Tropical fruits and by-products as a potential source of bioactive polysaccharides

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Abstract

Consumption of tropical fruits is growing around the world, not only due to their flavor and appearance but also for their nutritional value. In addition to the content in macro and micronutrients, tropical fruits contain substantial amounts of bioactive compounds in peels and seeds, which constitute an underexploited source of bioactive compounds such as phenolic acid, polyphenols, carotenoids, vitamin C and polysaccharides. Polysaccharides have attracted growing interest, particularly for their bioactive characteristics such as antioxidants as well as antiinflammatory, antimicrobial, anticoagulant, hepatoprotective and immunomodulatory properties. Therefore, obtaining functional ingredients from tropical fruits and by-products is feasible, and could be used to develop functional and nutraceutical foods to elaborate products of the pharmaceutical industry and food preservation. The present review provides the most relevant information published over the last ten years (2010-2020) on bioactive polysaccharides extracted with hot water reported in tropical fruits and by-products and their relationship with potential beneficial health effects.

Keywords: By-products, tropical fruits, polysaccharides, bioactive properties.

Introduction

Tropical fruits grow in tropical or subtropical climates in the geographic zone that extends from 30° south latitude up to 30° north latitude. The temperature in this area varies between 16 to 36 °C during the year (Dembitsky et al., 2011). The Food and Agriculture Organization (FAO) of the United Nations, estimated in 2018 that the world production of the main tropical fruits reached around 100 million tons, with an estimated increase of 3.3 % expected by the end of 2020.

The most widely consumed tropical fruits, such as avocado (Persea americana), mango (Mangifera indica), papaya (Carica papaya) and pineapple (Ananas comosus), have reached significant commercial success. They are available practically all year in areas with temperate climates (FAO, 2018). Other fruits such as açai (Euterpe oleracea), acerola (Malpighia emarginata), guava (Psidium guajava), jujube (Ziziphus jujuba), litchi (Litchi chinensis), longan (Dimocarpus longan), noni (Morinda citrifolia), passion fruit (Passiflora edulis) and pomegranate (Punica granatum), are struggling to find market sale sites since these fruits are imported from traditional producing countries. However, these fruits are increasingly in demand in international markets for their characteristic flavor, high nutrient content and variety of bioactive compounds such as phenolic acids, flavonoids, carotenoids and fiber (Enriquez-Valencia et al., 2020).

Over 50% of the global volume of tropical fruit produced each year is discarded as by-product, 42% of which is comprised of peels, rind/skin and 10% of seeds (Cheok et al., 2018). Most of the tropical fruits have substantial amounts of mainly polysaccharides in peel, rind/skin, seeds and pulps, which possess a varied biological activity.

Polysaccharides are polymeric carbohydrate molecules composed of long chains of monosaccharide units...
bound together by glucosidic bonds that generate various structures, with different biological properties (de Jesus Raposo et al., 2015). Polysaccharides extracted from tropical fruits and sub-products have gained interest due to their numerous biological activities such as antioxidant, antifatigue, antiinflammatory, anticoagulant, hepatoprotective, immunomodulatory, antidiabetic and anticancer (Zhang et al., 2016; Sousa et al., 2018). This review discusses the most relevant information published in the 2010-2020 period from the main scientific databases, including Scopus, Science Direct, PubMed, Medline and Scielo, on polysaccharides and reported bioactivities of exotic tropical and their relationship with their potential beneficial effects on health.

**Hot water extraction (HWE)**

The extraction is a crucial process in polysaccharides isolation and production. Several methods have been applied to extract them from different plant sources, such as tropical fruits and by-products (Maric et al., 2018). One of the most common methods employed is hot-water extraction (HWE), consisting on the immersion of the raw material into distilled water at high temperature, and further steps such as filtration, centrifugation, precipitation, concentration, and freeze-drying to obtain crude polysaccharides. Additionally, it has been stated that extraction factors, such as temperature, time, and solvent/material ratio, significantly affect the yield of extracted polysaccharides. HWE has been used in the extraction of polysaccharides from by-products and tropical fruits such, açaí, acerola, guava, jujube, litchi, noni, passion fruit and pomegranate (Holderness et al., 2011; Joseph et al., 2012; Huang et al., 2017); the scientific names, common names and place of origin of the tropical fruits examined in this review, are shown in table 1.

