



PREBIOTIC EFFECTS OF INULIN AND ACACIA GUM

(REVIEW)

*GjoreNakov¹, Darina Georgieva¹, Nastia Ivanova¹, Stanka Damyanova¹, Viktorija Stamatovska²,
Ljupka Necinova²

¹Department of Biotechnology and Food Technologies, University of Ruse "Angel Kanchev", Branch Razgrad,
Aprilsko vastanie Blvd. 47, Razgrad 7200, Bulgaria, gore_nakov@hotmail.com, nastiav2001@yahoo.com

²Faculty of Technology and Technical Science-Veles, University Ss. Kliment Ohridski Bitola, R.Macedonia,
stamvikima@gmail.com

*Corresponding author

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Abstract: *Prebiotics have great potential as agents to improve or maintain a balanced intestinal microflora to enhance health and wellbeing. They are non-digestible (by the host) food ingredients that have a beneficial effect through their selective metabolism in the intestinal tract. Key to this is the specificity of microbial changes. Thanks to the methodological and fundamental research of microbiologists, enormous progress has been made in understanding the gut microbiota. A large number of human intervention studies have been performed that have demonstrated that dietary consumption of certain food products can result in statistically significant changes in the composition of the gut microbiota in line with the prebiotic concept. The concept prebiotics is to enhance the growth of beneficial bacteria in the lower intestine. There is much interest in increasing the numbers and activities of beneficial bacteria (Bifidobacteria) in the large gut, preferably at the expense of more harmful bacteria. The focus of this review has been to point out the prebiotic effects (bifidogenic effects) of acacia gum and inulin. Some effects attributed to selected prebiotics have been proved by clinical trials, while others have been acquired on the basis of in vitro tests.*

Keywords: *prebiotics, inulin, acacia gum, prebiotic effects (bifidogenic effects)*

1. Introduction

Prebiotics are a category of nutritional compounds grouped together, not necessarily by structural similarities, but by ability to promote the growth of specific beneficial (probiotic) gut bacteria. Many dietary fibers, especially soluble fibers, exhibit some prebiotic activity; however, non-fiber compounds are not precluded from being classified as prebiotics presuming they meet the requisite functional criteria [1]. Gibson and

Roberfroid (1995) defined prebiotics as “a nondigestible 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, and thus improves host health.” Given the large number of bacterial strains present in the gastrointestinal (GI) tract, some of which are non-cultivable, the definition was revised to “a selectively fermented ingredient that allows specific changes, both in the composition and/or

activity in the gastrointestinal microflora that confers benefits upon host well-being and health” [3]. Roberfroid (2007) updated this definition in review article on prebiotics.

Definitions of prebiotics typically have in common an emphasis on the compound being non-digestible (and hence subject to colonic enzymatic activity and fermentation by colonic bacteria) and able to selectively stimulate the growth of one or more desirable or health-enhancing types of gut bacteria. While definitions of prebiotics do not emphasize a specific bacterial group, the number and/or activity of *Bifidobacteria* and other lactic acid-producing bacteria must be increased for the compound to qualify as a prebiotic. Either implicitly or explicitly within most definitions is the concept that the compound improve the health of the subject consuming it [1].

Prebiotics are a very specific type of food. While many of the food ingredients we consume are digested immediately, prebiotics are a healthy non-digestible food ingredient. Furthermore, prebiotics are heat resistant, which keep them intact during the baking process and allow them to be incorporated into every day food choices. By consuming a non-digestible ingredient, it allows for growth of bio-cultures by reaching the intestine unaffected by the digestion process. A prebiotic effect occurs when there is an increase in the activity of healthy bacteria in the human intestine. The prebiotics stimulate the growth of healthy bacteria such as bifidobacteria and lactobacilli in the gut and increase resistance to invading pathogens. This effect is induced by consuming functional foods that contain prebiotics. These foods induce metabolic activity, leading to health improvements. Healthy bacteria in the intestine can combat unwanted bacteria, providing a number of health benefits [5].

