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Dietary Fibre and Prebiotics

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DIETARY FIBRE AND PREBIOTICS

Dietary fibre intake is associated with a myriad of health benefits. Among others, their fermentation by the microbiota results in the formation of short chain fatty acids, which protect against pathogenic bacteria. Together with dietary fibres, prebiotics are colonic nutrients but prebiotics are degraded and utilized only by beneficial bacteria, namely bifidobacteria and/or lactobacilli. (S. Macfarlane, 2010)

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It is becoming increasingly accepted that the colonic microbiota is of key importance to health and well-being of the host. (Wallace et al., 2011) The growth and metabolism of the individual bacterial species resident in the large intestine, especially in the large bowel, depends primarily on the substrates available to them, which come from the diet. (G. T. Macfarlane & Cummings, 1999) The human adult colon is the most densely populated region where at least 50 genera of bacteria, comprised of about 400 to 500 different species, reside. In a healthy gut there is a balance between potentially harmful and beneficial bacteria. (Gibson & Roberfroid,

1995) (Wallace et al., 2011) (Patel & Goyal, 2012) Lactobacilli and bifidobacteria are considered to be beneficial with many health promoting properties which can be modulated by substrates obtained from diet. (Rabiu & Gibson, 2002)

DIETARY FIBRE

Today, there is no single definition for dietary fibre that is accepted worldwide. (Lunn & Buttriss, 2007) Dietary fibre includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibre promotes beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation. (Buttriss & Stokes, 2008) Fibres occur with different degrees of polymerization which is usually defined as the number of monomeric units. (Gibson & Roberfroid, 1995) Dietary fibre as for example cellulose, hemicellulose, pectin, lignin, inulin or oligofructose, which are naturally occurring in many foods like fresh vegetables and fruits, whole grains, legumes and nuts, reach the large bowel and are principal substrates for fermentation by different bacterial species. Furthermore they can be classified in terms of soluble/insoluble, fermentable/non-fermentable, and viscous/non-viscous, which form the bases of the physiological benefits. (Li & Uppal, 2010) Soluble fibres (e.g. Inulin, oligofructose, pectin) dissolve in water, forming viscous gels and in general are

more readily fermented and are earlier in the colon. (Blackwood et al., 2000); (Lattimer & Haub, 2010) Insoluble fibres (e.g. Cellulose, hemicellulose, lignin) are not water soluble, do not form gels and their fermentation is severely limited. (Lattimer & Haub, 2010) The physiological effects of fibres depend on the type (partially or highly fermentable), the dose of a specific fibre consumed and the individual physiological profile of the subject consuming the fibre-containing meal. (Tungland & Meyer, 2002)

FERMENTATION

The two main types of anaerobic fermentation that are carried out in the gut are proteolytic and saccharolytic, the latter being more dominant. Some metabolites resulting from protein breakdown (e.g. NH_3 , indol, cresol, H_2S) may be considered as potentially adverse to health. (Blaut, 2002) The process of fermentation can be described as an interaction where bacteria obtain the substrates that they need for growth from the host and return their by-products of their metabolism. (Gibney et al., 2009) Fibre particle size and degree of solubility have a considerable effect on susceptibility of fibres to bacterial fermentation. (Gibson, 2004) The bacteria in the colon can synthesize many different types of saccharolytic enzymes (e.g. polysaccharidases, glucosidases) and are able to degrade polymerized carbohydrates. (Bernalier-Donadille,

2010) The end-product of fermentation is pyruvate, which is further converted to short chain fatty acids (SCFA), principally acetate, propionate and butyrate. (Gibney et al., 2009) Between 10 and 60 g of dietary carbohydrates reach the colon every day. The major contribution comes from non-digested polysaccharides (resistant starch). (Rabiu & Gibson, 2002)

SHORT-CHAIN FATTY ACIDS (SCFA)

The health promoting SCFA's are acetate, propionate and butyrate which all act to lower the colonic pH. The impact of each of them differs, but all of them play a vital role in the maintenance of colonic integrity and metabolism. (Scott et al., 2008) Acetate, propionate and butyrate are rapidly absorbed in different regions in the colon into the portal blood and about 10-15% are excreted with feces. Acetate, the principal SCFA in the colon, is used as a fuel for muscle tissues, the heart and the brain. (Olmstead et al., 2008) Propionate is a primary precursor for gluconeogenesis but the exact metabolism of propionate in humans is less understood. (Hijova & Chmelarova, 2007) Butyrate is accepted as the most important SCFA in the colonocyte metabolism because it provides the cells of the intestine with a metabolic fuel and may be a protective factor for the health of these cells. (Cook & Sellin, 1998) Further it has been shown to induce apoptosis in colonic cancer cell lines and exert a level of control over the cell cycle. This suggests that butyrate might play a necessary role in preventing the uncontrolled proliferation of abnormal cells that occurs in the early

CONCLUSION

Inulin and oligofructose have the potential to elevate indigenous bifidobacteria and lactobacilli levels in the colon and thus influence the whole body's physiology and consequently health and well-being. (Conway, 2001)

