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Prebiotic Potential of underutilized Jerusalem artichoke in Human Health: A Comprehensive Review

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Abstract— *The global burden of non-communicable diseases has been rising over the last century, with the leading cause of neurological, metabolic and degenerative disorders. The several studies have reported that the incorporation of prebiotics in human diet is favourable to eliminate the pathological ailments. Since prebiotics occur naturally in plants including leeks, asparagus, onion, wheat, garlic, chicory, oats, soybean and Jerusalem artichoke. Jerusalem artichoke is a perennial tuber contains proteins, mono or poly- unsaturated fatty acids, vitamins, minerals and excellent amount of soluble dietary fibers such as inulin and fructo-oligosaccharides with negligible amount of starch which is digested with Bifidobacterium. It is associated with expansion of bioavailability of minerals, increase activity of favourable bacteria, ease the digestion of high protein diets, delay fat absorption, deliver roughage, prevent constipation, increase satiety value which results in various therapeutic properties such as antidiabetic, cardioprotective and hepatoprotective effects, anti-inflammatory, antimicrobial, anti-obesity, anti-inflammatory and other pharmacological properties. It is also used as a functional food ingredient in the design and production of child formulation, chocolates, sugar confectionaries, soups, sauces, meat products, bakery products, nutritional bars, beverages, milk products, dietary supplements and many other food products. Therefore, its remarkable therapeutic effects and various food applications make this tuber very valuable for further investigation in the area of pharmaceutical and food industries.*
Keywords— **Jerusalem artichoke, Prebiotics, Inulin, Fructo-oligosaccharides, Pharmacological properties.**

I. INTRODUCTION

Nowadays, besides the basic role of nutrition entailing in the supply of nutrients for growth and development, additional aspects are becoming increasingly significant, including the maintenance of health and counteracting diseases. The global burden of non-communicable diseases has been rising over the last century, with the leading cause of neurological, metabolic and degenerative disorders. The several studies have reported that the incorporation of prebiotics in human diet is favourable to eliminate these pathological conditions (Markowiak and Katarzyna, 2017). Prebiotics are non-digestible oligosaccharides and polysaccharides that positively stimulating the growth and/or activity of *bifidobacteria* and lactic acid bacteria in the colon. They exert antagonism against *Salmonella sp.* and *Escherichia coli*, limiting their proliferation, therefore, improve host health (Bindels, *et al.*, 2015). Prebiotics are occurring naturally in plants such as leeks, asparagus, onion, wheat, garlic, chicory, oats, soybean and Jerusalem artichoke and synthesized from enzymatic digestion of polysaccharides. Scientists have re-examined and classified prebiotics on the basis of common criteria in which, Inulin, fructose-oligosaccharides, galactosaccharides, lactulose and polydextose are recognized as the establishing prebiotics. On the other hand, isomalto-oligosaccharides, xylo-oligosaccharides and lactitol are categorized as emerging prebiotics (Sadler and Stowell, 2007). They exert a myriad of health promoting effects including; they are involved in formulating starter culture, maintain intestinal health, inhibiting cancer and preventing metabolic disorders. They also seem to promote a positive modulation of immune system as shown in Figure 1 (Delgado, *et al.*, 2011).

