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COMPARISON ON THE PREBIOTIC POLYSACCHARIDES AND OLIGOSACCHARIDES FROM PLANT STUDIES IN INDONESIA AND OUTSIDE OF INDONESIA

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Abstract

There are several studies that have been conducted to investigate the potential prebiotic effect from natural resources. Research on this topic is very interesting to be explored, especially for Indonesian researchers. However, Indonesian researchers may improve the research study by observing other studies worldwide. Thus, this review aims to summarize and compare studies on the prebiotic activity of polysaccharides or oligosaccharides from plants conducted in Indonesia and overseas. There are similarities between studies in Indonesia and those overseas including the in vitro studies trend, the use of hot water, and ethanol for extraction. In the meantime, the difference lies in the plants being examined for prebiotic effects. Most studies in Indonesia examined the prebiotic effect of tubers contain inulin and FOS as the main prebiotic oligosaccharide compounds detected. On the other hand, worldwide research has started exploring new sources of oligosaccharides apart from FOS and inulin. They have explored prebiotic potentials from waste materials and herbal plants. However, these studies need further research in animals and human trials. Moreover, referring to research conducted abroad, we also think that the search for prebiotic potentials from agriculture and traditional herbal medicine is also feasible in Indonesia. This review may help Indonesian researchers to improve the quality of research in prebiotic potential effect from natural resources.

Keywords: Extract, Oligosaccharides, Plant, Polysaccharides, Prebiotic.

1. Introduction

Non-digestible polysaccharides and oligosaccharides are known to have prebiotic effect as these compounds selectively enhance the growth of beneficial bacteria in the gut [1, 2]. Prebiotic polysaccharides and oligosaccharides fermented by the bacteria in the gastrointestinal tract to short-chain fatty acid (SCFA), mainly acetate, propionate and butyrate [3, 4]. The elevation of SCFA production can promote the number of beneficial bacteria like Lactobacilli and Bifidobacterium while reducing the pathogen bacteria including Salmonella and Helicobacter [5]. In addition to that, the increase of SCFA improves the general health of intestinal cells by inducing mucin production [6] and decreasing cell permeability [7]. Polysaccharides and oligosaccharides also have immunomodulatory property by directly interacting with immune cells [4, 8, 9].

Some polysaccharides that are reported to have prebiotic activity are hemicellulose, pectin, cellulose and resistant starch [9]. Prebiotic polysaccharides are contained in various plant material, including as cereal, mushrooms, herbs, chicory root, citrus, soybeans, and potatoes [4]. The well-known oligosaccharides are Fructosoligosaccharides (FOS), Galactooligosaccharides (GOS), Lactulose which derive galactooligosaccharides (LDGOS), xylooligosaccharides (XOS), arabinooligosaccharides (AOS), algae which derive from marine oligosaccharides (ADMO) [10]. Oligosaccharides can be obtained from natural sources, enzymes processing and chemical production and contained in the plants and many of them are edible plants [3, 10]. FOS occur mostly in the tubers, roots, fruits and vegetable as in Jerusalem artichoke, chicory, onions, scallion, garlic, spring garlic, and leekonion, garlic, nectarine and banana [11, 12]. XOS are the hydrolysis product of xylan, a polysaccharide that is commonly found in agricultural products such as corn husk, corn cob, cereal straw, sugarcane bagasse and green coconut husk [13]. As the name suggests, ADMO are originated from marine plants like seaweed and microalgae [14, 15].

Since the term prebiotic was firstly introduced in 1995, prebiotic polysaccharides or oligosaccharides source plants have been explored by many researchers all over the world. More recently, Indonesian researchers also have been working on finding potential plants for prebiotic resources. However, the review of their publication is still limited. Thus, this literature review aimed to summarize the publications about prebiotic activity of oligosaccharides/ polysaccharides from plants conducted in Indonesia and compared to the similar research topic in overseas. There are few research questions that will be addressed on this review, including what the polysaccharides/oligosaccharides are studied in Indonesia and overseas, the difference of study design and methods, the comparation between studied in Indonesia but not overseas and vice versa, the most studied in Indonesia and overseas, and the suggestion for further study.

