NUTRIOSE® 06: a useful soluble dietary fibre for added nutritional value

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Introduction

The World Health Organization and Food and Agriculture Organisation (WHO/FAO 2002) currently recommend that the well-balanced diet required to help control the global epidemic of obesity and for preventing diet-related chronic diseases should include: a balanced energy intake (55–70% from total carbohydrates, 15–30% from total fat and 10–15% from total proteins); foods that release their energy slowly, that is, only about 10% total energy from quickly digested sugars (mono- and disaccharides); and about 40% from complex sugars, such as fibres.

The recommended daily intake of fibre is variable in different countries, but is around 30 g per day per person in most European countries using fibre quantification based on the Association of Official Analytical Chemists (AOAC) 2001–03 method (Gordon & Okuma 2002). This efficient, widely recognised and reliable enzymatic-gravimetric high-performance liquid chromatography (HPLC) method was proposed to the AOAC for the determination of total dietary fibre in foods containing resistant maltodextrin, and is mainly characterised by the fact that it also takes into account low molecular weight resistant oligosaccharides using HPLC, unlike the previous conventional AOAC 985-29 method (Prosky *et al*. 1985), and the Englyst one (Englyst *et al*. 1982), which is still used as a reference in the UK (see Buttriss & Stokes 2008). A resistant dextrin, branded under the range's name NUTRIOSE® (NUTRIOSE® 06 manufactured by ROQUETTE, Lestrem, France) was launched in 2004 after many years of research. It is mostly resistant to digestion in the small intestine and largely fermented in the colon. According to one definition (Roberfroid 2005) and to different notices published by official committees in different countries (*e.g.* Italy and France), it is a soluble dietary fibre. It can therefore be added to make up to 20–25% (w/w) of a foodstuff and is officially recognised and labelled as soluble fibre in many countries. As such, it can be one very useful tool to help achieve the nutritional 'fibre' goal of the WHO/FAO. In addition to this, more and more evidence is emerging about the benefits that NUTRIOSE® can contribute to health as part of a balanced diet, such as reduced blood glucose response and improved gut health. It also offers an outstanding digestive tolerance threshold, allowing its consumption in the amounts best suited to achieving the desired beneficial changes in the gut ecosystem. An overview of these and other nutritional properties, already described in published papers or in papers in press, will be given in this paper. Moreover, as a completely soluble fibre, withstanding extreme conditions of temperature and processing, and very well tolerated when consumed, it is an ideal ingredient for fortifying the fibre content of food and drink; we will briefly conclude on its technical and industrial advantages.

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What is NUTRIOSE®?

Made from starch, NUTRIOSE® can be described as a resistant dextrin. A wide range of dextrins exist for human consumption, for nutrition or pharmaceutical purposes. NUTRIOSE® can be made from either wheat starch (NUTRIOSE® FB range) or maize starch (NUTRIOSE® FM range), using a highly controlled process of dextrinisation. During this process, the starch undergoes a degree of hydrolysis followed by repolymerisation. It is this repolymerisation that converts the starch into fibre, by causing non-digestible glycosidic bonds to be formed, which cannot be cleaved by enzymes in the digestive tract, and in addition, causes some hindrance to the cleavage of the digestible bonds