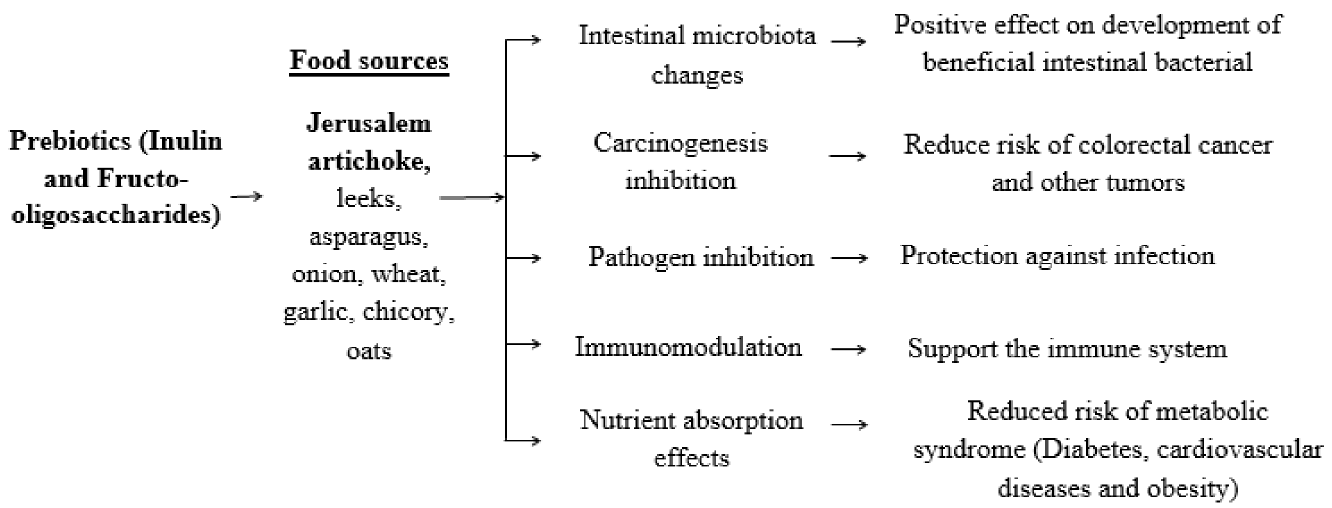

Fig.1: Mechanism of prebiotics and their effects

II. JERUSALEM ARTICHOKE

Jerusalem artichoke, a sunflower species belongs to *Asteraceae* family is botanically known as *Helianthus tuberosus* L. The stem is 5-10 ft tall, ridged and stout which can become woody over time. The leaves are situated near the top of the stem and flowers are small and bright yellow (Pan, *et al.*, 2009). It has an underground rhizome system which bears uneven and elongates varying from knobby to round clusters small fleshy tubers resembling to potatoes. The colour of tubers varies from pale brown, red and purple depending upon the climate conditions (Talipova, 2001). These tubers originated from the United States that become naturalized as an economic crop worldwide in temperate areas and is presently also grown in Canada, France, Germany, Netherlands, USSR, Japan and India (Slimestad, *et al.*, 2010).

Jerusalem artichoke tuber contains proteins, mono or poly-unsaturated fatty acids, vitamins, minerals and dietary fibres with negligible amount of starch (Barta and Patkai, 2007). Its tubers have functional food ingredients such as inulin and fructo-oligosaccharides contributing nutraceutical properties (Kays and Nottingham, 2007). According to Barclay, *et al.*, (2010) that artichoke tubers contain 10-20% of inulin on fresh weight basis and known to have prebiotic effects. Similarly, El-Kholy and Mahrous, (2015) stated that the aqueous extract of Jerusalem artichoke tubers contains higher amount of inulin (21.46g/100g) and three major sugars: sucrose (4.33g/100g), fructose (3.25g/100g) and glucose (2.77g/100g). It has high amount of biologically active components including sesquiterpenes, flavonoids, isoflavonoids, phenols, phenolic acids, glycoalkaloids, phytic acids, coumarins, organic acids, polyacetylenes, and their derivatives naturally occurring isomers of caffeoylquinic acid. It also possesses antidiabetic, anti-inflammatory, antimicrobial, anti-obesity, anticancer and other pharmacological properties (Kapusta, *et al.*, 2013).