A prebiotic effect has been attributed to many food components, sometimes

without due consideration to the criteria required. In particular, many food oligosaccharides and polysaccharides (including dietary fibre) have been claimed to have prebiotic activity, but not all dietary carbohydrates are prebiotics [3-4]. For a food ingredient to be classified as a prebiotic it must fulfil [6] the following criteria:

- Neither be hydrolyzed, nor absorbed in the upper part of the gastrointestinal tract;
- Be selectively fermented by one or a limited number of potentially beneficial bacteria commensal to the colon, e.g. bifidobacteria and lactobacilli, which are stimulated to grow and/or become metabolically activated;
- Prebiotics must be able to alter the colonic microflora towards a healthier composition, for example by increasing numbers of saccharolytic species while reducing putrefactive microorganisms.

Inulin, oligofructose or fructo-oligosaccharide (FOS) are the best studied prebiotics. To date, all known and suspected prebiotics are carbohydrate compounds, primarily oligosaccharides, known to resist digestion in the human small intestine and reach the colon where they are fermented by the gut microflora. Studies have provided evidence that inulin and oligofructose (OF), lactulose, and resistant starch (RS) meet all aspects of the definition, including the stimulation of *Bifidobacterium*, a beneficial bacterial genus. Other isolated carbohydrates and carbohydrate-containing foods, including galactooligosaccharides (GOS), transgalactooligosaccharides (TOS), polydextrose, wheat dextrin, acacia gum, psyllium, banana, whole grain wheat, and whole grain corn also have prebiotic effects [7].

Predominance of *Bifidobacteria* in the large intestine is essential for the prevention of many diseases and for maintaining good health. One main

strategy is the prebiotic approach – the use of selective carbohydrate substrates in the diet for the growth of indigenous bifidobacteria. To be effective, these carbohydrates must reach the colon undigested and unabsorbed in the upper gastrointestinal tract and be selectively

2. Inulin

Inulin is a non-digestible oligosaccharide that, for nutritional labelling, is classified as dietary fibre [3]. Inulin is a soluble dietary fibre. Inulin and oligofructose belong to a class of carbohydrates known as fructans. The main sources of inulin and oligofructose that are used in the food industry are chicory and Jerusalem artichoke. They are considered as functional food ingredients since they affect physiological and biochemical processes in rats and human beings, resulting in better health and reduction in the risk of many diseases. Experimental studies have shown their use as bifidogenic agents, stimulating the immune system of the body, decreasing the levels of pathogenic bacteria in the intestine, relieving constipation, decreasing the risk of osteoporosis by increasing mineral absorption, especially of calcium, reducing the risk of atherosclerosis by lowering the synthesis of triglycerides and fatty acids in the liver and decreasing their level in serum [8].

Inulin is a generic term that covers all linear fructans with β (2–1) bonds, with a variable degree of polymerization [9]. This specific type of glycosidic bond gives inulin its unique structural and physiological properties. Because of the beta configuration of the bonds between

utilized by the bacteria present there [8]. Inulin and acacia gum are examples of such carbohydrates.

In this review, we present an overview of the prebiotic effects (bifidogenic effects) of inulin and acacia gum.

fructose monomers, inulin-type fructans resist enzymatic hydrolysis by human salivary and small intestinal digestive enzymes – specific for alpha-glycosidic bonds. As a result, inulin-type fructans are indigestible and are fermented in the colon [1], [4].

The "bifidogenic effect" can be defined by a specific stimulation of lactic acid bacteria. Lactic acid bacteria including *Lactobacilli* and *Bifidobacteria* are thought to be beneficial for the host as they are associated with beneficial health effects. This group of bacteria can protect the host by inhibiting potential harmful bacteria (eg. *Clostridium*, *Staphylococcus*,...) through different mechanisms [10].