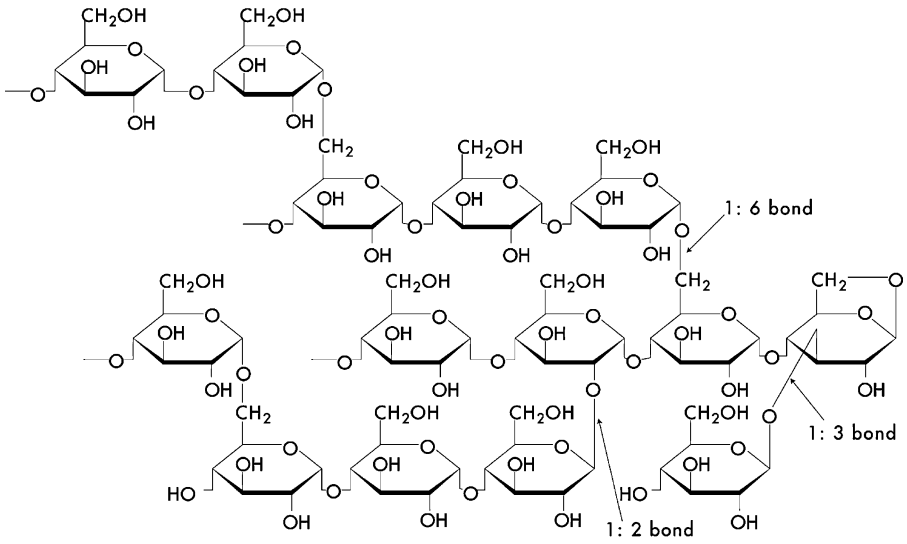

Figure 1 Structural formula of NUTRIOSE® 06.

(Fig. 1). Dextrinisation is followed by a separation step, which ensures the optimum molecular weight distribution to give consistent rheological and technical performance and also the right amount of fibre, which is 85% for NUTRIOSE® 06 according to the AOAC method 2001–03 (Gordon & Okuma 2002; Roturier *et al.* 2003; Roturier & Looten 2006). The product is then put through further refining steps, including removal of simple sugars to obtain a content of mono- and disaccharides below 0.5% on dry substance, and is finally spray-dried. Therefore, although a glucose polymer, NUTRIOSE® 06 may thus be considered sugar-free. About 25% of its osidic linkages are not hydrolysed by human digestive enzymes (Table 1). It is totally soluble in cold water without inducing viscosity, thanks to its fibre content, its analytical characteristics and further physiological properties that we will describe hereafter. Foods containing this product are consequently able to claim 'source of fibre' or 'rich in fibre' if content criteria defined by the European Commission regulation are respected (European Commission 2007). For the record, a claim that a food is a source of fibre, and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least 3 g of fibre per 100 g or at least 1.5 g of fibre per 100 kcal. A claim that a food is high in fibre, and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least 6 g of fibre per 100 g or at least 3 g of fibre per 100 kcal.

How is NUTRIOSE® 06 digested?

By application of equations published by Roberfroid (1999), the caloric value of NUTRIOSE® 06 is 7.1 kJ per g (1.7 kcal per g) based on the marketable form and this value is consistent with clinical determination in healthy young men (Vermorel *et al.* 2004) and in agreement with the consensual caloric value of soluble dietary fibres (Livesey 1992). This value can be used for energy content determination for foods in Europe (Coussement 2001). Unlike standard starch and like a resistant one, NUTRIOSE® 06 is actually partially hydrolysed in the upper part of the digestive tract (Vermorel *et al.* 2004): only 15% is enzymatically digested in the small intestine, while the rest passes to the colon, where 75% of the initial amount is slowly and progressively fermented in the large intestine and 10% is excreted (Van den Heuvel *et al.* 2004).

Table 1 Indicative values of glycosidic bonds distributions (in %) respectively in (1) NUTRIOSE® 06; (2) standard maltodextrin (GLUCIDEX®, ROQUETTE, Lestrem, France); and (3) starch

Type of osidic linkages	(1)	(2)	(3)
(1,4)	41	95	95
(1,6)	32	5	5
(1,2)	13	0	0
(1,3)	14	0	0

