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REVIEW ARTICLE

Inulin from Several Tubers Available in Indonesia and the Growth of Gut Microbiota

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ABSTRACT

Indonesia has many types of tubers, some of them are gembolo tuber (*Dioscorea bulbifera*), lesser yam (*Dioscorea esculenta*), yam bean (*Pachyrhizus erosus*), and dahlia tuber (*Dahlia pinnata*); which are the sources of prebiotics. The term of prebiotics has been used since 1995 to describe the non-digestible components in food that positively alter gut microbiota activity and exhibit beneficial properties to the human body. One of the prebiotics that can be found in tubers is inulin. This review was aimed to compare inulin content in the above-mentioned tubers and their roles towards the growth of gut microbiota. Library searches using Semantic Scholar database was done. Findings showed that gembolo tuber contains the highest inulin content, followed by lesser yam, dahlia tuber, and yam bean. Moreover, inulin increases the population of *Lactobacillus*, *Bifidobacterium*, and *Bacteroides*, while inhibits the growth of *Escherichia coli* and reduce the growth of *Clostridium*.

Keywords: inulin; gembolo; dahlia; lesser yam; yam bean

INTRODUCTION

The concept of prebiotics was firstly introduced in 1995 by Glenn Gibson and Marcel Roberfroid. It contains non-digestible food components which contribute in gastrointestinal microbiota colonies and thus support digestive health. According to Althubiani *et al.* (2019), prebiotic is non-digestible components over metabolization by microorganisms in the colon to modify gut microbiota or to treat advantageous health effects to humans. There are many types of prebiotics such as inulin, fructo-oligosaccharide (FOS), and raffinose which are obtained from plants especially tubers (Lestari *et al.*, 2013).

Inulin was found more than two centuries ago (Mensink *et al.*, 2015). It is composed primarily of fructose polymer bonded by β-chain fructofuranoside which cannot be hydrolyzed in the digestive tract. Thus, it is fermented by gut microbiota that can lead to improved probiotic growth, such as *Bifidobacterium*, *Lactobacillus casei*, and *Lactobacillus plantarum*. Additionally, inulin has potential effects to retard adverse pathogenic bacteria growth in the gut, for instance *Escherichia coli* (Darilmaz *et al.*, 2018; Schaafsma & Slavin, 2015).

In prebiotic industry, inulin is expected to drive the market of fiber-rich food products. It covers more than 40% of the prebiotic industry in terms of revenue (Purwadi, 2018).

Indonesia has tremendous potential for plant tubers which have not been applied as a functional food (Herawati *et al.*, 2019). Some of the potential tubers are gembolo tuber (*Dioscorea bulbifera*), lesser yam (*Dioscorea esculenta*), yam bean (*Pachyrhizus erosus*), and dahlia tuber (*Dahlia pinnata*). The most utilized and consumed fresh tuber in Indonesia is yam bean. It has been cultivated widely in Sumatra, Java, and Borneo (Nusifera & Karuniawan, 2009). Lesser yam and gembolo tuber are poorly utilized and less produced in Indonesia (Pratiwi *et al.*, 2016; Agustin *et al.*, 2019). As for dahlia tuber, it has been utilized as an animal feed and feed additive (Nesmawati, 2016).