**Structural characteristics of tropical fruit polysaccharides and by-products**

The physicochemical and structural characteristics of polysaccharides, mainly include monosaccharide composition, molecular weight, configuration, type, and position of its glycosidic bond (Liu et al., 2015). Several polysaccharides have been isolated from tropical fruits and their by-products, by a sequence of techniques such as deproteinization and ion-exchange chromatography (IEC), that separates acidic and neutral polysaccharides applying different concentrations of salts such as NaCl, as an eluent solution (Huang et al., 2014).

In order to separate the different molecular weight polysaccharides, methods such as high-performance liquid chromatography (HPLC), gel permeation chromatography (GPC), high-performance gel permeation chromatography (HPGPC) and size exclusion chromatography (SEC) (Li et al., 2020; Batista et al., 2020), are utilized. To determine the monosaccharide composition, Holderness et al. (2011) and Jiao et al. (2018) reported the application of gas chromatography coupled to mass spectrometry (GC-MS), HPLC, and high-performance or anion-exchange chromatography coupled with pulsed amperometry detection (HPAECPAD). After this step, polysaccharides are subsequently collected, dialyzed, concentrated and lyophilized to produce a pure polysaccharide.

Polysaccharides with various monosaccharides, chemical structures and functional groups, are analyzed with a combination of methods such as Fourier transform infrared spectroscopy (Rong et al., 2019), GC-MS (Hu et al., 2020), periodate oxidation-Smith degradation and methylation analysis (Wang et al., 2015; Rong et al., 2019) to determine the backbone structures. Nuclear magnetic resonance (NMR) is commonly used to analyze the configurations of glycoside residues of the polysaccharides. One-dimensional (1D) proton and carbon nuclear magnetic resonance spectroscopy (1H and 13C NMR) have been generally employed for their structural characterization (Zhang et al., 2016).

Many different polysaccharides have been isolated from seeds, rinds, pulp and peels from tropical fruits, and the structural characterization, including monosaccharide chain, ratios of the monosaccharide compositions and molecular weight, are summarized in Table 2.

Characteristics such as sugar compositions, molecular weight, sugar backbone, ratios of the monosaccharide compositions and position of the functional groups are im-

### Table 1

| Name          | Scientific name | Other names | Origin                          | Reference                  |
|---------------|-----------------|-------------|---------------------------------|----------------------------|
| Açaí          | Euterpe oleracea | Naidí, azai, acai | North of Brazil                 | (de Oliveira and Schwartz, 2018) |
| Acerola       | Malpighiae marginata | Semeruco, cercita | Brazil                          | (Prakash and Baskaran et al., 2018) |
| Guava         | Psidium guajava  | Semeruco, cercita | Mexico, Central and South America | (Chen et al., 2015) |
| Jujube        | Ziziphus jujube  | Jujube      | South and east Asia              | (Hasan et al., 2014)        |
| Litchi        | Litchi chinensis | Lichi, lychee, Hong Hua | Malay Peninsula                | (Soni and Agrawal, 2017) |
| Longan        | Dimocarpus longan | Dragon eye | China                           | (Lim et al., 2013)          |
| Noni          | Morinda citrifolia | Fruta del diablo, Indian mulberry | Southeast Asia                | (Carrillo-López and Yahia, 2011) |
| Passion fruit | Passiflora edulis | Pasionaria, chinola | Southern Brazil                | (Lim et al., 2012)          |
| Pomegranate   | Punica granatum  | Himalayan region |                               | (Jacob et al., 2019)        |
Biological activities of fruit polysaccharides

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Table 2. Caracterización de polisacáridos de las frutas tropicales en esta revisión.
Table 2. Characterization of polysaccharides from tropical fruits considered in this review.