2. Methods

2.1. Search methods

The plants were investigated based on their types and parts used for prebiotic activities and the studies were divided into three categories namely in vitro, in vivo, and clinical trial. The literature search was performed in Google Scholar, Wiley, ScienceDirect, PubMed and Garuda in October 2020. To limit the search process, authors of this study used such keywords as “prebiotic”, “Indonesia”, “test”, “activity”, “evaluation”, “microbiota” and “plants”, respectively or in combination together as presented in Fig. 1. The search was performed both in English and Indonesian languages. All studies in Indonesian were included in the search yet the international publication was limited to those published within the last five years (from 2015 to 2020).

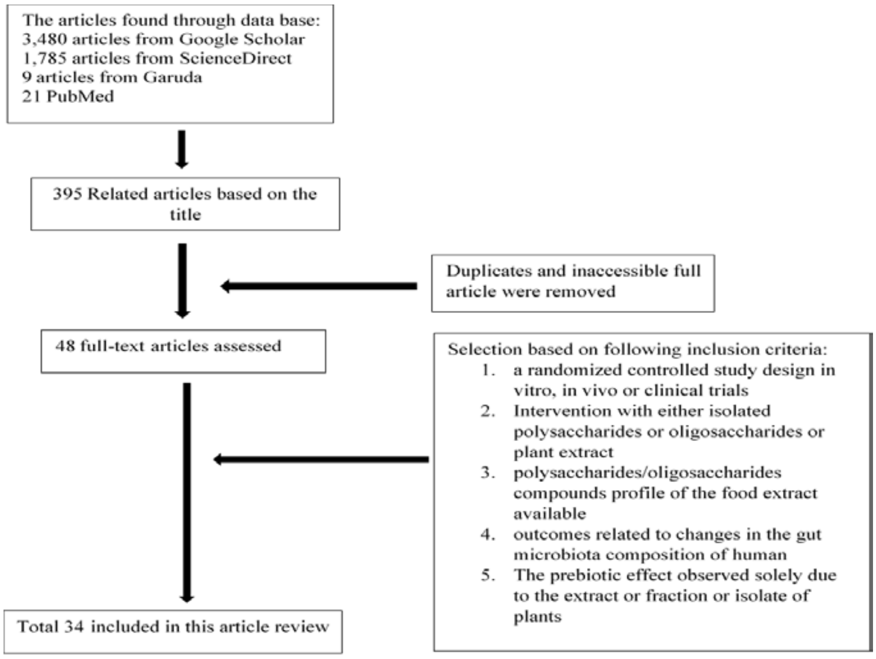

Fig. 1. The flowchart of article selection process.

2.2. Paper selection

Firstly, all articles were screened based on the titles; the irrelevant titles were removed. Following that, the duplicated articles and inaccessible full-text articles were also removed. The full text articles’ content was then reviewed based on the following inclusion criteria: (1) a randomized controlled study design in vitro, in vivo or clinical trials; (2) intervention with either isolated polysaccharides or oligosaccharides or plant extract; (3) polysaccharides/oligosaccharides compounds profile of the food extract available; (4) outcomes related to changes in the gut microbiota composition of human, with stimulation of microorganisms recognized as prebiotic targets.; and (5) language of the publication; English or Indonesian. Studies of prebiotic studies on food formulation using plant-derived prebiotic were excluded.

2.3. Data extraction

The included studies were reviewed, and the following data were extracted: sample source, exposure dosage, polysaccharides/oligosaccharides components, subject and sample size, intervention period, outcomes related to gut microbiota and host health, papers’ first author and date of publication.

2.4. Quality categorization

Due to the limitation of available Indonesian journal articles, the quality of journals assessed in this literature review were categorized into international reputable journals and national accredited journals.

3. Results and Discussion

3.1. Comparation between studies on the same prebiotic polysaccharides and/or oligosaccharides in Indonesia and outside Indonesia

There are many groups of polysaccharides/oligosaccharides that have prebiotic properties. Some studies in Indonesia and outside Indonesia conducted researched the same compound group that was obtain from plants (Table 1). Those compound groups including inulin, FOS, mannan, XOS, β-glucan and lactulose. The tuber and roots are the main part of plant that are contained those prebiotic components [16-23]. Conventional carbohydrate extraction method using hot water followed with precipitation by alcohol is mostly applied in the studies included in this research [24].

Table 1. Characteristic of included studies on prebiotic effect of oligosaccharides/polysaccharides from plants extract.