III. PREBIOTIC COMPONENTS IN JERUSALEM ARTICHOKE

INULIN

Inulin is a plant polysaccharide that comprises all straight-chain fructans consisting of fructosyl units linked by β-D(2-1) glycosidic bond (Roberfroid, 2005). It is a polydisperse mixture of molecules which can be symbolized by as GFn, where G is the glucosyl moiety, F is the fructosyl moiety and n is the number of fructosyl moiety linked by β(2-1) linkages. The degree of polymerization of inulin typically ranges from 2 to 60 as shown in Figure 2. The presence of β(2-1) bond prevents inulin from being digested like typical carbohydrate and is responsible for its reduced calorie value and dietary fibre effects (Abed, *et al.*, 2016).

Inulin is a “functional food ingredient” and known to have prebiotic potential, which is associated with expanding bioavailability of minerals, inhibition of pathogenic bacteria and increase activity of beneficial bacteria in the digestive tract. It also ease the digestion of high protein diets, deliver roughage, prevent constipation, delay fat absorption, increase satiety value without having extra calories which results in lowering blood glucose, cholesterol and triglycerides levels (Lopez-Molina, *et al.*, 2005).

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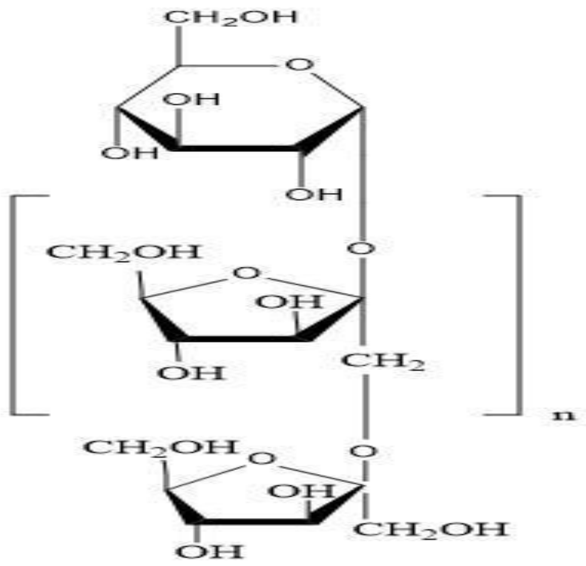

Fig.2: Structure of inulin, n=2-60

FRUCTO-OLIGOSACCHARIDES (FOS)

Fructo-oligosaccharides (FOS), also known as "oligofructan and oligofructose" that are naturally present in vegetables and fruits (Muir, *et al.,* 2009). They are short chain of fructose polymer which are composed of D-fructose units linked with β(2-1) and not hydrolysed by human digestive enzymes. They are obtained from the hydrolysis of inulin using endoinulinase enzyme or by conducting enzymatic reaction of sucrose transfructosylation residues using the β fructofuranosidase or fructosyl- transferase (De-Sousa, *et al.*, 2011). Ketose (GF_2), nystose (GF_3) and fructofuranosyl nystose (GF_4) are the three key chemical structures of FOS, in which the fructose units (F) are linked at β(2-1) glycosidic bonds and the terminal glucose units (G) are linked to fructose unit at the α(1-2) glycosidic bond as shown in Figure 3 (Ibrahin, 2018).

FOS can be used as a substitute for sucrose in foods such as, yogurt, nutritional bars, diet beverages and in low calorie sweetener for diabetes. They are claimed to enhance the growth of favourable bacteria in the colon and used as soluble dietary fibre for constipation and traveler's diarrhoea (Costa, *et al.*, 2015). It is associated with Improving mineral absorption (calcium and magnesium), lowering of blood pressure and responsible for the inhibition of the production of the reductase enzyme that contribute to cancer (Coundray, *et al.*, 2003). It also prevents obesity, stimulates the immune system, reduce the synthesis of triglycerides and fatty acids in the liver and decrease blood glucose levels (Kolida and Gibson, 2007). Table 1 illustrates the amount of inulin and fructo-oligosaccharides present naturally in plants such as Jerusalem artichoke leeks, asparagus, onion, wheat, garlic, chicory, oats and soybean (Thammarutwasik et al., 2009).

