidimensional approaches including HPLC-RID, FTIR, XRD, NMR, DSC, and TGA assays. The chemical composition, total polyphenols, total flavonoids, total flavonols, and antioxidant capacity by DPPH and ABTS assays were also measured. HPLC-RID analysis showed that the mucilage's sugars are composed of glucose, xylose, rhamnose, galacturonic acid, arabinose, galactose, and fucose with total sugars of 0.375 mg/mL, which were subsequently confirmed by FTIR and NMR results. The specific signals of these sugars were also observed in 13C and 1H NMR spectra and their chemical fingerprint was obtained by FTIR. XRD patterns showed that mucilage has high calcium content, and the glass transition temperature was observed at 85.9 °C. Meanwhile, total phenolic content, flavonoids, and flavonols were about 7.96 mg GAE/g FW, 3.61 mg QE/g FW, and 1.47 mg QE/g FW, respectively. The antioxidant capacity of mucilage was around 26.15 and 22.5 μmol TE/g FW for DPPH and ABTS methods, respectively. It can be concluded that OFI

cladode mucilage showed promising properties that would improve and open new opportunities and trends in the food, pharmaceutical, cosmetic, and other industries. The use of pure liquid mucilage could also be economically profitable due to its low cost, availability, and effectiveness for many edible applications.

Keywords: Opuntia ficus-indica; biopolymers; mucilage; bioactive compounds; liquid extraction

Graphical Abstract

١. Introduction

The consumer's interest in more natural and healthy products has recently led to research and development for natural compounds with bioactive properties that can replace synthetic compounds [1]. Due to the rising demand for goods that promote health and wellbeing, one of the food industry's fastest-growing segments is functional foods, for instance. Among synthetic compounds added to food as food supplements or food-improving technological properties, polymers cover a pivotal role. Polymers help to improve the texture and rheological features of food [2]. Recently, plant-derived biopolymers, such as mucilage, have received significant attention due to their effective role in producing eco-friendly and economical products [3]. For example, the worldwide hydrocolloids market has expanded significantly recently due to the rising demand from various industries (oil, paper, pharmaceutical, textiles, and food), reaching $8.5 billion in 2022. Mucilage belongs to the class of soluble dietary fibers, constituted by large molecules of sugars and uronic acids. Mucilage can be classified as a hydrocolloid as it is a long-chain polymer that dissolves in water to give a thickening or viscosity-producing effect. The mucilage in plants plays various functions, such as H2O storage, seed germination helper, and thickening of membranes [4]. For human utilization, plant mucilage has been traditionally exploited for food, cosmetic, and pharmaceutical industries due to its non-toxic and biodegradable properties [5]. It is used as a natural gelling agent to increase thickening, texturizing, stabilizing, or emulsifier as an alternative to synthetic polymers and additives [6]. The production of natural edible coatings with a high nutraceutical value, helpful for the preservation of fruit and food, is further made fascinating by the rheological properties of mucilage; its concentrations vary on genotype, cladode age, and environmental factors. However, seeking innovative and low-cost sources for plant mucilage is still demanded.

In this context, Opuntia ficus-indica L. (OFI), i.e., cactus pear, prickly pear, Indian fig, or barbary fig) is one of the most promising and economic sources of mucilage [3]. On around 100,000 acres, OFI plants are grown for use as fruits and vegetables in more than 30 countries. Mucilage from OFI (like other succulent plants) has the capacity to absorb huge amounts of water, forming a viscous colloid with interesting rheological properties, and has the potential use as an additive for several industrial products [7.[

Meanwhile, OFI, cultivated or wild, can be found in various agro-climatic conditions, especially in warm climates, throughout the world and in the Mediterranean basin. Several parts of the plant have been used for centuries as a medicinal

remedy. The anatomy and physiology of OFI make this plant a multipurpose dryland crop destined to become more important in view of an ever-increasing world population and water and land scarcity [8]. OFI is cultivated mainly for fruit production, but also for forage, in lands suffering from aridity during drought periods when there is a shortage of herbaceous plants. It is also cultivated to produce tender pads, called 'nopalito', limited to Mexico and Southern US, where it is traditionally consumed both as fresh and/or processed stuffs [9.[

OFI fruits contain polyphenols and betalains, promising protective agents against inflammation, oxidative stress, and metabolic-related diseases [10,11]. Cladodes are not only rich in polyphenols but also contain polysaccharides and soluble fibers which are able to counteract hyperglycemia and related physiological disorders. Recently, the health benefits of OFI have received much attention owing to its content of bioactive compounds .