Plants	Prebiotic component	Test bacteria	Study	Extraction methods	Reference
Studies outside Indonesia					
Pfaffia glomerata	Inulin	1. Lactobacilli 2. Bifidobacteria	In vitro	Extracted with distilled water (1:15 w/v) at 100 °C and precipitated with alcohol.	[16]
Stevia rebaudiana	FOS	1. Lactobacilli 2. Bifidobacteria	In vitro	Extracted with water (1:15 w/v) at 80 °C and precipitated with ethanol PA (1:3 v/v).	[17]
Chinese Sesbania cannabina seeds	Galactomannan	1. *L. acidophilus* 2. *L. rhamnosus* 3. *B. animalis* 4. *B. longum*	In vitro	Extracted with water (1:12 w/v) at 80 °C and precipitated with ethanol (1:3 v/v).	[18]
Amorphophallus konjac C. Koch.	Galactomannan	1. *L. pentosaceus* 2. *B. animalis* 3. *L. plantarum* 4. *L. casei ssp.* 5. *L. brevis*	In vitro	Ready to use konjac flour	[20]
Trigonella foenum-graecum L. seed	Galactomannan	*Bacillus coagulans* MTCC 5856	In vitro	Chemical and enzymatic method	[25]
Rice straw	Xylooligosaccharides	1. *L. acidophilus* 2. *L. fermentum* 3. *L. plantarum* 4. *L. helveticus*	In vitro	Enzymatic method (xylanase)	[26]

		5. *B. animals* 6. *B. longum*			
Bamboo shoot	Xylooligosaccharides	1. *B. adolescentis* 2. *B. infantis* 3. *B.bifidum* 4. *L. acidophilus*	In vitro	Ultrasonic-assisted extraction processor (using distilled water (1:20 w/v) at 49° C) and precipitation with ethanol (70%, 75%, and 80%)	[27]
Oat	β-glucan	1. *Lactobacillus* 2. *B. longum*	In vitro	Extraction with ethanol-enzyme (lichenase) and hot water	[28]
Edible mushrooms	Lactulose	1. *L. acidophilus* 2. *L. plantarum* 3. *B. cereus* 4. *E. coli* 5. *S. paratyphi* 6. *S. aureus*	In vitro	Extracted using water-ethanol (95%) at 80 °C.	[29]
Studies in Indonesia					
Gembili tuber (*Dioscorea esculenta*), Dahlia (*Dahlia L.* spp.) and yam tubers (*Pachyrhizus erosus*)	Inulin	1. *L. plantarum* 2. *L. casei*	In vitro	Extracted with water (1:4) at 80 °C and precipitated with ethanol 80%.	[21]
Local Bananas (Musa sp.): Tanduk, Uli, Raja Sereh, and Cavendish	Inulin	1. *Lactobacillus paracasei* 2. *E.coli* 1. *Lactobacillus sp* 2. *Enterobacteriaceae*	In vitro In vivo	Extracted with ethanol 80% and ethanol absolute at 20 °C and -2 °C	[30]
Bestak sweet potato (*Ipomoea batatas*)	Inulin, FOS	1. *Lactobacillus plantarum Mut7 (FNCC 250)* 2. *Bifidobacterium longum JCM 1217* 3. *Escherichia coli FNCC 0091*	In vitro	Extracted with ethanol 80% at 60 °C.	[22]
Gembolo Tuber (*Dioscorea bulbifera*)	Inulin, lactulose	1. Lactobacillus 2. Bifidobacteria 3. Bacteroides 4. Clostridium	In vitro	Not mentioned	[23]
Buton forest onion (*Eleutherine bulbosa* (Mill.) Urb.)	Inulin, FOS	1. *Pseudoalteromonas piscicida 1Ub* 2. *Bacillus sp. NP5.a, Vibrio parahaemolyticus.*	In vitro	Extracted with 96% ethanol (1:4 w/v), twice at room temperature and at 40 °C.	[31]
Garlic (*Allium sativum*)	FOS	*L. acidophilus*	In vitro	Grinded into puree	[32]

Porang tuber (*Amorphophallus oncophyllus*)	Glucomannan	1. Lactobacillus 2. Bifidobacteria 3. *E. coli*	In vitro	Extracted with water at 55 °C and precipitated with ethanol.	[19]
Cassava dregs	Xylooligosaccharides	1. Lactobacillus 2. Bifidobacteria 3. *E. coli*	In vitro	Chemical (using ethanol 90%) and enzymatic method (using xylanase)	[33]
Sargassum crassifolium	β-glucan	Fecal microbiota of rats	In vitro	Extracted using ethanol 96% and water.	[34]

Recently, many researchers are interested in utilizing agricultural by-product as the source of prebiotic carbohydrate. XOS is the prebiotic oligosaccharides found in the agricultural waste such as rice straw and cassava dregs [26, 33]. Studies on the discarded parts of fruits (peel and seed) discovered that these parts were the potential source of prebiotic (Table 2). However, the prebiotic compounds in the source were not characterized yet.