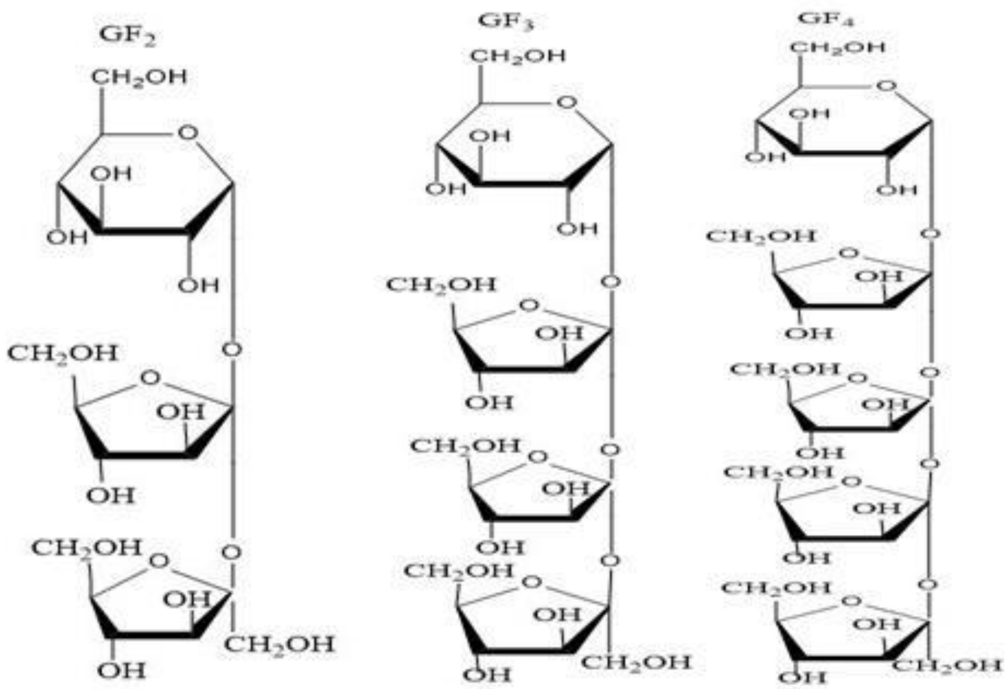

Fig.3: Structure of fructo-oligosaccharides

Table 1: Inulin and fructo-oligosaccharides content of food products

Food Sources	Inulin (g/100g)	Fructo-oligosaccharides (g/100g)
Jerusalem artichoke tuber (*Helianthus tuberosus*)	**16.0-20.0**	**10-15**
Raw onion pulp (*Allium cepa*)	1.1-7.5	2.0-6.0
Asparagus raw (*Asparagus officinalis*)	2.0-3.0	5.0-10
Chicory root (*Cichoriumintybus*)	35.7-47.6	5.0-10
Barley (raw cereal) (*Hordeumvulgare*)	0.5-1.5	0.5-1.5
Wheat (flour baked) (*Titicum sp.*)	1.0-3.8	1.0-3.8
Garlic (*Allium sativum*)	9.0-16.0	3.0-6.0
Leek (*Allium ampeloprasum*)	3-10	2-5
Banana (*Musa sapientum*)	0.3-0.7	0.3-0.7
Yacon (*Smallanthus sonchifolius*)	3-19	3-19
Artichoke (*Cynara scolymus*)	3-10	<1
Dandelions (*Taraxacum officinale*)	12-15	NA
Rye (*Secale cereale*)	0.5-1.0	0.5-1.0