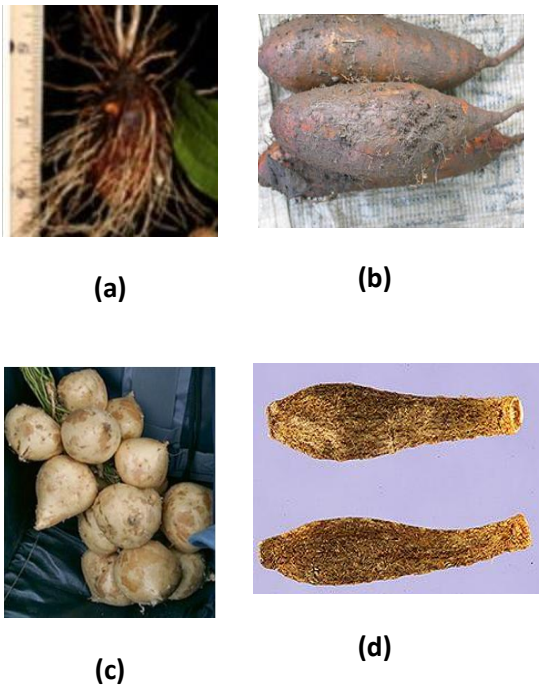

Figure 1. Morphology of **(a)** Gembolo, *Dioscorea bulbifera* (Raman *et al.*, 2014), **(b)** Lesser yam, *Dioscorea esculenta* (Lim, 2016), **(c)** Yam bean, *Pachyrhizus erosus* (Reddy, 2015), **(d)** Dahlia tuber, *Dahlia pinnata.* (USDA, 2019).

Gembolo tuber, as shown in **Figure 1(a)**, is a plant grown underground with shade- and drought-tolerant. It is rich in carbohydrate and has potential as food reserves. The underground tubers are usually yellow in color and have both regular spherical shape and irregular shape (Prasetia *et al.,* 2018). Meanwhile, lesser yam (*Dioscorea esculenta*) tuber, as shown in **Figure 1(b)**, acts as storage organs of the plants. It is obtained from the swollen ends of the stolon grown from the crown plants (Kay, 1973). **Figure 1(c)** showed yam bean (*Pachyrhizus erosis*) tuber that is a crop of family *Leguminosae*. It has been popularly known in tropical and subtropical regions, especially Indonesia. In visual, yam bean has brown skin, white flesh, and crispy texture with irregularly globular shape. This tuber contains oligofructose inulin that provide sweet flavour (Kumalasari *et al.,* 2014). **Figure 1(d)** showed dahlia (*Dahlia pinnata*) tuber. Inulin in dahlia tuber is mainly found in Asteraceae, Boraginaceae, Asparagaceae, Liliaceae and Amaryllidaceae family. Moreover, dahlia tuber is also rich in minerals and trace elements that could reduce the risk of cardiovascular disease (Ioana *et al.*, 2017).

The aim of this paper review is to compare inulin content and to evaluate the changes of gut microbiota composition performed *In vitro* in dahlia tuber, gembolo tuber, lesser yam, and yam bean.

METHODOLOGY

This review was done based on research papers which were retrieved from Semantic Scholar database with the keywords “prebiotic activity”, “gembolo”, “dahlia tuber”, “lesser yam”, “umbi bengkuang”, and “inulin”. The research papers used were those published from 2005 to 2019. A total of 29 research papers were selected to be reviewed.

INULIN CONTENT OF VARIOUS TUBERS

Inulin content of four different types of tubers commonly found in Indonesia were compared and summarized as seen in **Table 1** below. Data shows that gembolo tuber has

the highest inulin content (161 mg/100g) and the lowest inulin content is in yam bean (48.66 mg/100g). The comparison also showed that different extraction and measurement methods produce different inulin content within the same sample.

Table 1. Comparison of inulin content in various tubers found in Indonesia

Source	Inulin content (mg/100g)	Extraction method	Measurement Test	Reference
Gembolo tuber	161	Not specified		Widyawati, 2017
Dahlia tuber	78.21	Ethanol 80%	Dry weighing	Zubaidah & Akhadiana, 2013
Lesser yam	153	Not specified		Widyawati, 2017
	67.66	Ethanol 80%	Dry weighing	Zubaidah & Akhadiana, 2013
Yam bean	48.66			

HEALTH BENEFITS OF INULIN

The health effect of inulin has been proven through scientific studies (Abed *et al.*, 2016). Inulin acts as dietary fiber and prebiotic due to its property where fructose moieties were joined by β-(2-1)-D-fructosyl linkages. This property makes it resistant to digestion in the human small intestine due to the β-configuration. Thus, it can be digested by bacteria present in the large intestine which converts inulin into short-chain fatty acids, mainly acetate, propionate, and butyrate. Acetate will be metabolized in muscle to produce adenosine-5'-triphosphate (ATP), while propionate will be transported to the liver for gluconeogenesis. Butyrate is an important energy source for colonocytes and anti-tumor properties (Miremadi & Shah, 2012). Due to its non-digestibility properties, inulin exhibits low caloric value with 1.5 kcal/g or 6.3 kJ/g (Shoaib *et al.*, 2016).