The bifidogenic effect of inulin and oligofructose is now well established in various studies, not only in adult participants but also in other age groups. This bifidogenic shift in the composition of the colonic microbiota is likely the basis for the impact of these prebiotic compounds on various parameters of colonic function. Mainly from animal and *in vitro* studies and also from some human trials, there are indications, for instance, that inulin-type fructans may reduce the production of potentially toxic metabolites and may induce important immune-mediated effects [9].

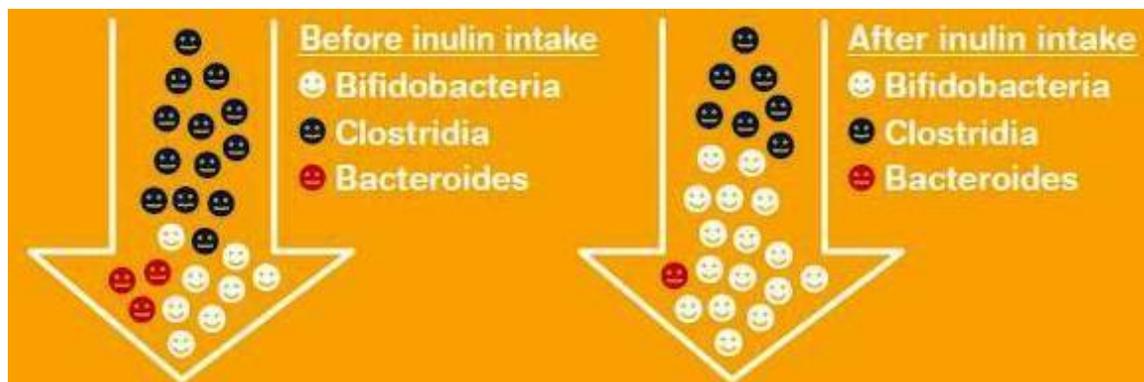


Fig. 1: Prebiotic effect of inulin consumption on the composition of colonic microbiota[11]

Gibson and Wang (1994) confirmed the prebiotic effects of inulin and oligofructose in an *in vitro* study. The fermentability was compared to a range of reference carbohydrates in batch culture. Bacterial growth data showed preferential fermentation by *Bifidobacteria* while populations of *Escherichia coli* and *Clostridium perfringens* were maintained at relatively low levels [6]. Gibson et al. (1995) studied the selective stimulation of bifidobacteria by inulin and oligofructose in a 45-day study of eight healthy male human subjects. Volunteers were fed controlled diets of 15 g/d sucrose for the first 15 days followed by 15 g/d oligofructose for a further 15 days. Four volunteers went on to consume 15 g/d inulin for the final 15 days of the study [6]. The studies of Gibson et al. (1995) showed that oligofructose and inulin significantly modified the *in vivo* composition of the microbiota by stimulating the growth of *Bifidobacteria* [8].

Results from Kaur and Gupta (2002) have shown that ingestion of inulin compared to other sources of carbohydrate like sucrose, could significantly reduce the count of pathogenic bacteria such as bacteroids, fusobacteria and clostridia and increase the count of positive microorganisms such as *Bifidobacteria* [14]. Similar human studies in adult European, Japanese and North American populations have been reported

for inulin using different daily doses. It has been suggested that the beneficial effect of inulin could be due to the ability of bifidobacteria to change the colonic environment by inhibiting detrimental bacteria via the formation of bacteriocins, the successful competition for substrates or adhesion sites on the gut epithelium, and stimulation of the immune system [8].

In vitro data supporting the selective stimulation of bacterial growth by inulin has been generated in numerous studies that are summarised in Table 1. This has been carried out in defined pure culture fermentation and by using a mixed faecal inocula in both batch and continuous culture [3].

Inulin is naturally present in many different foods. Some every day foods, such as asparagus, leek, onions, banana, wheat and garlic are sources of inulin. Higher concentrations exist in herbs. Dandelion root, elecampane root and chicory root all have large amounts of inulin. Chicory root is the most common source of inulin due to its extremely high concentration as well as its similarities to the sugar beet. The methods used for the extraction of inulin from the chicory root are comparable to the extraction of sucrose from the sugar beet. This allows for similar equipment to be used, making it easier for chicory root producers to cultivate inulin.