| Fruits | Part | Mono saccharide composition | Molar ratio (%) | MW KDa | Backbone structure | Other compounds | Reference |
|--------|------|-----------------------------|-----------------|--------|------------------|----------------|-----------|
| Açaí  | Fruit | Fuc:Rha:Ara: Gal:Glu:Xyl: GalA:GalA | 0.5:4.5:47: 11.5:2.3: 2.8:28.4 | 200 | β-(1,3) -linked galactan | Protein | Phenolics (Holderness et al., 2011) |
| Acerola | Fruit | UroA:Ara: Gal:Xyl:Rha | 52:23:32:4: 7.2:4:83:5 | 75 | (15) -linked α-Araf | Protein | Klosterhoff et al., 2018 |
| Bitter gourd | BP1 Fruit | Rha:Ara: Xyl:Man: Glu: Gal | 2.73:9.84: 3.83:5.46: 23.5:54.6 | 85 | ND | Purified | (Li et al., 2010) |
| BP3 Fruit | Rha:Ara: Xyl: Man:Glu: Gal | 2.21:8:29:3:31:11.6:19:34:55.25 | 100 | ND | Purified | |
| Guava | Fruit | Rha:Glu: Gal:A: Gal: Ara | ND | ND | (15) -linked α-L-Ara (13) -linked α-L-Ara | Purified | (Jiao et al., 2018) |
| Jujube | JPC Fruit | Man:Rib:Glu: Gal: GlcA: Gal: Man: Xyl: GalcA: Glu: Xyl: UroA | 5.3:3:1:3:6: 11.4:13:4:14:5:23.4: 25:1:25 | ND | ND | Protein | (Chi et al., 2015) |
| Litchi | Pulp | Rha:Ara: Xyl: Man:Glu: Gal | 0.31:5:44: 71:2:2:6:6:11:1.5 | 970 | ND | Protein | Phenolics (Huang et al., 2017) |
| Seeds | Ara:Man:Glu: Gal | 6.33:3:38: 10:4:1:1 | 6.70 | 1,4-α-Glc and 1,4-β-Man | Purified | (Wu et al., 2020) |
| Longan | LPD2 Pulp | Ara:Man:Glu: Gal | 0.25:0.49:1: 0.5 | 9640 | (14)-β-Glc and (16)-β-Man | Acetyl groups | (Rong et al., 2019) |
| Noni | Juice | Gal:Gal:Ara: Rha:Man | 29:1:30:9: 31:5:4:3:6 | ND | ND | Acetyl groups | (Sousa et al., 2018) |
| Pomegranate | Rind | ND | ND | 110 | 8-1-3 galactop | ND | (Joseph et al., 2012) |

ND: Not determinated; MW: Molecular weight; KDa: Kilodaltons.
Fuc: Fucose, GalA: galacturonic acid, Gal: galactose, Glu: glucose, Ara: arabinose, Ram: rhamnose; Man: mannose, Xyl: Xylose, UroA: Uronic acid, p:pyranose.
that acerola polysaccharide presented the highest scavenging activity, decreasing in a 59% the ABTS radical, followed by polysaccharides from pineapple (55%), passion fruit (34%), and mango polysaccharide with the lowest scavenging capacity (10%) at the same concentration.

The in vivo antioxidant effects of polysaccharides from tropical fruits and by-products were also investigated. Chi et al. (2015) reported that oral administration of polysaccharide conjugates from jujube (200 mg/kg) in rats, increased the activities of the antioxidant enzymes glutathione peroxidase (GSH-Px) and superoxide dismutase (SOD) to 20.4 and 17.2%, whereas the level of malondialdehyde (MDA) decrease 31.4%. In a different study, Sousa et al. (2018) reported that polysaccharide extracted from noni (10 mg/kg) stimulates glutathione-S-transferase about two-fold and decrease malondialdehyde levels about 8.2-fold in rats with carrageenan-induced paw edema.

**Immunomodulatory activity.** It has been demonstrated that immunomodulatory polysaccharides can interact with the immune system, leading to the activation and triggering of several molecular and cellular events or suppressing the activity of lymphoid cells (Minzanova et al., 2018; Yin et al., 2019). In this sense, different studies have reported in vivo and in vitro immunomodulatory activities of polysaccharides from tropical fruits and by-products. Rong et al. (2019) isolated a polysaccharide (LPD2) from longan pulp. They observed that the treatment with 50 µL of LPD2 at concentration of 100 µg/mL, increased the splenic lymphocytes by 250% and the macrophage phagocytosis by 205.1% to the control value. In other studies, longan pulp polysaccharides were evaluated at 100 and 200 mg/kg, both treatments showing potent immunomodulatory properties in mice models, including enhanced DTH response, macrophage phagocytosis and ConA-stimulated splenocyte proliferation (Zhong et al., 2010).

Polysaccharide (LCP50W) isolated from litchi pulp exhibited in vivo immunomodulatory activity, enhancing Natural Killers (NK) cells cytotoxicity and promoting mouse splenocytes proliferation (Huang et al., 2014).