FOOD APPLICATIONS OF JERUSALEM ARTICHOKE

Currently, one of the trends in food segment is the health and wellness linked with the growth of food industry. Formulation of functional foods containing prebiotic component is widely used in the design of numerous dietary and pharmaceutical supplements in recent years, not only for economic reasons but by scientific evidence of its remunerations (Burgain, *et al.*, 2011). Hence, Jerusalem artichoke as a source of inulin and fructose-oligosaccharides, have been incorporated into a wide variety of food products. It is used as a functional food ingredient in the design and production of child formulation, chocolates, sugar confectionaries, soups, sauces, nutritional bars, meat products, bakery products, beverages and drinks, yoghurts, desserts, milk products, dietary supplements and many other food products as depicted in Table 2 (Wang, 2009). Though, consumers may appreciate tasty food while promoting beneficial effects to their own health (Coman, *et al.*, 2012). According to Millani, *et al.*, (2009) consumption of child formulations incorporated with these agents is associated with improving allergy cases and preventing constipation. Radovanovic, *et al.*, (2014) conducted that wheat bread fortified with Jerusalem artichoke powder have optimal nutritional value with low Glycemic index (53.70) and low Glycemic load (7.67). Likewise, Rodrigues, *et al.*, (2012) reported that preparation of cheese with inulin and fructo-oligosaccharides is associated with lower atherogenecity index.

Table 2: Application of Jerusalem artichoke in food products

Food Products	Applications
Beverages and drinks	Mouthfeel, sugar replacement, foam stabilization and prebiotics
Yoghurts and desserts	Texture and mouthfeel, sugar replacement, fiber and prebiotics
Meat products	Texture stability, fat replacement, and fiber
Breads and fillings	Texture, sugar or fat replacement, fiber and prebiotics
Cake and biscuits	Moisture retention, sugar replacement, fiber and prebiotics
Dietary supplements	Sugar or fat replacement, fiber and prebiotics
Child formulations	Body and mouthfeel, texture, fiber, stability and prebiotics
Sugar confectionaries	Sugar replacement, fiber and prebiotics
Chocolate	Sugar replacement, heat resistance and fiber
Soups and sauces	Sugar replacement and prebiotics

THERAPEUTIC PROSPECTIVE OF JERUSALEM ARTICHOKE AS FUNCTIONAL FOOD INGREDIENT ANTIDIABETIC PROPERTIES

There is evidence that soluble fibres are beneficial in the reduction of serum glucose and insulin postprandial by raising the viscosity of the nutrients in the small intestine that results in delaying the release of glucose (Saad, 2006). Oral administration of Jerusalem artichoke tuber extracts caused a significant decrease in blood glucose levels by 33.8% in hyperglycemic rats due to the presence of an optimum quantity of polysaccharide inulin (Asian, *et al.*, 2010). Similarly, Al, *et al.,* (2012) elucidated that diets fortified with artichoke tuber induced a significant decrease in serum glucose in the hyperglycemic rats. Wang, *et al.*, (2016) reported that fermented Jerusalem artichoke extract showed significant decrease in blood glucose concentration and serum insulin level in mice. In support of these observations, Okada, *et al.*, (2017) also reported that Jerusalem artichoke tubers improve glucose tolerance in rats. Likewise, Ahn, *et al.*, (2018) revealed that Supplementation of Jerusalem artichoke has been associated with reduced level of fasting glucose and homeostasis model assessment insulin resistance of diabetic patients.

CARDIOPROTECTIVE PROPERTIES

The pronounced decrease occurred in serum total cholesterol, triglycerides, LDL and VLDL in rats fed with Jerusalem artichoke tuber compared with the positive control (Zaky, 2009). Likewise, Gaafar, *et al.*, (2010) stated that supplementation of inulin extracted from artichoke tubers resulted in a decrease in total cholesterol, triglycerides, total lipids, LDL and VLDL-cholesterol levels in diabetic rats. Meanwhile, HDL level was increased significantly. In addition, Asma and Gindy, (2016) have shown that bread substituted with Jerusalem artichoke powder, barley flour and a mixture of both induced significant decrease in triglycerides, total cholesterol and LDL- cholesterol of rats in the hyperglycemic groups in comparison with control group.

