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Review

Mushroom as a potential source of prebiotics: a review

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The demand from health conscious consumers has lead to emergence of various functional foods. Trend in food science and technology has shown development of prebiotic, which is able to modulate the human gut microbiota and improve the host health in return. The concept has been introduced for more than a decade with inulin and oligosaccharides being the most established and studied prebiotics. Better understanding on the benefits of prebiotics has urged a need for invention of new sources of prebiotics. This paper reviewed the potential of mushrooms as a source of prebiotic with thorough explanation on its concept and application.

Introduction

Mushroom growing has a long tradition in Eastern Asian countries, especially in China, where it started around 600 A.D. with *Auricularia auricular* or also known as Wood Ear. In Europe, cultivation of *Agaricus bisporus*, the button mushroom, was first achieved in France during the seventeenth century (Kues & Liu, 2000).

There are at least 12, 000 species of fungi that can be considered as mushrooms, with at least 2000 species are edible (Chang, 1999). According to Sanchez (2004) over 200 species have been collected from the wild and used for various traditional medical purposes, mostly in Far East. About 35 species have been cultivated commercially and 20 are cultivated on an industrial scale. The most cultivated mushroom worldwide is *A. bisporus* (button mushroom), followed by *Lentinus edodes* (shiitake), *Pleurotus* spp (oyster mushrooms), *Auricula auricula* (wood ear mushroom), *Flamulina velutipes* (winter mushroom) and *Volvariella volvacea* (straw mushroom).

Table 1 summarizes worldwide production of mushroom as updated by the Food and Agriculture Organization of the United Nations (2009). China was found to be the biggest producers for mushrooms, as they produced more than 1.5 million metric tons in the year 2007. This showed an increment of about 65% in 10 years times. This was followed by United States and Canada. Israel and India showed drastic increased in the number of metric tons produced in 10 years, while Singapore and Kazakhstan can be regarded as new beginners as they are producing the least mushrooms since 1997. Production of mushrooms seems to continuously increase over time. This might due to high consumer demand and increase in consumer awareness on the health benefits of mushrooms. Thus, this review will emphasize on the scientifically proven health benefits of mushrooms, recent trend on functional foods and the potential of mushroom as a prebiotic as well as the concept of prebiotic.

Health benefits of mushrooms

Mushrooms have been used not only as a source of food but medicinal resource as well (Wasser, 2002). The medicinal properties of mushrooms have been confirmed through an intensive research conducted worldwide. According to Chang (2001), medicinal mushrooms have been used as a dietary supplement or medicinal food in China for over 2000 years. The extractable ingredients of mushrooms were incorporated in products and were claimed to improve biological function of human body. It had received great attention since the late 1980s.

According to Mahajna, Dotan, Zaidman, Petroza, and Wasser (2009), fungi from the Basidiomycota received great interest because it contains large number of biologically active compounds such as polysaccharides,

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Table 1. Worldwide production of mushroom.

Country	Production (tonnes)		Percentage (%)
	1997	2007	
China	562,194*	1,605,000	65.0*
United States	366,810	390,000	5.9*
Canada	68,020	81,500	16.5*
India	9000*	48,000	81.3*
Indonesia	19,000*	30,000	36.7*
Republic of Korea	13,181	28,500	53.8*
Islamic Republic of Iran	10,000*	28,000	64.3
Vietnam	10,000*	18,000	44.4*
Thailand	9000*	10,000	10*
Israel	1260	9500	86.7*
Jordan	500	700	28.6*
Kazakhstan	–	500	100*
Singapore	–	10	100*

* FAO estimate. Source: FAO, 2009.