Glycaemic and insulinaemic responses of NUTRIOSE® 06

In addition to simply increasing the fibre content of foods, NUTRIOSE® 06 may also have a potential role in weight management, because of its ability to provide

long-lasting energy. A key index that has become accepted as an indicator of the ability of carbohydrate to prevent diseases of lifestyle and to help to reduce the incidence of obesity is the glycaemic index (GI). This measures the glycaemic response (an indication of the rate at which the blood glucose level rises and how it is sustained over time) after the ingestion of carbohydrate foods. The GI is defined as the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of a test food, expressed as a percent of the glucose response to the same amount of carbohydrate from a standard food taken by the same subject (FAO 1998). The insulinaemic index (II), generally correlated to the GI, is similarly defined as the incremental area under the blood insulin response curve of a 50 g carbohydrate portion of a test food expressed as a per cent of the insulin response to the same amount of carbohydrate from a standard food taken by the same subject. The GI and II seem relevant for some nutritional considerations dealing with sustained physical effort and also for appetite regulation, with lower GI foods being the better choice in both cases. An important consideration is that GI values can also be determined for mixed meals and whole diets. When NUTRIOSE® 06 is ingested it induces low glycaemic (glucose response = 25) and insulinaemic responses (insulin response = 13) (Donazzolo *et al.* 2003). It can therefore be used as a slow energy release carbohydrate to partially or totally replace other carbohydrates, such as sugars and starches. For example, when used in a concentrated fruit drink (Fig. 2) and consumed after dilution with water, syrups made with NUTRIOSE® 06 elicit a glucose response of only 10% of the equivalent product made with sugar (Lefranc-Millot *et al.* 2006a).

Possible role in weight management

The benefits of including more fibre in the diet are well acknowledged. In addition to simply increasing the fibre content of foods, NUTRIOSE® 06 may also help to delay the return of the sensation of hunger (Van den Heuvel *et al.* 2004), which is consistent with previous observations and reviews on topics such as the influences on satiation and post-ingestive satiety of foods with a low GI (Bellisle 2008) and high-fibre content (Slavin & Green 2007). Therefore, and as will be attested by shortly published results of a recent clinical study, NUTRIOSE® 06 has a potential role in weight management. Indeed, dietary intervention using NUTRIOSE® 06 supplementation as a soluble fibre significantly modified some biological markers and reduced some of the risk factors usually associated with the metabolic syndrome in 120 overweight men (unpublished observations). Moreover, the effects on vigilance and cognitive performances after NUTRIOSE® 06 administration suggest that the glycaemic response is not the only factor to be considered for predicting the efficiency of a food ingredient on the two initially mentioned parameters (Rozan *et al.* 2008). This point, together with the previously mentioned results on weight management, lead us to put forward the idea that the colonic effects of NUTRIOSE® 06, and mainly the production of short-chain fatty acids (SCFAs) as contributors to the daily energy supply, are also key factors in providing a long-lasting energy supply. This point remains to be clearly demonstrated by clinical studies that will be complicated to design with unquestionable markers in humans. Indeed, products should be, for example, tested in ileostomised patients, which is not always easy to implement or ethically acceptable.

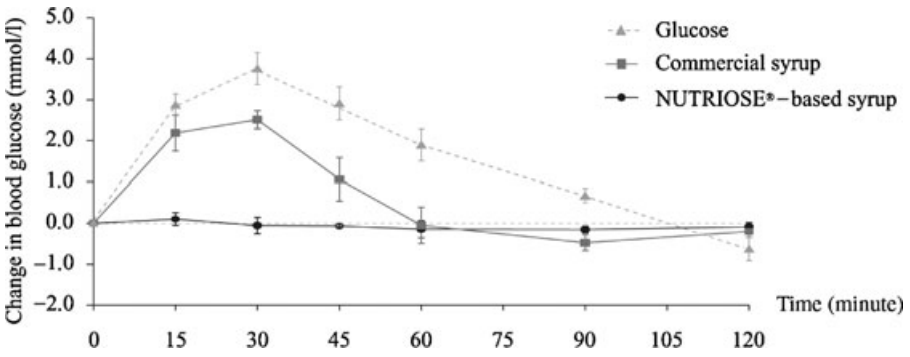

Figure 2 Mean change in human blood glucose concentrations after the ingestion of either NUTRIOSE® 06-based syrup (based on concentrated fruit syrup including 18.3 g per 100 g NUTRIOSE® 06), commercial syrup reference (both products being similarly diluted, as prescribed by the manufacturer) or 50 g anhydrous glucose ingestion. Compared with glucose, the mean glycaemic response (GR) value for the commercial syrup (51 ± 6) is significantly higher ($P = 0.001$) than the mean GR value for the NUTRIOSE® 06-based syrup (6 ± 3).