Table 2. Included studies on agricultural by-products extract with prebiotic potential.

Plants	Test bacteria	Study	Extraction method	Reference
Studies outside Indonesia				
Guava	Lactobacillus spp	In vitro	Extracted using ethanol 80% at 80 °C.	[35]
Acerola (*Malpighia glabra* L) and guava (*Psidium guayaba* L)	Lactobacillus and Bifidobacterium	In vitro	Lyophilized and grounded.	[36]
Cranberry (*Vaccinium macrocarpon* Ait Ericaceae) seed	Bacillus coagulans MTCC 5856	In vitro	Ready to use CSF	[37]
Cashew apple (*Anacardium occidentale* L)	L. acidophilus, L. casei and L. paracasei	in vitro	Freeze-dried and grounded.	[38]
Study in Indonesia				
Durian seed	Lactobacillus plantarum dan Bifidobacterium longum	in vitro	Extracted from durian using water (50° C) and ethanol 97%.	[39]

3.2. The plant extract that studied overseas, excluded Indonesia

Some studies from Indonesia and overseas included in this research conducted different prebiotic components or plant extracts (Table 3). Studies from overseas explored prebiotic activity of extracts or juice from fruit flesh, herbs, edible nuts and grain but such studies were not found in Indonesia. Fruits are known to have prebiotic activity because they are rich of dietary fibers which are carbohydrates with a varying chain length (DP) from 2 to 60 units [11, 40]. Some *in vitro* studies included here tested the prebiotic effect of kiwifruit (various kiwi cultivars), dragon fruit, and tamarillo [41-43]. All these fruits are emerging novel prebiotics regarding their potential effect in modulating the gut microbiota and increasing the number of *Bifidobacterium* and decrease *Bacteroides*. Extraction method of those fruits are shown in Table 3.

Recently, the effect of herb medicines and spices to the beneficial bacteria growth has started to be researched, but these sources were not explored yet by Indonesian researchers. Three researchers from overseas screened the *in vitro* prebiotic activity of *Murraya koenigii* leaves, *Emblica officinalis* fruit, *Terminalia bellerica* fruit, *Terminalia chebula* fruit, bark of *Ulmus rubra*, *Glycyrrhiza glabra* root, black pepper, cayenne pepper, cinnamon, ginger, Mediterranean oregano, rosemary, and turmeric (Table 3). All the herbs, with the exception of turmeric, showed prebiotic activity by enhancing beneficial bacteria (*Lactobacillus spp.* and *Bifidobacterium spp.)* Some studies suggested that other than carbohydrate, phytochemicals in the herbs and spices like polyphenol, tannin, saponin and anthocyanin, are responsible for prebiotic properties with secondary effects on host immunological and metabolic marker [44-47].

Polymerized polyphenol and polysaccharides of nuts are substrates for “good” bacteria in the gut [48]. Almond has been reported to have good impact on gut microflora by increasing the number of *Lactobacillus* or *Bifidobacteria in vitro* and in human clinical trials [49-51]. In a study included here Liu et al. [52] compared the *in vitro* fermentation properties and *in vivo* prebiotic effect of raw and roasted almonds and found that they had prebiotic effects as well as regulated intestinal bacteria and improved the metabolic activities. Another study investigated the prebiotic activity of acorn [53]. Combined with sago, acorn preserved microbial diversity and added the number of beneficial bacteria and SCFA production in the animal model. That microbiota modulation led to ameliorate high-fat-diet-induced insulin resistance in the animal.

Like most of the grains, lentil is also a source of prebiotic carbohydrates. Previous study reported that the prebiotic carbohydrates of lentil are raffinose-family oligosaccharides (RFO), sugar alcohols (SAs), FOS, and resistant starch (RS) [54]. A study included here found that other than possessing prebiotics properties, the hydroalcoholic extract of lentils was able to reduce the cholesterol level of rats [55].

Table 3. Included studies on plant extract that studied overseas but not in Indonesia.