Inulin and oligofructose are found in a number of vegetables and plants. Most of the eaten food-stuffs like wheat, onions, garlic, leeks, artichokes or bananas have tiny amounts of inulin and oligofructose, thus adequate consumption of vegetables, fruits and whole-grains should be warranted. (Gibson & Roberfroid, 2008) The concept of prebiotics is 17 years old and is still a relatively new field of study. (S. Macfarlane et al., 2006) There are still great deficiencies in our knowledge of the exact mechanisms of prebiotic action and their involvement in disease processes. (Sandra Macfarlane, 2010) New developments in molecular techniques for microbiological analysis will allow the acquisition of definitive information on species rather than genera that are influenced by a test carbohydrate. Maybe then the picture will become clearer for classifying certain carbohydrates where evidence is currently sparse or absent (e.g. RS). (Gibson & Roberfroid, 2008)

stages of colorectal cancer. Increased dietary fibre intake and thus enhanced butyrate production is associated with a reduced risk of colon cancer. (Lunn & Buttriss, 2007) Acidification of the gut by SCFA's may modify the metabolism of bile acids. The conversion of primary bile acids to secondary bile acids, as these are believed to be associated with increased risk of colon cancer, may be reduced. (Tungland & Meyer, 2002) The reduced pH creates an unfavourable environment (Lunn & Buttriss, 2007) that impedes the growth of certain harmful bacterial species, particularly enterobacteriaceae, while encouraging the growth of health-promoting genres. (Gibson & Roberfroid, 1995) Significant amounts of minerals may be absorbed throughout the length of the gut. (Venter, 2007) Studies indicate that highly fermentable carbohydrates (e.g. pectin, inulin, oligofructose) have resulted in improved metabolic absorption of certain minerals, such as calcium, magnesium and iron. Predominantly butyrate enlarges the absorption surface by promoting proliferation of enterocytes and in addition the low pH dissolves insoluble mineral salts and increases their diffusive absorption via the paracellular route. (Tungland & Meyer, 2002)

DEFINITION OF PREBIOTICS AND ITS ORIGINS

Even though all non-digestible carbohydrates can all be classified as "colonic foods", not all are prebiotics. (Gibson

& Roberfroid, 1995) The terms dietary fibre and prebiotics are often used interchangeably but what distinguishes prebiotics from other fibres is that prebiotics selectively stimulate the growth of only beneficial microfloral microorganisms. Prebiotics therefore are unique dietary fibres that preferentially promote the growth and/or metabolic activity of species that contribute to health benefits. (Olmstead et al., 2008) They highly stimulate bacterial fermentation, resulting in the replication and stimulation of bifidobacteria and lactobacilli and the formation of SCFA. (Venter, 2007) Bifidobacteria are a part of a stable adherent microbiota that helps to maintain the mucosal barrier. (Fahey, 2010) When bifidobacteria grow on prebiotic substrates they seemingly do so at the expense of bacteroides, clostridia and coliforms. (Gibson & Roberfroid, 1995)

The term "prebiotic" was first coined and introduced in 1995 by Glenn Gibson and Marcel Roberfroid, who exchanged "pro" to "pre" which means "before". (Aida et al., 2009) The definition was updated in 2004 when prebiotics were defined as "selectively fermented ingredients that allow specific changes, both in the gastrointestinal microflora that confer benefits upon host well-being and health." The definition considers microflora changes in the whole gastrointestinal tract and as such extrapolates the definition into other areas that may benefit from a selective targeting of bifidobacteria and lactobacilli.

The criteria used for classification of a food ingredient as a prebiotic are as follows:

- Resistance to digestive processes in the upper gastrointestinal tract
- Fermentation by gastrointestinal microbiota
- Selective stimulation of growth and/or activity of beneficial bacteria which are associated with health and well-being.

ESTABLISHED PREBIOTICS

According to Gibson and Roberfroid only the inulin-type fructans, namely inulin and oligofructose, are proven prebiotics which fulfill all three criteria, notably the last criteria. The final demonstration of prebiotic attributes should of course not only include in vitro tests but also in vivo nutritional feeding trials in targeted species (humans, animals) using validated methodologies that are supported by sound science. Other candidates (e.g. resistant starch, pectin,

cellulose, β -glucan) have the potential to act as prebiotics, but current confirmatory evidence in humans is scant or even absent and more studies are required. (Gibson & Roberfroid, 2008) However, oligogalactose and lactulose are regarded as established probiotics as well as summarized in table 1.

Inulin and oligofructose are members of a larger group called "fructans". Fructans are linear or branched oligo- or polysaccharides composed of fructose moieties linked by β -(2 $\rightarrow$ 1) glycosidic bonds. (Kelly, 2008) Inulin is composed of a mixture of oligo- and polymers in which the degree of polymerization varies from 2 to 60. For the inulin content of various plants see table 2. Oligofructose is defined as having a chain length no longer than 9 fructose molecules. (Roberfroid, 2007) Fructooligosaccharides (FOS) and oligfructose are often used interchangeably but FOS are synthetic oligosaccharides. (Olmstead et al., 2008) The specificity of bifidobacteria for inulin and oligofructose are likely due to the production of several enzymes that are particularly suited to metabolizing oligosaccharides, including β -fructofuranosidases. (Gibson & Rastall, 2004)

The volume of the increase in bifidobacteria numbers is related to the size of the person's intestinal bifidobacteria population prior to prebiotic treatment. The daily dose is thus, by itself, not a determinant for its prebiotic effect. (Gibson & Roberfroid, 2008) A recommended daily dose for prebiotics has not been established. Some results of clinical trials suggest an optimal and well-tolerated daily dose of 7-10 g/day that increases bifidobacteria and lactobacilli populations, but bifidogenic effects have also been observed at lower doses (e.g. 4 g/day). (Olmstead et al., 2008)

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