glycoproteins, triterpenes and antibiotics (Wasser, 2002). However, among all bioactive compounds, polysaccharide has been extensively studied. Several glycans have been isolated from the fruit bodies, spores and the mycelium of *''Reishi''* or *''Mannentake''* (*Ganoderma lucidum*) (Bao, Duan, Fang, & Fang, 2001; Bao, Liu, Fang, & Li, 2001; Liu, Yuan, Chung, & Chen, 2002). Previous studies suggested that these polysaccharides had immunomodulating properties, including the enhancement of lymphocyte proliferation and antibody production (Bao, Liu, *et al.*, 2001) as well as producing both anti-genotoxic and antitumor promoting activities (Kim, Kacew, & Lee, 1999; Sone, Okuda, Wada, Kishida, & Misaki, 1985; Wasser, 2002). Antitumor activity of mushroom polysaccharides (sclerotia of *Pleurotus tuber-regium*) against human hepatic cancer cell has been observed by Tao, Zhang, and Cheung (2006). Other than that, polysaccharides isolated from the fruiting bodies of *Pleurotus ostreatus* have also been proven to exert antitumor activity against Hela tumor cell (Tong *et al.*, 2009). The sporoderm-broken germinating spores (SBGS) of *Reishi* were also found to show a significant antitumor effect, especially in the prevention of the recrudescence or metastasis of cancerous cells. It mitigates the toxic and side effects of radiotherapy and chemotherapy in some patients (Bao, Liu, *et al.*, 2001).

These polysaccharides are of different chemical composition, with most belonging to the group of β-glucans. In order to exhibit their antitumor activity, the main chain of the glucan have to be β-(1 $\rightarrow$ 3) linkages with additional β-(1 $\rightarrow$ 6) branch points (Wasser, 2002). The antitumor activities of *Reishi* polysaccharides were exhibited mainly by the branched (1 $\rightarrow$ 3)-β-d-glucan moiety (Sone *et al.*, 1985; Yoshioka, Tabeta, Saito, Uehara, & Fukuoka, 1985). However, the antitumor activities also depend on several factors-solubility in water, size of the molecules, branching rate and its form. The antitumor activity of polysaccharides and their clinical quality can be improved by chemical modification such as Smith degradation (oxydo-reducto-hydrolysis), formolysis and carboxymethylation (Wasser, 2002).

In other study, the crude extracts of *Reishi* exhibited anticancer activity in *in vitro* systems against a variety of cancer cells including leukemia, lymphoma, breast, human bladder (Lu *et al.*, 2004), prostate, liver, lung and myeloma cell lines. The mechanism of action include the inhibition of proliferation, induction of apoptosis, induction of cell cycle arrest, inhibition of invasive behavior and suppression of tumor angiogenesis in many experimental systems including prostate cancer (Mahajna *et al.*, 2009). Daba and Ezeronye (2003) had reviewed the anticancer effect of polysaccharides isolated from various higher basidiomycetes mushrooms including *Lentinus edodes, Schizophyllum commune* and *Grifola frondosa*. Their review also covered the mode of action of those polysaccharides, the chemical structure as well as some result obtained from the experimental and clinical trails.

Latest finding by Hearst *et al.* (2009) had revealed another benefit of mushrooms. Shiitake (*Lentinula edodes*) and Oyster (*P. ostreatus*) mushrooms were tested for their antibacterial and antifungal properties. Surprisingly, shiitake extract was found to be effectives as an antimicrobial substance and was significantly more antibacterial than ciprofloxacin. Mushrooms extracts were also reported to exhibit antioxidant properties. Study done by Tsai *et al.*, (2009) has discovered antioxidant properties of *P. ostreatus*, *Pleurotus ferulae* and *Clitocybe maxima*. While Bao, Ushio, and Ohshima (2008) discovered antioxidant properties from *Flammulina velutipes*. Antioxidant properties of oyster mushrooms (*P. ostreatus*) were also being studied by Jayakumar, Thomas, and Geraldine (2009). At a maximum concentration of 10 mg/ml, the ethanolic extract of oyster mushroom showed significant reducing power as compared to commercial antioxidant, the butylated hydroxyl toluene (BHT). This indicates the potential of mushrooms to become a food supplement or even as a pharmaceutical agent.

Besides its antibacterial, antimicrobial and antioxidant properties, extract of mushrooms are also potential color stabilizer. Ergothioneine extracted from *F. velutipes* was able to overcome browning of ground beef and big eye tuna meats *(Thunnus obesus)* up to 12 and 7 days of storage, respectively. This duration was double and triple to a duration of a controlled storage meats (6 days for ground beef and 2 days for big eye tuna meat), which was not incorporated with the extract (Bao *et.al.*, 2008).