Table 1.

Studies made to demonstrate the *in vitro* selectivity of inulin in pure culture, mixed batch culture and mixed continuous culture fermentation

STUDY	OBSERVATIONS	REFERENCE
Examining the growth of bifidobacteria on different types of oligofructose in pure culture. Eight species tested as well as species of <i>Clostridium</i> , <i>Bacteroides</i> , <i>Enterococci</i> and <i>Escherichia coli</i> .	Linear oligofructose had more of a bifidogenic effect than greater molecular-mass molecules and branched-chain varieties. <i>Bifidobacterium</i> species showed a preference for fructans compared with glucose.	Gibson & Wang (1994b)
Species of <i>Bifidobacterium</i> (<i>longum</i> , <i>breve</i> , <i>pseudocatenulatum</i> , <i>adolescentis</i>) were tested in pure culture for their ability of fermenting oligofructose.	<i>B. adolescentis</i> was seen to grow best and was able to metabolise both short- and long-chain oligofructose.	Marx et al. (2000)
The ability of <i>Bifidobacterium</i> and <i>Lactobacillus</i> to grow on MRS agar containing oligofructose was investigated.	Seven out of eight bifidobacteria and twelve out of sixteen lactobacilli were able to grow on agar containing oligofructose.	Kaplan & Hutkins (2000)
Batch culture using faecal inocula to study fermentation of inulin, oligofructose, starch, polydextrose, fructose and pectin.	<i>Bifidobacteria</i> most increased with oligofructose and inulin whilst populations of <i>E. coli</i> and <i>Clostridium</i> were maintained at relatively low levels.	Wang & Gibson (1993)
Batch culture using faecal inocula to study fermentation of oligofructose, branched fructan, levan, maltodextrin.	Fluorescence <i>in situ</i> hybridisation revealed that branched fructan had the best prebiotic effect, followed by oligofructose.	Probert & Gibson (2002)
Continuous culture fermentation to study fermentation of oligofructose.	Selective culturing showed <i>Bifidobacterium</i> and, to a lesser extent, <i>Lactobacillus</i> , preferred oligofructose to inulin and sucrose. <i>Bacteroides</i> could not grow on oligofructose.	Gibson & Wang (1994b)

This dietary fibre is used as a prebiotic agent in functional foods to stimulate the growth of beneficial intestinal bacteria. It is soluble in hot water, allowing the inulin to be easily incorporated into drinks, dairy products, and baked goods [15].

Because inulin, oligofructose, and FOS are classified as soluble fibers they can be used as a means of increasing dietary fiber or to replace sugars or fats. Depending on the taste, texture, and other attributes desired, different mixtures are considered for inclusion in food products like

confectionery, fruit preparations, milk desserts, yogurt and fresh cheese, baked goods, chocolate, ice cream and sauces. Inulin can also be used for the preparation of fructose syrups. In these applications they are considered to be a functional food ingredient, added to make health claims and/or persuade the consumer the product is a healthier choice than one that does not contain inulin-type prebiotics [8], [16].

2. Acacia gum

Acacia gum (GUM) or gum arabic (Codex *Alimentarius* Rome 2000) is a soluble dietary fibre obtained from the stems and branches of *Acacia senegal* and *Acacia seyal*. These trees are abundant in the

central Sudan, central Africa and in West Africa [17]. This product is known under different names, gum arabic (Codex *Alimentarius* Rome 2000) [10]. It is composed mainly of complex

polysaccharides (95%) that consist of highly branched galactan polymers, with galactose and/or arabinose side chains, possibly terminated by rhamnose or glucuronic acid residues [17].

Acacia gum has readily been used in the food industry for decades as a food additive. The joint FAO/WHO expert committee on food additives recognizes acacia gum as a food additive (INS 414) that can be used with no specified ADI. In the USA, Acacia gum enjoys a GRAS (Generally Recognised As Safe) classification [18]. In Europe, acacia gum is also recognized as a food additive (E 414) under the “*quantum satis*” principle [19]. In 2001 the French administration has officially recognized AG as a dietary soluble fiber which allows the fiber content of acacia gum to be taken into account for the nutritional content labeling of fiber [10].