Furthermore, LCP50W enhanced Th1 cytokine IFN-γ secretion, reduced Th2 cytokine IL-4 secretion, and improved T-bet expression while inhibiting the GATA-3 gene expression. In addition, LCP50W promoted the cell cycle toward the S phase (Jing et al., 2014). Three polysaccharides fractions (GSF1, GSF2 and GSF3) were isolated from guava seeds, and administered to mouse splenocytes and peritoneal macrophages to confirm the activity, based on changes in Th1/Th2 and pro-inflammatory and anti-inflammatory cytokines secretion, respectively. All fractions, particularly GSF3, were found to have a Th2-inclination activity and anti-inflammatory capacity (Lin and Lin, 2020). Polysaccharides induced robust y6 T cell stimulatory activity in human, mouse, and bovine PBMC cultures. Also, it was found that acai polysaccharides were active by promoting myeloid and y6 T cells activation, and when polysaccharides were delivered in vivo in mice, they induced myeloid cell recruitment and IL-12 production (Holderness et al., 2011).

**Modulation of blood glucose.** Modulation of blood glucose properties of the polysaccharides is mediated different ways including inhibiting α-amylase and α-glucosidase activities, improving cell dysfunction, targeting signaling pathways to improve glucose metabolism and enhance insulin action (Yuan et al., 2019).

The α-glucosidase can hydrolyze α-1,4-glycosidic bonds from non-reducing ends of polysaccharides to release glucose. The released glucose is absorbed by the small intestine into the blood, increasing the blood glucose level and aggravating type II diabetes; therefore, the inhibition of this enzyme is important to regulate blood glucose.

Several studies have reported the inhibition of this enzyme in vitro by polysaccharides of tropical fruits and by-products. For example, Zhang et al. (2016) described that the water-soluble polysaccharide (GP-90) isolated from guava pulp showed α-glucosidase inhibition with IC50 value =2.27µg/mL, this value was 1379 times higher than the positive control acarbose (IC50=3.13 mg/mL). Similar findings have been reported by Jiao et al. (2018) in the polysaccharide (GP70-3) from guava fruit also exhibited an important α-glucosidase inhibitory activity in vitro (IC50=-2.54 µM), which was 1867 times higher than acarbose (IC50=-4.74 mM). Also, an isolated polysaccharide from litchi seeds (LSP-W-4) exhibited inhibitory activity against mammalian (rat-intestinal acetone powder) and yeast (Saccharomyces cerevisiae) α-glucosidase, with IC50 values of 66.97 and 75.24 µM, respectively (Wu et al., 2020). Moreover, the oral administration of 200 mg/kg lychee polysaccharide suspension showed a glucose-lowering effect decreasing from 29.3 to 23 mM/L after 30 min administration to alloxan-induced diabetic rats (Huang et al., 2017).

Polysaccharides derived from jujube (ZSP) at 0, 200 or 400 mg/kg were administrated intragastrically to fructose treated mice with (20% high-fructose water), which had impaired insulin sensitivity, hyperglycemia and hyperinsulinemia. Administration of ZSP at 400 mg/kg reduced the levels of glucose in serum from 9.62 to 8.42 mEq/L, insulin concentrations were lowered markedly from 72.73 to 44.61 pmol/L, the homeostasis model assessment for insulin resistance (HOMA-IR) score of the mice treated with 200 or 400 mg/kg displayed a reduction of 25.3 and 31.3%, compared to the control group. Also, the β-cell function values (HOMA-β) were reduced by 10.6 and 20.0%, at 200 and 400 mg/kg, respectively (Zhao et al., 2014).

The studies reported above indicated that polysaccharides from tropical fruits and by-products showed the capacity to modulate glucose on blood.

**Anticancer activity.** Polysaccharides isolated from fruit sources have been described to act on cancerous cells, primarily via apoptosis induction. Polysaccharides from tropical fruits act through DNA damage, disruption of mitochondrial membrane, cell cycle arrest and nitric oxide production, to kill cancer cells and prevent metastasis (Khan et al., 2020).

The antiproliferation impact of jujube polysaccharides on melanoma cells indicated a dose and time-dependent behavior. The IC50 value was 3.90 mg/mL after 24 h of treatment,
and reduced to 3.36 mg/mL after 48 h. The cell cycle assay showed that polysaccharides decreased cyclin B expression, causing the arrest of melanoma cells in the G2/M phase (Hung et al., 2012). In another study, Huang et al. (2014) showed the inhibitory effect of polysaccharides from litchi pulp on the proliferation of human liver (HepG2) and human cervical (Hela) cancer cells, of 41.4 and 26.7 %, at 750 µg/mL, respectively, while the growth of human lung epithelial (A549) cancer cells decreased 27.2 % at 450 µg/mL.