Other than its medicinal properties, consumption of edible mushrooms also leads to a significant health improvement. This is because they are low in calories, sodium, fat and cholesterol, while contain high percentage of protein, carbohydrate, fiber, vitamins and minerals. These nutritional properties make mushrooms a very good dietary food, which can contribute to the formulation of a well-balanced diet (Manzi, Gambelli, Marconi, Vivanti, & Pizzoferrato, 1999).

This has urged an effort from a team of researchers from Johns Hopkins Bloomberg, School of Public Health in Baltimore to investigate the efficiency of mushrooms substituting food in controlling weight gain. Their study has shown that substituting ground white button mushrooms for lean ground beef in a single meal for four consecutive days significantly reduced daily energy and fat intake, without affecting the palatability, appetite, satiation and satiety. One can reduce 1 lb of body fat by just having less than 10 meals. If this substitution constantly made once a week, about 20, 000 kcal or more than 5 lbs can be reduced in a year (Cheskin *et al.*, 2008).

Current trends on functional foods

In recent years, much attention has been paid to physiological functions of foods due to increasing concerns for health (Arihara, 2006). People have turned to natural food sources such as plants and herbs for these enhancers, rather than artificial substances. Increases in consumer demand have resulted in emerging of various health promoting products in the market. They are called *dietary supplements, designers foods, super food, nutraceutical* as well as *functional foods*. These terms are actually referred to foods that have special beneficial effects on the human (Childs & Poryzees, 1997).

There are actually hundreds of definition describing the concept of functional foods. Unfortunately, great variations between various definitions make it difficult to provide industry partners with robust information on market trends and market potential, or to appropriately protect consumers through legislation. These have initiated Doyon and Labrecque (2008) together with a group of experts from North America and Europe to redefine the definition of functional foods by using the Delphi technique. Functional food is now defined as food that is, or appears similar to a conventional food. It must be a part of standard diet, which is consumed on regular basis and in normal quantities. Other than that, it should also been proven to reduce the risk of specific chronic diseases or beneficially affect target functions beyond its basic nutritional functions.

This showed that consumers are more aware on what they eat and drink as they have become more proactive in improving their health. There are a lot of products containing functional ingredients in the market—infant milk formulae, bakery products, chocolate, dairy products and health drinks. Prebiotics are among those functional food ingredients which raise much attention recently (Blades, 2000; Roberfroid, 2002; Roberfroid, 2000).

A concept of prebiotic

Prebiotic oligosaccharides have gain interest in food research area since the last few decades and they are getting more and more attention recently. Prebiotics such as oligosaccharides and inulin have become a great interest as a functional food ingredient because it is able to manipulate the composition of colonic microbiota in human gut by inhibition of exogenous pathogens (Rycroft, Jones, Gibson, & Rastall, 2001), thus improving the host health (Roberfroid, 2000; Roberfroid, 2002).

The term prebiotic was actually introduced by Gibson and Roberfroid (1995), who exchanged ‘‘pro’’ to ‘‘pre’’, which means ‘‘before’’ or ‘‘for’’ (Schrezenmeir & Michael, 2001). They defined prebiotics as ‘‘a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon’’. They found that the definition of prebiotics is more or less overlaps with the definition of dietary fiber, except for its selectivity for certain species. Cummings, Macfarlane, and Englyst (2001) on the other hand had classified prebiotics as those carbohydrates with relatively short chain length.

This definition was being updated by Gibson, Probert, Rastall, and Roberfroid (2004) as ‘‘selectively fermented ingredients that allow specific changes, both in the composition and/or activity in the gastrointestinal microbiota that confers benefits upon host well-being and health’’. Gibson (2004) recognized dietary carbohydrate such as fibers as a candidate prebiotics, but oligosaccharide was found to be more promising. Currently available prebiotics such as inulin and its derivatives as well as galacto-oligosaccharides (GOS) are relatively cheap to manufacture and has been widely used as a functional ingredient in food (Macfarlane, Macfarlane, & Cumming, 2006). Examples of some prebiotics and their properties are shown in Table 2.