More than twenty studies have been performed since the late 70’s to understand the relationships between acacia gum and the colonic microflora. It is widely recognized that acacia gum induces [10]:

- A bifidogenic effect;
- A specific stimulation of SCFAs production;
- A high gut tolerance.

While >80% of current production is used by the food industry for various applications (emulsification, encapsulation, coating, gum candies, etc.), GUM is traditionally consumed by African and Indian populations to improve digestive comfort and intestinal transit. *In vitro*, its fermentation is slow and supports the growth of *Bifidobacteria*. Thus, GUM may be a bifidogenic soluble dietary fibre that would not induce uncomfortable intestinal side effects in the healthy consumer [17].

First studies performed *in vitro* showed that among different genus of bacteria from human faeces, bifidobacteria strains were able to use acacia gum for their growth [20].

Various studies mention its potential as a prebiotic agent. Wyatt et al. addressed the issue in one volunteer by applying 10 g gum arabic and noted an increase in the numbers of *Bacteroides* and *Bifidobacterium* [22]. *In vitro* studies showed that GUM supported the growth of pure cultures of bifidobacteria strains and increased total lactic acid-producing bacteria counts in continuous cultures of human faecal microflora. In the stools of one volunteer, Wyatt et al. measured an increase in the proportion of bacteria able to ferment the gum, among which species of *Bacteroides* and *Bifidobacterium* were found. These preliminary findings suggested that GUM could be prebiotic [17].

The bifidogenic properties of acacia gum were confirmed in a single blind controlled study performed on 10 healthy volunteers consuming either acacia gum (Fibregum™) at the dose of 10 g/d and 15 g/d during 10 days or sucrose as control at the same dose.

Concentrations of *Bifidobacteria*, *Lactobacilli* and total lactic acid bacteria groups were significantly increased with Acacia gum at the dose of 10 g/d compared to control without affecting neutral groups as bacteroides. The bifidogenic effect was even more pronounced (+1 log) in subjects having low initial bifidobacteria count (<9.5 log). The effect was also significant at the dose of 15 g/d [17-18].

Lower dose (6 g/d) of acacia gum was tested in a randomized double blind controlled study involving 96 healthy volunteers. After 1 week of consumption, 6 g/d of acacia gum (Fibregum™) induced a 0.7 log increase of faecal *Bifidobacteria* compared to initial value that was at the limit of statistical significance (p=0.09). Moreover, the effect of this fiber was greater compared to FOS that induced a 0.3 log increase.

These experimental studies allow concluding that acacia gum has a prebiotic effect at the dose of 10 g/d and that the extent of the effect is at least equal to the effect of FOS [10], [18].

Due to the growing range of supplemented products, consumers are exposed to increasing amounts of prebiotics and may ingest daily doses above the threshold for induction of side effects. In vitro fermentation time for acacia gum is significantly longer than that for FOS and studies have suggested a more favourable abdominal side-effect profile. Replacement of a proportion of FOS by acacia gum may thus attenuate the side effects of prebiotics with the additional advantage of a synergistic effect on the growth of intestinal bifidobacteria [23].

The prebiotic efficacy of Acacia gum was also clinically confirmed when consumed

for up to 4 weeks [22]. Daily consumption of water was taken as the negative control and that of 10 g inulin as the positive control. Compared with the negative control, the number of *Bifidobacteria* and *Lactobacilli*, 4 weeks after consumption were significantly higher for Acacia gum (10g): approximately 40-fold and 6-fold difference in outgrowth. Moreover, at this dose the numbers of *Bifidobacteria* and *Lactobacilli* were significantly higher for acacia gum than for inulin: respectively an approximately 10-fold and 7-fold difference. (Graph 1) All subjects tolerated the 4 weeks of consumption of acacia gum and no significant changes were observed during the intervention period as compared to subjects who consumed the negative or positive control.