Plants	Test bacteria	Study	Extraction method	Reference
Kiwifruit	Human fecal microbiota from healthy volunteers.	in vitro	Freeze-dried	[42]
Dragon fruit	Fecal microbiota of rats	In vitro	enzymatic method (the enzyme name was not mentioned).	[43]
Tamarillo (*solanum betaceum* Cav)	Human fecal microbiota from healthy volunteers	in vitro	Extracted with citric acid 1%, water, HEPES buffer 20 mM and ethanol 72%.	[41]
Murraya koenigii and *Brassica oleracea* var. *botrytis* leaves	*L. acidophillus, L. rhamnousus, L.casei, L. fermentum, L. plantarum, L. sakei*	In vitro	Extracted using three solvent, ethanol 50%, hot	[56]

			water and cold water.	
Triphala powder (fruit of *Emblica officinalis*, *Terminalia bellerica*, and *Terminalia chebula*), slippery elm powder (bark of *Ulmus rubra*) and licorice *(Glycyrrhiza glabra* root).	Human fecal microbiota from vegan or vegetarian volunteer	In vitro	Ready to use herb powder	[57]
Black pepper (BLP), cayenne pepper (CAP), cinnamon (CIN), ginger (GIN), Mediterranean oregano (ORE), rosemary (ROS), and turmeric (TUR)	*Bifidobacterium* spp. and *Lactobacillus* spp	in vitro	Extracted with pure water using reflux method	[58]
Raw and roasted almonds (*Prunus amygdalus*)	*Bifidobacterium* spp., *Lactobacillus* spp., *E. coli.*	in vitro	Hydrolysed under simulated gastric and duodenal digestion.	[52]
	Rat fecal microbiota	In vivo	Made into slurry.	
Acorn and sago	Human fecal microbiota from healthy volunteer	In vitro	Extracted with ethanol-hot water (acorn). Enzymatic method (using α-amylase and Pullulanase)	[53]
Lentil (*Lens culinaris* Medik)	Fecal bacteria	In vitro	Extracted with ethanol 30%	[55]

3.3. The most studied prebiotic polysaccharides or oligosaccharides in Indonesia and overseas

Research of prebiotic in Indonesia was just started recently. Most of the studies investigated prebiotic properties of tubers which mostly content the well-known prebiotic oligosaccharides, inulin, and FOS. Inulin and FOS have been extensively studied by many researchers outside Indonesia [10]. Thus, in the last five years, the exploration by worldwide researchers had been shifting to newer prebiotic compounds from various sources, including agricultural by-products, foods, herbs, and spices. They tested the prebiotic activity mainly from agricultural by-products. These sources are cheap, available in abundance and help reducing waste and pollutant [59]. Herb and spices have been used for gastrointestinal disorder in a long time. Moreover, these materials were also known contains oligosaccharides and polyphenols, which are known to have prebiotic properties. Hence many researchers abroad are interested in testing the prebiotic effects of various spices and herbs.

3.4. Further study direction for Indonesia

Reflecting on the research on plant-based prebiotics abroad, research in Indonesia can be developed on various prebiotic sources apart from tubers. Examination on many herbal drugs traditionally used for gastrointestinal disorders, which offers a vast field for future research. Furthermore, it is necessary to continue to *in vivo* and clinical trials. since most of the research is still pre-liminary and/or in the *in vitro* stage. Some of studies in Indonesia did not include control groups neither statistical test, thus, we think that studies in the future need to include control groups and conducting statistical test in their research to avoid bias conclusion. Lastly, prebiotic research in Indonesia predominantly aimed for further developing to be a functional food or feed. In our opinion prebiotics are also possible to be formulated into nutraceutical or cosmetics.

4. Conclusion

Researchers in Indonesia have started investigating the prebiotic potential of local Indonesian plants. Tubers are a source of prebiotics that are widely studied in Indonesia, where inulin and FOS are the main prebiotic oligosaccharide compounds detected in these tubers. In addition, exploration of the prebiotic potential of traditional herbal medicine was also carried out. Meanwhile, research on prebiotic sources outside Indonesia in the last five years were mostly conducted on agricultural by-products. Studies in Indonesia and overseas, both were conducted in vitro, thus further investigating in animal and human trial are needed. Referring to studies conducted overseas, we can suggest the search for prebiotic potential from agricultural and traditional herb medicine is also feasible for future research in Indonesia because Indonesia is an agricultural country where a lot of traditional herbal medicines are being used.

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