Ingestion of prebiotic was believed to enhance immune function, improve colonic integrity, decrease incidence and duration of intestinal infections, down-regulated allergic response as well as improve digestion and elimination of faeces (Douglas & Sanders, 2008). However, these effects were not the direct consequences upon prebiotic ingestion. Wang (2009) suggested that the effect of prebiotics was actually indirect, because it is the changes in the gastrointestinal microbiota compositions (bifidobacterias, lactobacilli, as well as the histolyticum subgroup; bacteroides and clostridia) that give rise to the prebiotics effect. Bifidobacteria and lactobacilli are the beneficial bacteria that serve as prebiotics target (Macfarlane, Steed, & Macfarlane, 2008). A positive effect of prebiotic reflects significant increase in numbers of bifidobacteria and lactobacilli, while retarding the development of histolyticum subgroup (Palframan, Gibson, & Rastall, 2003). Probert and Gibson (2002), Langlands, Hopskin, Coleman, and Cummings (2004) as well as Macfarlane *et al.* (2006) are among those who reported the increases in number of bifidobacteria and lactobacilli in the gut, as a result of prebiotic action. Gibson, Beatty, Wang, and Cumming (1995) found that bifidobacteria was able to stimulate the immune system, produce vitamin B, inhibit pathogen growth, reduce blood ammonia and blood cholesterol levels as well as help to restore the normal flora after antibiotic therapy, while the lactobacilli aid digestion of lactose in lactose-intolerant individuals, reduce constipation and infantile

Table 2. The composition of prebiotics, their properties and production methods.

Prebiotics	Composition	Production Method	DP	Status	References
Inulin	β(2-1) fructans	Hot water extraction from chicory root	11–65	Commercialized	Coppa, Bruni, Zampini, Galeazzi, & Gabrielli, 2002; Franck, 2002; Roberfroid, 2002; Roberfroid, 2005
Fructo-oligosaccharides (FOS)	β(2-1) fructans	Tranfructosylation from sucrose, or hydrolysis of chicory inulin	2–10	Commercialized	L'Homme, Arbelot, Puiserver, & Biagini, 2003; Losada & Olleros, 2002
Galacto-oligosaccharides (GOS)	Oligo-galactose (85%) with some glucose and lactose	Produced from lactose by β-galactosidase	3–5 2–5	Commercialized	Alander *et.al.*, 2001; Ziegler *et.al*, 2007
Soya-oligosaccharides (SOS)	Mixture of raffinose (F-Gal-G) and stachyose (F-Gal-Gal-G)	Extracted from soya bean whey	3–4	Commercialized	Crittendan & Playne, 1996; Hayakawa *et.al.*, 1990; Jaskari, 1998
Xylo-oligosaccharides (XOS)	β(1-4)-linked xylose	Enzymic hydrolysis of xylan	2–4	Commercialized	Crittendan & Playne, 2002; Yamada, 1993
Pyrodextrins	Mixture of glucose-containing oligosaccharides	Pyrolysis of potato or maize starch	Various	Commercialized	Macfarlane *et al.*, 2006
Isomalto-oligosaccharides (IMO)	α(1-4) glucose and branched α(1-6) glucose	Transgalactosylation of maltose	2–8	Commercialized	Kaneko, Yokoyama, & Suzuki, 1995; Kohmoto, Fukui, Takaku, & Mitsuoka, 1991

DP, degree of polymerization; F, fructose; Gal, galactose; G, glucose. Source: Macfarlane *et al.*, 2006; Vernazza, Rabiu, & Gibson, 2006 and Wang, 2009.

diarrhea, help resist infections such as salmonellae and help to relieve irritable bowel syndrome (Manning & Gibson, 2004).

Mushrooms as a potential source of prebiotics

Recent developments in prebiotics have heightened the need to search for another potential source of prebiotics. Mushrooms seem to be a potential candidate for prebiotics as it contains carbohydrates like chitin, hemicellulose, β- and α-glucans, mannans, xylans and galactans (Table 3 simplified findings on the composition of carbohydrate in mushrooms).