Moreover, the results obtained are not necessarily representative of those that would be obtained in healthy volunteers.

Prebiotic effects

Numerous definitions of prebiotics with more or less subtle variations have been given in the past decades.

Common well-known prebiotics in use include, in particular, various types of oligosaccharides (*e.g.* inulin, fructo-oligosaccharides and galacto-oligosaccharides) (Alexiou & Franck 2008), having a long history of safe use, although there is some concern about excess production of digestive gas in the gut when consumed in large amounts. However, new types of compounds claiming prebiotic properties are also emerging, inducing a need for a broader definition of prebiotic effects and reflecting more recent understanding of the microbial ecology of the human microbiota. Taking all these considerations into account, the FAO has very recently revised the definition of a prebiotic as 'a non-viable food component that confers a health benefit on the host associated with modulation of the microbiota' (FAO 2007).

Focusing on the physiological effects observed after prebiotic ingestion, NUTRIOSE® has been studied according to one definition (Woods & Gorbach 2001) characterising a prebiotic by: 'an increase in "beneficial bacteria" and/or a decrease in "harmful bacteria," a decrease in intestinal pH, production of SCFAs and changes in bacterial enzymes concentrations'. NUTRIOSE® 06 has been shown to display all these prebiotic effects through colonic fermentations. The different results are derived from many studies, carried out *in vitro*, in animals (rats) and in humans (Van den Heuvel *et al.* 2005; Lefranc-Millot *et al.* 2006b; Pasman *et al.* 2006). These fermentations benefit the colonocytes in the digestive epithelium, encourage an increase in the population of beneficial glucidolytic flora (Fig. 3), decrease colonic pH (Fig. 4) and subsequently decrease potentially pathogenic flora (*e.g.* the number of *Clostridium perfringens* decreases significantly in human faeces after a 14-day administration of 15 g per day NUTRIOSE® 06, $P < 0.05$). The production of SCFAs from the fermentation of carbohydrates in the colon also contributes a significant quantity to the body's daily energy supply, as the SCFAs are used as metabolic fuel. Because this fermentation is not sudden but is progressive through the colon, the sustained production of SCFAs, in addition to the initial release of glucose from the partial digestion in the small intestine, makes NUTRIOSE® 06 a long-lasting source of energy.

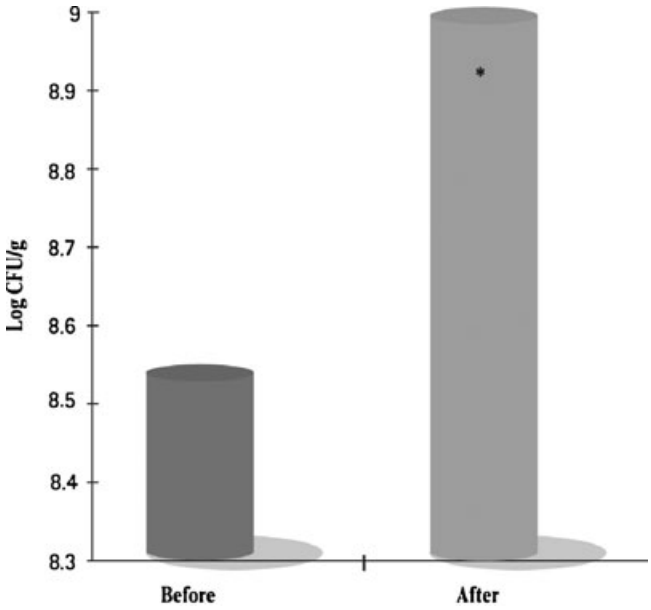

Figure 3 One example of saccharolytic flora (*Bacteroides*) increased in human faeces after a 14-day oral administration of 10 g per day NUTRIOSE® 06. $*P < 0.05$.