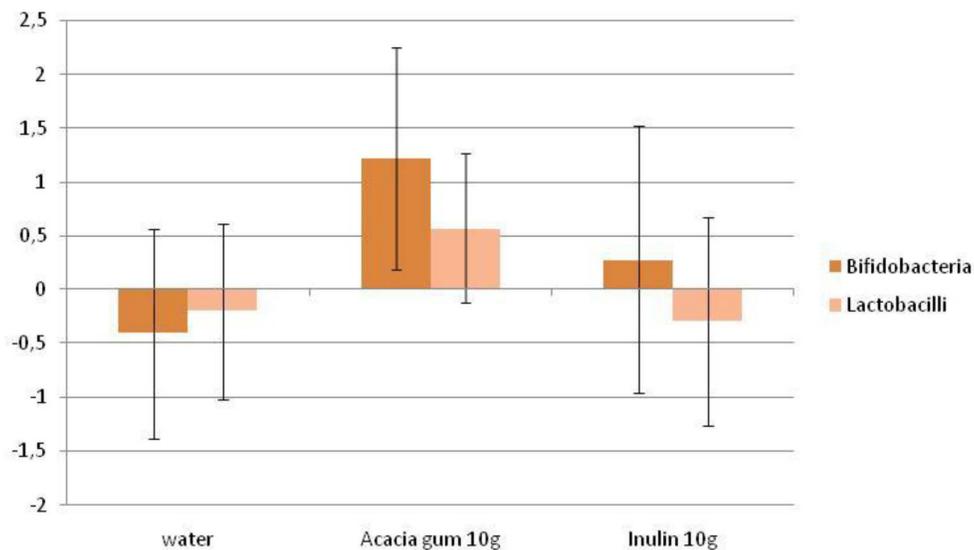


Fig. 2. The change in 10-logarithmic numbers of bacteria during 4 weeks of consumption of 10g acacia gum, 10g inulin or water [10]

Acacia gum was shown to produce a greater increase in *Bifidobacteria* and *Lactobacilli* than an equal dose of inulin, and resulted in fewer gastrointestinal side effects, such as gas and bloating [22]

When used as food additive, acacia gum is a texturiser, thickener, stabiliser, emulsifier and coating agent. Such variety of functions with a single product is unique.

When used as ingredient for its health benefits, acacia gum is a dietary fibre with prebiotic effects. The health benefits of acacia gum are given by the non digestible behaviour of the high molecular weight molecule. Acacia gum is a dietary fibre (more than 90 % on dry basis) with high

4. Conclusion

Prebiotics are nondigestible food ingredients that benefit the host by selectively stimulating the growth or activity of one or a limited number of bacteria in the colon. Because of their positive attributes *Bifidobacteria* and *Lactobacilli* are the most frequent target organisms. Several researchers believe a potentially more important factor in influencing growth of *Bifidobacteria*, as well as other microorganisms, is the initial presence and counts of specific gut microorganisms prior to supplementation. While more research in this area is needed, it is at least possible that in order to boost

gut tolerance and prebiotic effect. Low viscosity in water system, low calorific value (1,8 – 2 kcal/g) and non-cariogenic effect explain the wide field of applications in dietary food and nutraceutical products [24].

the amounts of a specific *Bifidobacteria* species or other bacteria, that species must initially be present.

Inulin and acacia gum have been demonstrated to be effective prebiotics. This has been shown through both invitro and in vivo assessments in different laboratories. Experimental studies have shown their use as bifidogenic agents and decreasing the levels of pathogenic bacteria. Because of their recognised prebiotic properties, principally the selective stimulation of colonic bifidobacteria, both inulin and acacia gum are increasingly used in new food product developments.