Chitin – a water insoluble polysaccharides – accounting up to 80–90% of dry matter in mushroom cell wall, with the N-containing chitin as one of the skeletal fungal polysaccharides that responsible for the rigidity and shape of the wall. Chitin only presents in some taxonomical group of Zygo-, Asco-, Basidio- and Deuteromycetes and does not present in other group like Oomycetes (Vetter, 2007). Manzi, Marconi, Aguzzi, and Pizzoferrato (2004) studied the chitin content in eight samples of *Boletus* spp. mixtures and found that it ranges from 68 to102 mg/g of dry matter. Chitin molecules were indigestible for human and plays role as a dietary fiber (Bauer-Petrovska, Jordanoski, & Kulevanova, 2001; Kalac, 2009 and Cheung, 1996). The bioactivities of water insoluble polysaccharides was however less as compared to water soluble polysaccharides (Tao *et al.*, 2006). This was supported by a study done by Mizuno, Saito, Nishitoba, and Kawagashi (1995) where no antitumor activity of chitin was found.

Most of mushrooms polysaccharides present as linear and branched glucans with different types of glycosidic linkages such as (1 → 3), (1 → 6)-β-glucans and (1 → 3)-α-glucans. However, some of them are true heteroglycans containing arabinose, mannose, fucose, galactose, xylose, glucose and glucuronic acids as main side chain components or in different combinations. Even though mushrooms polysaccharides are of different chemical composition, most of them belonging to the group of β-glucans (Wasser, 2002). In *Pleurotus* spp. it ranges from 2.2 to5.3 mg/g of dry matter, while in *Lentinula edodes* it was reported to be around 2 mg/g of dry matter as well (Manzi & Pizzoferrato, 2000). In the following year, Manzi, Aguzzi, and Pizzoferrato (2001) revealed the concentration of beta glucan in another three different species of mushrooms including the raw and cooked. Beta glucan in raw *A. bisporus* was ranging from 1.2 to1.7 mg/g, while in cooked ranging from 0.8 to4.2 mg/g. Raw *P. ostreatus* and dried *Boletus* contains 139.2 mg/g and 548.8 mg/g of beta glucan respectively, while the cooked mushroom has slightly higher concentration of beta glucan.

Digestive enzymes secreted by the pancreas or brush border of vertebrates, and of mammals in particular, are unable to hydrolyze β-glucosidic bonds. This make them resistant to acid hydrolysis in the stomach and remain non-digestible by human digestive enzymes (Van Loo,

Table 3. Carbohydrate constituents isolated from various types of mushrooms.

Carbohydrate constituents	Sources	Revealed by
β-glucan	*Pleurotus ostreatus*	Yoshioka *et al.*, 1985; Synytsya *et al.*, 2008; Tong *et.al.*, 2009
	Pleurotus eryngii	Synytsya *et al.*, 2008
	Pleurotus tuberregium	Tao *et al.*, 2006
	Ganoderma lucidum	Wang & Zhang, 2009
Water-soluble heteropolysaccharides constituted with D-galactose, D-mannose, D-xylose, L-fructose, L-(or D)-arabinose	*Ganoderma lucidum* *Phellinus baumii Pilat*	Sone *et al.*, 1985; Miyazaki, 1982; Ge, Zhang & Sun, 2009
Xylose, Fructose, Mannose, Glucose, Sucrose, Trehalose	Edible mushrooms in Korea Pleurotus ostreatus, Agaricus bisporus, Flammulina velutipes, Pleurotus eryngii, Lentinus edodes Medicinal mushrooms in Korea Agaricus blazei, Sparassis crispa, Brown rice – Phellinus linteus, Ganoderma lucidum, Inonotus obliquus	Kim *et al.*, 2009
Krestin	cultured mycelial biomass of *Trametes versicolor* (Turkey tail)	Wasser, 2002
Chitin	*Boletus* spp	Manzi *et al.*, 2004
	European species of wild mushrooms (*Agaricus* spp, *Boletus* spp)	Kalac, 2009
Lentinan	fruiting bodies of *Lentinus edodes*	Wasser, 2002
Schizophyllan	liquid culture broth product of *Schizophyllum commune* (Split Gill)	Wasser, 2002
(1 → 3)-α-d-glucan and β-(1 → 3)-linked glucans	spores of *Ganoderma lucidum*	Bao, Liu, *et al.*, 2001; Bao, Duan, *et al.*,2001
Water soluble polysaccharides; (1 → 6) -linked-α-d-glucopyranosyl, (1 → 2,6)-linked-α-d-glucopyranosyl, (1 → 6)-linked-α-d-galactopyranosyl	*Armillaria mellea*	Sun, Liang, Zhang, Tong, & Liu, 2009