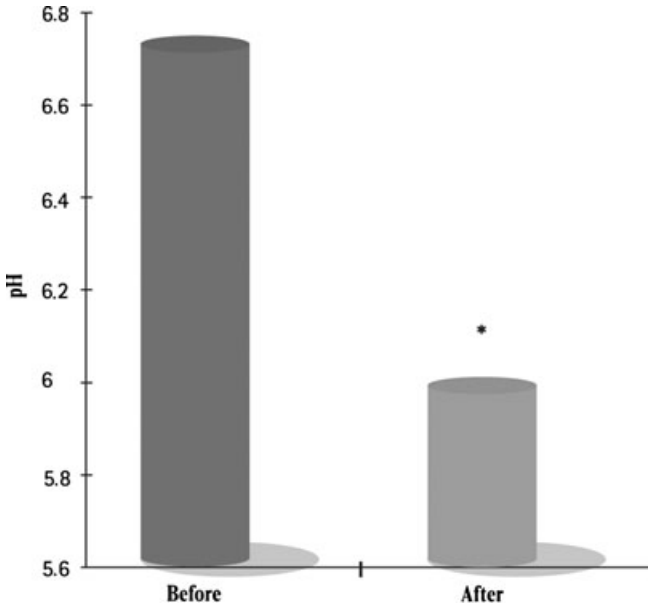

Figure 4 pH of human faeces before and after a 14-day administration of 20 g per day NUTRIOSE® 06. $*P < 0.05$.

This slow and progressive fermentation is in contrast to some other soluble fibres where rapid fermentation may cause digestive discomfort such as bloating, flatulence and diarrhoea. When consumed in the quantity specified to give the claimed nutritional benefit, NUTRIOSE® 06 is outstandingly well tolerated, with a thresh-

old of 45 g per day producing no symptoms of digestive discomfort at all and no occurrence of diarrhoeal events at a dosage of 100 g per day (Van den Heuvel *et al*. 2004; Vermorel *et al*. 2004; Lefranc-Millot *et al*. 2006b; Pasman *et al*. 2006).

Future research

Apart from the clinical results obtained in overweight people, a cholesterol-lowering effect of NUTRIOSE® 06 has been demonstrated in moderately hypercholesterolemic hamsters (Juhel *et al*. 2007). This effect is likely to be related to reduced cholesterol and bile salt absorption and is promising for the prevention of moderate hypercholesterolaemia. Moreover, NUTRIOSE® 06 appears to exhibit a promising effect on intestinal well-being and immunity maintenance, as beneficial effects have been demonstrated on intestinal biomarkers involved in the regulation of pain and the regulation of inflammation in mice. These preliminary results suggest that it may influence the regulation of local immunity and perhaps be a promising and safe treatment for patients with irritable bowel syndrome (Lefranc-Millot *et al*. 2007).

Some technical considerations

This ingredient is easy to process and consume because it is usable, without undesired digestive effects, at efficacious doses. Moreover, it has a clean neutral taste, with no sweetness. It dissolves rapidly and has only a very limited impact on viscosity, although it can provide improved mouth feel in, for example, diet drinks. It can be added to foods without being noticeably present, a clear advantage in many foods where additional viscosity, gumminess or gritty texture would be undesirable. It is stable at conditions of high temperature, variable pH and processes involving high shear. Because of this stability, the quantity of fibre added as NUTRIOSE® 06 to a formulation will remain the same over the course of its shelf life.

Conclusion

With its low glycaemic response, long-lasting energy release, gut 'wellbeing' benefits and high tolerance, NUTRIOSE® offers a wide range of health benefits in addition to simply fortifying the fibre content of food and drink. It withstands heat and acid, is soluble in liquids and produces only limited viscosity. As the food industry struggles to cope with the implications of a global obesity epidemic, NUTRIOSE® offers a range of preventative solutions including a way to reduce energy density, while being very easy to use. More detailed information on some of the properties briefly described previously will soon be detailed in new scientific papers currently in press.

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