Non-digestibility properties of inulin also play a role in preventing constipation by providing a stool bulking effect similar to other soluble fibers, such as pectin and guar gum. Inulin can also reduce the risk of atherosclerosis by decreasing triacylglycerol (TAG) in blood. Studies on rodents showed that inulin consumption can decrease TAG by lowering lipid breakdown in the liver as the possible main mechanism both in humans and animals. While, the mechanism of how inulin affects lipid metabolism is still under research (Shoaib *et al.*, 2016)

EFFECT OF INULIN TOWARDS GUT MICROBIOTA GROWTH IN VARIOUS TUBERS

In vitro studies on total bacterial count of *Lactobacillus*, *Bifidobacteria*, *Bacteroides*, *Clostridium*, and *E. coli* after being treated with inulin from each tuber (gembolo tuber, dahlia tuber, lesser yam, and yam bean) can be seen in **Table 2**. Studies done by Herawati *et al.* (2019) used human fecal as the source of bacterial strains, hence there were no specific strains identified. Meanwhile, the experiment of the other tubers used specific cultured bacteria strains from growth media.

Table 2. *In vitro* studies comparison of various tubers on bacterial populations

Bacteria		Prebiotic Source	Fiber Type	Total Bacteria Count (log cfu/mL)		Method	Result	References
Genus	Species			0h	24h			
Lactobacillus	Not specified	Gembolo	Oligosaccharides	3.46	4.88	Fecal fluid from infants <6 month y/o inoculated to basal nutrient medium added with gembolo extract	Inulin stimulate the bacteria growth	Herawati *et al.*, 2019
	L. plantarum	Control (-)	Without inulin	8.8	9.3	Bacteria strains grown in MRS agar supplemented with inulin extract	Increasing colonies number after 24h incubation, associated with high levels of inulin contained in each tuber. Control (-) was at declining phase while others still increasing.	Zubaidah & Akhadiana, 2013
		Control (+)	Inulin (commercial)	8	10.5			
		Dahlia	Inulin (extract)	9.4	10.2			
		Lesser Yam		9.4	10			
		Yam Bean		9	10.5			
	L. casei	Control (-)	Without inulin (glucose)	7.5	8		*L. casei* able to utilize inulin as carbon source. Inulin supplementation is better to *L. casei* viability.	Kusmiyati *et al.*, 2018
		Control (+)	Inulin (commercial)	7.3	7.5			
		Dahlia	Inulin (extract)	7.4	7.8			
		Control (-)	Without inulin (glucose)	5.5	8.1		Inulin from Lesser Yam can stimulate bacteria growth better than glucose and commercial inulin	Winarti *et al.*, 2013
		Control (+)	Inulin (commercial)	5.4	8.1			
		Lesser Yam	Inulin (extract)	5.3	8.5			
		Control (-)	Without inulin	8.4	9.3		Increasing colonies number after 24h incubation, associated with high levels of inulin contained in each tuber. Control (-) was at declining phase while others still increasing.	Zubaidah & Akhadiana, 2013
		Control (+)	Inulin (commercial)	8.4	10.5			
		Dahlia	Inulin (extract)	9	10.4			
		Lesser Yam		9.3	10.3			
		Yam Bean		8.3	10.3			

Table 2. *In vitro* studies comparison of various tubers on bacterial populations (continue)