2006). The non-digestible property of mushroom carbohydrate enables it to be considered as a potential source of prebiotic, as it meets part of prebiotic's definition. However, intense studies need to be carried out, before such claim could be made because not all dietary carbohydrates are prebiotics (Gibson *et al*., 2004).

Synytsya *et al.* (2008) gave a positive overview that mushrooms extract of *P. ostreatus* and *P. eryngii* were able to stimulate the growth of probitics – *Lactobacillus* ssp. (4 strains: Lac A–D), *Bifidobacterium* ssp.(3 strains: Bifi A–C) and *Enterococcus faecium* (2 strains: Ent A and B) – to some extent. Maximum growth rate, maximum biomass concentration and final acid production were observed in the study. It was found that extract from *P. eryngi* support the growth of *Lactobacillus* strains better than *P. ostreatus*. Lactobacillus B and C showed the highest production of short chain fatty acid (SCFA), while Bifidobacteria A showed the lowest amount of SCFA when supplemented with both extracts.

Wang (2009) has highlighted and pointed out the important criteria of prebiotics. Fig. 1 illustrated the criteria for classification of a food ingredient in order to be regarded as prebiotic. The first criteria for prebiotics, which is non-digestible or resistant to upper gut tract is actually to ensure that the prebiotics can withstand digestive processes before they reach the colon, thus stimulate the beneficial bacteria; bifidobacteria and lactobacilli effectively (Gibson & Collins, 1999; Macfarlane *et al*., 2008). Resistance to digestive processes includes resistance towards gastric acidity, hydrolysis by mammalian enzymes and gastrointestinal absorption (Gibson *et al*., 2004). Some of the non-digestible oligosaccharides presently available or in development as food ingredients include carbohydrates in which the monosaccharide unit is fructose, galactose, glucose and/or xylose. The non-digestible oligosaccharides are made of one, two or even three monosachharides and have no nutritional significant (Quigley, Hudson, & Englyst, 1999; Roberfroid, 2000). It is water soluble and exhibits some sweetness. However, the degree of sweetness depends on the chain length. It was reported that inulin with degree of polymerization more than ten does not taste sweet anymore (Roberfroid, 2000).

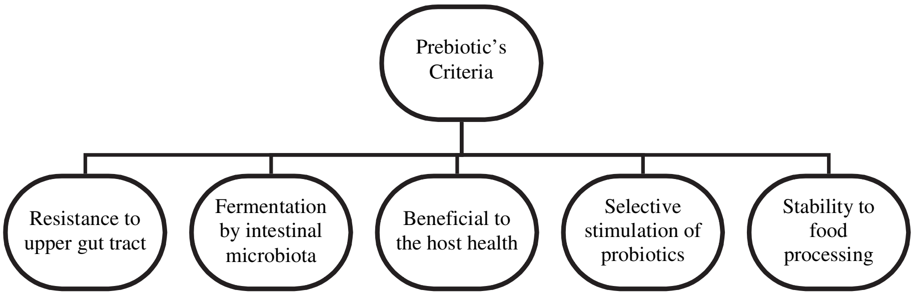

Fig. 1. Criteria for classification of a food ingredient as prebiotic. (Source: Wang, 2009).

Criteria which allow the classification of a food ingredient as a prebiotic also include selective fermentation by potentially beneficial bacteria in the colon (Gibson *et al.*, 2004; Wang, 2009). The effects of this fermentation may lead to an increase in the expression or change in the composition of short-chain fatty acids, increased fecal weight, a mild reduction in luminal colon pH, a decrease in nitrogenous end products and reductive enzymes, an increased expression of the binding proteins or active carriers associated with mineral absorption and immune system modulation (Douglas & Sanders, 2008), which is beneficial to the host health; requirement for the third criteria.