HEPATOPROTECTIVE PROPERTIES

The study stated by Ghanem, *et al.*, (2016) concluded that the supplementation of low calorie pan breads containing Jerusalem artichoke as a source of inulin showed significant decrease in Glutamate oxaloacetate transaminase and Glutamate pyruvate transaminase enzyme level in diabetic mice when compared with control group. Kim and Han, (2013) concluded that the aqueous extract of Jerusalem artichoke prevented elevation of aminotransferase, alanine aminotransferase, serum aspartate, y-glutamyl transpeptidase and lactate dehydrogenase levels in STZ-induced diabetic rats. Another result revealed by Yang, *et al.*, (2012), that artichoke tubers may improve hepatic insulin sensitivity, decreases the synthesis of fatty acids and triglycerides in liver and lowers their circulating level in mice. Later, Abdel-Hamid, *et al.*, (2015) concluded that Jerusalem artichoke tubers showed a promising hepatoprotective effect against CCL4 (Carbon tetrachloride)-induced fibrosis via modulation of apoptotic signaling and fibrogenic activity.

ANTIOBESITY PROPERTIES

According to Kaur and Gupta, (2002) that inulin is a low calorie food ingredient as it comprises less than half amount of calorie content of digestible carbohydrates. Cho, *et al.*, (2010) revealed that the supplementation with Jerusalem artichoke tuber exerted the antiobesity effects in the diet of obese rats due to the presence of dietary fibres, rendering a good source for preventing obesity. Later, Guess, *et al.*, (2015) concluded that human subjects supplemented with inulin lost significantly more weight and had lower hepatic muscle fat content compared to control.

ANTI-INFLAMMATORY PROPERTIES

Diets fortified with inulin suppress G protein-coupled receptor-43 overexpression which combat high-fat-diet-induced obesity through the modification of the gut microbiota and resulted in decreased level of circulating lipopolysaccharide and lower C-reactive protein levels to attenuate inflammation (Dewulf, *et al.*, 2013). According to Koleva *et al.*, (2012) administration of inulin and fructo-oligosaccharides attenuate chronic intestinal inflammation in HLA-B27 transgenic rats. Hence, administration of Jerusalem artichoke might reduce systemic inflammation due to the presence of fructo-oligosaccharides and inulin.

ANTIMICROBIAL PROPERTIES

The administration of artichoke as a source of soluble fibers increase the number of *lactobacilli*, *bifidobacteria,* and certain butyrate-producing bacteria such as *Clostridium perfringens* group (Costabile, *et al.*, 2010). Likewise, the study showed that its extracts exerted antifungal activity against *Rhizoctoniasolani*, *Botrytis cinerea* and *Alternariasolani* (Liu, *et al.*, 2007). Gengaihi, *et al.*, (2009) reported that tuber extracts have antimicrobial activity against the test gram-positive (*Candida albo*, *Pseudomonas*, *Bacillus subtilis* and *Staphylococcus aureus*) and gram-negative bacteria (*Saccharomyces cerevisiae*, *Arthrobacter*, *Kill bacteria tiffy*, *Escherichia coli*, and *Enterobacter* due to the presence of many potent compounds such as bitter sesquiterpene, lactones, inulin, flavonoids and coumarins.

IV. CONCLUSION

The review paper revealed that Jerusalem artichoke tuber as prebiotic agent appears to be unique among the currently available adaptogenic tubers. It possesses antidiabetic, cardioprotective and hepatoprotective effects, antiobesity, anti-inflammatory, antimicrobial and many other pharmacological properties. Its powder has been used in numerous dietary supplements such as child formulation, chocolates, sugar confectionaries, soups, sauces, nutritional bars, meat products, bakery products, beverages, milk products and many other products in food industry. Hence, its remarkable therapeutic effects and various food applications make this tuber very valuable for further investigation in the area of pharmaceutical and food industries.

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