Bacteria		Prebiotic Source	Fiber Type	Total Bacteria Count (log cfu/mL)		Method	Result	References
Genus	Species			0h	24h			
Bifidobacteria	Not specified	Gembolo	Oligosaccharides	6.95	7.35	Fecal fluid from infants <6 month y/o inoculate to basal nutrient medium added with gembolo extract	Inulin stimulate the bacteria growth	Herawati *et al.*, 2019
	B. longum	Control (-)	Without inulin (glucose)	5.4	9	Bacteria strains grown in MRS agar supplemented with inulin extract	Inulin can be utilized by *Bifidobacteria* as energy source longer than glucose. Possible cause due to higher molecular weight of inulin than glucose	Winarti *et al.*, 2013
		Control (+)	Inulin (commercial)	5.2	8.6			
		Lesser Yam	Inulin (extract)	5.4	8.4			
Bacteroides	Not specified	Gembolo	Oligosaccharides	1.3	1.89	Fecal fluid from infants <6 month y/o inoculate to basal nutrient medium added with gembolo extract	Increasing colonies number after 24h incubation (at slower rate), possible causes due to pH of the medium (still in optimum pH for *Bacteroides*)	Herawati *et al.*, 2019
Clostridium				4.52	5.25		Increasing colonies number after 24h incubation (decrease after 48h), possible cuases due to high glucose presence (utilized by *Clostridium* to grow)	
Escherichia	*E. coli*	Control (-)	Without inulin	7.5	8.5	Bacteria strains grown in MRS agar supplemented with inulin extract	Slow growth rate in inulin supplemented medium, but fast growth in medium without inulin. Inulin could not support the growth of *E. coli*	Kusmiyati *et al.*, 2018
		Control (+)	Inulin (commercial)	7.2	7			
		Dahlia	Inulin (extract)	7.4	7.7			
		Lesser Yam	Without inulin (glucose)	5.8	8.5	Bacteria strains grown in M-9 agar supplemented with inulin extract	Inulin from Lesser Yam and commercial inulin can inhibit *E. coli* growth more than 1 log cycles, while glucose can not inhibit *E. coli* growth.	Winarti *et al.*, 2013
			Inulin (commercial)	5.8	7.8			
			Inulin (extract)	5.8	7.4			

As shown in **Table 2**, the growth of *Lactobacillus* strains in all tubers was increased after 24 hours. The increasing numbers of bacterial populations indicated that *Lactobacillus* could well utilize the oligosaccharide and inulin as carbon sources (Herawati *et al.*, 2019; Kusmiyati *et al.*, 2018; Winarti *et al.*, 2013; Zubaidah & Akhadiana, 2013). The difference in the increase rate of populations also indicated that microbes have specific enzyme to break down the carbon sources and utilize it for cell metabolism (Zubaidah & Akhadiana, 2013). Dahlia tuber is found to give the lowest growth rate to *Lactobacillus*, while the highest growth rate is given by lesser yam. In addition, the growth of *Bifidobacteria* strains treated by gembolo tuber and lesser yam are also increased. However, the *Bifidobacteria* population in gembolo tuber are not as high as that in lesser yam. This could be caused by different methods used to grow the bacteria. Furthermore, lesser yam-treated *B. longum* population were increased (Winarti *et al.*, 2013).

The growth of *Clostridium* and *Bacteroides* in gembolo tuber was found to be increased, even though these bacteria are considered as pathogenic bacteria. The main cause was the presence of contaminating sugars, such as fructose, glucose, and sucrose, which may promote the growth of *Bacteroides* and *Clostridium*. However, according to Herawati *et al.* (2019), the population of *Clostridium* in gembolo tuber only increased in the first 24 hours, then decreased and reached the basal rate at 48 hours. Both commercial inulin and inulin extract could inhibit the growth rate of *E. coli* population better than the negative control (glucose) after 24 hours and remained in the stationary phase until 72 hours (Winarti *et al.*, 2013).

CONCLUSION AND FUTURE PERSPECTIVE

Gembolo tuber contains the highest inulin content compared to dahlia tuber, lesser yam, and yam bean. Inulin has many health benefits, including lowering the risk of atherosclerosis, acting as dietary fiber and prebiotic, and preventing constipation. *In vitro* studies of gut microbiota using inulin extract and gembolo oligosaccharides increased the growth of *Lactobacillus*, *Bifidobacterium*, *Bacteroides* population in a 24 hours interval. On the other hand, inulin inhibited the growth of *Escherichia coli* after 24 hours and the growth remained in stationary phase until 72 hours. As for *Clostridium*, it was increased in the first 24 hours interval and decreased to the basal rate at 48 hours. However, it needs further exploration on the effects of various tubers, commonly found in Indonesia, as a prebiotic source and their utilization by gut microbiota in the human body.

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