Selective stimulation of the growth and/or activity of intestinal bacteria potentially associated with health and well-being is considered as one of the criteria of prebiotics (Gibson *et al.*, 2004). Prebiotics are reported to be particularly suited to the growth and activities of probiotics, bifidobacteria and lactobacilli (Wang, 2009) and suppress the growth of clostridia and bacteroides. Palframan *et al.* (2003) had came out with a comparative quantitative tool known as Prebiotic Index (PI) for measurement of prebiotic effects *in vitro*. Assumption from the equation is that the increases in the population of bifidobacteria and/or lactobacilli are considered a positive effect, while an increase in bacteroides and clostridia (histolyticum subgroup) are negative. PI can be calculated using the following equation:

$$\text{Prebiotic Index} = \frac{\text{Bif}}{\text{Total}} - \frac{\text{Bac}}{\text{Total}} + \frac{\text{Lac}}{\text{Total}} - \frac{\text{Clos}}{\text{Total}}$$

Where Bif is bifidobacterial numbers at sample time/numbers at inoculation, Bac is bacteroides numbers at sample time/numbers at inoculation, Lac is lactobacilli numbers at sample time/numbers at inoculation, Clos is Clostridia numbers at sample time/numbers at inoculation and total is total bacteria numbers at sample time/numbers at inoculation.

Ghoddusi, Grandison, Grandison, and Tuohy (2007) studied the prebiotic effect of several candidate prebiotics-inulin, fructooligosaccharides, polydextrose and isomaltooligosaccharides alone and in combination—by using Prebiotic Index. Mixture of fructooligosaccharides and inulin showed the highest PI at 8 h and 24 h as compared to the rest. Inulin alone however showed negative PI at 8 h, but a positive PI at 24 h.

However, this is the toughest criteria to be fulfilled. Not all candidate prebiotics showed selective fermentation. Study conducted by Langlands *et al.* (2004) and Duncan, Scott, and Ramsay (2003) demonstrated that fermentation of prebiotics-inulin has caused an increased in other bacterial genera such as *Roseburia, Ruminococcus* and *Eubacterium* in the gut. This is because different people harbour different bacterial species and the composition of the microbiota can be affected by a variety of other factors such as diet, disease, drugs, antibiotic, age and others (Macfarlane *et al.*, 2006).

Last but not least, a prebiotic must be able to withstand food processing conditions so that they remain intact—not degraded or chemically altered—and available for bacterial metabolism in gut Huebner, Wehling, Parkhurst, and Hutkins (2008). As a result, the gastrointestinal health of human can be improved (Tuohy, Probert, Smejkal, & Gibson, 2003). Huebner *et al.* (2008) has tested a few commercial prebiotics over several processing conditions. It has conclusively shown that only heating at low pH caused significant reduction in prebiotic activity of inulin, while fructooligosaccharides (FOS) contained product was observed to be the least stable. Other processing condition tested—processing at low pH and Maillard reaction condition—showed minimum changes in prebiotic activity.

Conclusions

The roles of prebiotic in improving and maintaining human health have been studied extensively. Food containing prebiotics can now be found easily in the market. These include bread, cereal bar, spread, confectioneries, sauces, infant milk formulae, beverages and health drink. Developing a new potential prebiotic from inexpensive and abundant materials like mushrooms are those qualities that need to be considered. There are great advantages of incorporating the mushrooms extracts in food as its polysaccharides were reported to exhibit immunomodulating properties, antitumor activities as well as anticancer activities. Consumers will not only benefited with the prebiotic effect of mushrooms extract, but also enjoying the medicinal benefit of it. Even though scientific experiments have proven a significant prebiotic effect of *P. ostreatus* and *Pleurotus eryngii* on selective microorganisms, an intensive and more thorough research need to be conducted as other prebiotic criteria has not been confirmed. It needs to be supported with thorough *in vivo* and *in vitro* studies. Furthermore, the flavor of mushrooms extract need to be further studied and evaluated as it may impart the sensory properties of final product. To date, only compounds responsible for the flavor of mushrooms have being published and no reported data was found on the flavor of extracted polysaccharides from mushrooms. Those findings however reflect a great potential of mushroom to be regarded as a source of prebiotics.

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