Polysaccharide (PSP001) isolated from pomegranate was evaluated on KB (nasopharyngeal carcinoma), K562 (leukemia) and MCF-7 (breast cancer) cells, as an antineoplastic agent. The effects were observed at 72 h of incubation for K562 cells and MCF-7 at a concentration of 0.001 µg/mL, with IC50 values of 52.8 and 97.21 µg/mL. PSP001 showed its best cytotoxicity to 200 µg/mL against KB and MCF-7 cell lines, while in K562 cell line was at 1000 µg/mL (Joseph et al., 2012). Additionally, polysaccharides from passion fruit (PFPM) dissolved in water, were administered to mice transplanted with the Sarcoma 180 tumor into the left hind groin. A tumoral growth inhibition was observed. The oral administration of PFPM at 50 and 100 mg/kg inhibited the tumor growth by 40.5 and 48.7 %, respectively. The intraperitoneal administration (10 and 25 mg/kg) led to tumor inhibition of 70.4 and 72.89 %, respectively. The author concluded that inhibition is associated with the proportion of extensive coagulative necrosis of the tumors extirpated from treated mice (Silva et al., 2012).

**Antinflammatory activities.** Inflammation is a complex biological reaction of vascular tissue to detrimental stimuli, such as pathogens, damaged cells or irritants, that consists of both vascular and cellular responses (Yan-Hang and Ke-Wu, 2019). The continuous presence of inflammatory mediators such as interleukin 1-beta (IL-1β) and tumor necrosis factor-alpha (TNF-α) can upregulate nitric oxide production and prostaglandin E2. Also, enhancing the activity, cyclooxygenase-2 (COX-2), the stimulation of inducible NO synthase (iNOS) and microsomal PGE synthase-1 (mPGES-1) expression in target cells, play a critical role in developing various significant pathologies, including colitis, atherosclerosis, chronic fatigue syndrome, cardiovascular disorders, neurodegenerative diseases, and some types of cancer (Chi et al., 2015).

Some studies have supported the anti-inflammatory activities of the polysaccharides from tropical fruits. PFPe, a polysaccharide from passion fruit, was applied on carrageenan-induced rat paw edema. Carrageenan (50 µg/paw) provoked edema that reached a maximum level after 3 h. Intraperitoneal treatment with PFPe at doses of 0.3, 1.0 or 3.0 mg/kg, resulted in a reduction of paw edema formation at 3 h of 34.2, 39.5 and 60.6%, respectively. However, only the treatment at 3 mg/kg could decrease the inflammatory response caused by histamine (85.3 % reduction), serotonin (5-HT) (58 % reduction), or PGE2 (62.2 % reduction). The results indicate that PFPe administration decreases the inflammatory response by modulating the release or synthesis of serotonin and histamine by reducing neutrophil migration (Silva et al., 2015).

Yue et al. (2015) described that wild jujube polysaccharides (WJPS) alleviated inflammatory bowel disease, in mice with colitis induced by 2,4,6-trinitrobenzene sulfonic acid (TNBS). WJPS significantly decreased the severity of colitis and improved the mucosal damage in mice. Treatment with WJPS decreased the inflammatory reaction by attenuation of IL-6, IL-1β, and TNF-α stimulis tests.

Batista et al. (2020) showed that polysaccharides from noni (PLS) exhibited significant anti-inflammatory activity in a rat model using acetic acid-induced colitis. Administration of PLS at 3 mg/kg, reduced IL-1β and TNF -α levels in the colon (1.61 and 2.90 pg/mL) compared to the colitis group (3.58 and 4.71 pg/mL), respectively. Also, it inhibited the colon expression of COX-2 (0.32 COX-2/p38) compared to the colitis group (0.66 COX-2/p38). The author implies that PLS shows anti-inflammatory capacity against intestinal injury by reducing the pro-inflammatory action of cytokines, COX-2 expression and inflammatory cell infiltration in the inflamed colon.