5. References

- [1] KELLY G., Inulin-type prebiotics – A Review: Part 1, *Alternative Medicine Review*, Volume 13, Number 4, (2008).
- [2] GIBSON G.R., ROBERFROID M.B., Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics, *J. Nutr.* 125: 1401-1412, (1995).
- [3] GIBSON G.R., PROBERT H.M., LOO J.V., RASTALL R.A., ROBERFROID M.B., Dietary modulation of the human colonic microbiota: updating the concept of prebiotics. *Nutr Res Rev* 17: 259-275, (2004).
- [4] ROBERFROID M. Prebiotics: the concept revisited, *J. Nutr.*, 137:830S-837S, (2007)
- [5] http://www.prebiotic.ca/prebiotic_fibre.html.
- [6] KOLIDA S., TUOHY K., GIBSON G.R., Prebiotic effects of inulin and oligofructose, *British Journal of Nutrition*, 87, Suppl. 2, S193–S197, (2002).
- [7] SLAVIN J., Fiber and Prebiotics: Mechanisms and Health Benefits, *Nutrients*, 5, 1417-1435, (2013).
- [8] KAUR N., GUPTA A. K., Applications of inulin and oligofructose in health and nutrition, *J. Biosci.* 27 703–714, (2002).
- [9] MEYER D., Stasse-Wolthuis M., The bifidogenic effect of inulin and oligofructose and its consequences for gut health, *European Journal of Clinical Nutrition*, 63, 1277–1289, (2009).
- [10] Fibregum™, Colloides Naturels International, www.cniworld.com (2010).
- [11] <http://www.inspiredbyinulin.com/get-inspired/healthy-food/inulin-and-weight-management.html>.
- [12] GIBSON G.R., WANG X., Enrichment of bifidobacteria from human gut contents by oligofructose using continuous culture, *FEMS Microbiology Letters*, 118, 121–128, (1994).
- [13] GIBSON G. R., BEATTY E. R., WANG X. CUMMINGS J. H., Selective stimulation of bifidobacteria in the human colon by oligofructose and inulin, *Gastroenterology*, 108, 975–982, (1995).
- [14] MIREMADI, F., SHAH, N. P. Applications of inulin and prebiotics in health and nutrition, *International Food Research Journal* 19(4): 1337-1350 (2012).
- [15] <http://www.prebiotic.ca/inulin.html>

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- [16] COUSSEMENT P.A. Inulin and oligofructose: safe intakes and legal status. *J Nutr.*, 129:1412S-1417S, (1999).
- [17] CHERBUT C., MICHEL C., RAISON V., KRAVTCHENKO T., SEVERINE M., Acacia gum is a bifidogenic dietary fibre with high digestive tolerance in healthy humans, *Microbial Ecology in Health and Disease*, 15: 43 -50, (2003).
- [18] BARAY S., Chapter 7: Acacia Gum, Section I: Soluble Fibers, In: *Fiber Ingredients: Food Applications and Health Benefits*, (Edited by Cho S.S., Samuel P.). CRC Press, Taylor & Francis group, 121-131 (2009).
- [19] http://www.food.gov.uk/science/additives/enumerlist#.U43Q7_1_uSo.
- [20] SALYERS AA. *et al.* Degradation of polysaccharides by intestinal bacterial enzymes. *AM. J. Clin. Nutr.* 31:S128-130, (1978).
- [21] WYATT T.M., BAYLISS C.E., HOLCROFT J.D., A change in human faecal flora in response to inclusion of gum arabic in the diet, *British Journal of Nutrition*, 55, 261–266, (1986).
- [22] CALAME W, WESELER AR, VIEBKE C, FLYNN C, SIEMENSMA AD. Gum arabic establishes prebiotic functionality in healthy human volunteers in a dose-dependent manner, *British Journal of Nutrition*, 100, 1269–1275, (2008).
- [23] Goetze O., Fruehauf H., Pohl D., Giarre M., Rochat F., Ornstein K., MenneD., FRIED M., THUMSHIRN M., Effect of a prebiotic mixture on intestinal comfort and general wellbeing in health, *British Journal of Nutrition*, 100, 1077–1085, (2008).
- [24] <http://www.treegums.org/products/gum-acacia/>