**Antifatigue effects.** Fatigue is a defensive system in response to life-threatening, over exhaustion and often leads to muscle soreness, anxiety and depression. If persistent fatigue is not eliminated, it may lead to different pathologies such as aging hypertension (Zheng et al., 2010). The search for natural compounds that delay fatigue or accelerate its elimination in human beings with few side effects is continuous (Xu et al., 2013), then the study of polysaccharides is a field that is beginning. For example, Zheng et al. (2010) studied the effect of antifatigue activity from hot-water longan seed polysaccharides, administered orally to ICR male mice using a swimming test, including hepatic, serum urea nitrogen and blood lactic acid content evaluation. The results show that the polysaccharides in doses ranging from 50, 100, 150 and 200 mg/kg, extended swimming time from the control (650 s) to 1100, 800, 1250 and 900 s, respectively, increased hepatic glycogen in all mice except at 50 mg/kg, compared with the control. All dosages decreased blood urea nitrogen and blood lactic acid but only at doses of 50 and 100 mg/kg.

Other studies reported the effect of the oral administration of arabinan-rich pectin from acerola fruit (ACSW) for 28 days at doses of 50, 100 and 200 mg/kg, could lengthen the swimming time, which showed a longer time to exhaustion (95, 151 and 129 min, respectively), related to the control (53 min). Furthermore, the mitochondrial respiratory capacity of the skeletal muscle, was enhanced at 200 mg/kg (Klosterhoff et al., 2018).

**Hepatoprotective activity.** The administration of polysaccharides from acerola (ACP) at 200, 400 and 800 mg/kg to mice fed with high-fat diets (HFD), reduces the content of total triglycerides in the liver (16.1, 17.9 and 44.2 %, respectively) and attenuation of hepatic steatosis. ACPs markedly ameliorated hepatic lesions produced by HFD feeding, showing near-normal appearance with a well-preserved cytoplasm. The authors conclude that hepatic damage decreased by...
It has been suggested that the interaction between polysaccharides and α-glucosidase is affected by the molecular weight. Low molecular weight polysaccharides exhibited a higher inhibition capacity (Dou et al., 2015). Related to the type of inhibition, polysaccharides containing sulphate produced a mixed inhibition while the desulphated generated non-competitive inhibition (Qian et al., 2015). However, Dou et al. (2015) reported a mixed inhibition in non-sulphated polysaccharides. For anticancer activities, the presence of β-(1,3) linkages in the main chain of the polysaccharide are important since allow an increase in immunocompetent cells activities (Wasser, 2002). Various chemical structures have been reported for the antitumor polysaccharides in different studies, including a backbone composed of (15)-linked-Araf (Jiao et al., 2018). Also, other authors reported that low molecular weight polysaccharides exhibited stronger antiproliferative activities (Hung et al., 2012).

Polysaccharides containing sulphate groups, possess strong immunomodulatory capacity, which notably reduces when the polysaccharides are desulphated (Yi et al., 2012). Nevertheless, other authors reported that low molecular weight polysaccharides exhibited stronger immunomodulatory activity, and that the polysaccharides molecular weight might play a more critical role than sulphate content, because low molecular weight might increase the capacity of polysaccharides to identify and bind immune complexes (Yi et al., 2012). Other investigations reported that the acetyl groups played a crucial role in maintaining the high immunoregulatory activity of polysaccharides since promotes the formation of hydrophobic pockets in polysaccharides, triggering different immunostimulatory responses (Ferreira et al., 2015).

For the above mentioned, it is necessary to carry out more in-depth studies to characterize polysaccharides of tropical fruits and their by-products, and the relationship of their structure with different biological activities.

**CONCLUSION**

Tropical fruits and their by-products are an excellent source of bioactive compounds, including polysaccharides that have shown antioxidant, immunomodulatory, anti-inflammatory, among other activities, so their application to promote beneficial health effects are promising. Therefore, polysaccharides are an alternative for new functional foods. The by-product production of these fruits is extremely high, and the seeds and skins have proven to be an important source of bioactive compounds. The preparation of new polysaccharide-based alcoholic and non-alcoholic beverages, and their use in the preparation of bakery products and pasta, can contribute to human health benefits. These benefits could improve the demand, distribution, and marketing of these tropical fruits. Therefore, it is necessary to develop additional work on the bioactivities of the polysaccharides from tropical fruits and their by-products to generate more information that allows us to develop functional foods, regarding the stability of their bioactive compounds and the benefits of their consumption.
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