sc-FOS GOFOS™ may provide nutritional browning-related advantages vs. inulin-derived oligofructose

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Short-chain fructo-oligosaccharides (sc-FOS) are amongst the most researched non-digestible soluble prebiotic dietary fibers consumed by humans. A myriad of beneficial attributes has been documented for prebiotics beneficial activity, and certainly for sc-FOS including strong bifidogenic effect, ability to lower counts of potential pathogens, acidification of colon by inducing short-chain fatty acid (SCFA) bacterial production, increased absorption of Ca^{+2} and Mg^{+2}, anti-tumor activity, synthesis of B and K vitamins and immunomodulation. sc-FOS is manufactured employing an enzyme having a fructosyltransferase activity starting from the disaccharide sucrose (glucose + fructose; *GF*) as raw material. Sc-FOS use in human nutrition is mainly targeted towards applications in the food industry such as sugar reduction, fiber enrichment and prebiotic action. In addition, sc-FOS can also be used in food additives and nutraceutical market as well as in pet and animal feed industries.

Reducing vs. non-reducing oligosaccharides and their participation in non-enzymatic Maillard browning reactions

Sugar-based sc-FOS is composed of oligofructose molecules of the GFn-type i.e., oligofructose molecules composed of 2,3 or 4 fructosyl monomeric units chemically bonded to each other having a glucosyl terminal unit at the non-reducing end. ***Therefore, Nystose (GF2), Kestose (GF3) and Fructosyl-Nystose (GF4) are non-reducing oligosaccharides unable to directly participate in Maillard chemical browning reactions***. Maillard reactions typically occur during food processing practices performed at elevated temperatures. Such conditions may include practices such as baking, boiling, or frying where reducing sugars or oligosaccharides i.e., molecules having a free carbonyl group may participate by chemically reacting with the amine moiety of amino acids present in polypeptides and proteins. In contrast to sugar-based sc-FOS (buildup of only GFn-type oligosaccharides), inulin and oligofructose (inulin's enzymatic hydrolysis product) consist, in addition to GFn-type structures, also FFn-type fructose oligomers having no terminus of a glucosyl moiety therefore being classified as chemically reducing, able to participate in Maillard browning reactions in foods. Table #1 shows a comparison of several types of commercial non-digestible oligosaccharides (NDO's) and polysaccharides, and their related ability to participate in Millard browning based on their classification as reducing /non-reducing sugars.

Table #1- Types of oligosaccharides/polysaccharides vs. their potential to participate in Maillard browning reactions

Non digestible polysaccharide or oligosaccharide (NDO)	Produced from	Reducing/non-reducing	Participation in Maillard browning
Sc-FOS (short-chain fructo-oligosaccharides	sucrose	NO	NO
Inulin	Chicory root	YES	YES
Hydrolyzed Inulin (oligofructose)	Inulin	YES	YES
GOS (Galacto-oligosaccharides)	Milk lactose	YES	YES
XOS (Xylo-oligosaccharides)	Xylan	YES	YES

Aiming to demonstrate the above effect we have shown in our food application laboratory that the browning intensity of cookies formulated with sc-FOS is lower when compared to the same cookies with the only difference of the latter being formulated using inulin or inulin-derived oligofructose. Cookies made with sc-FOS brown just like their sucrose counterpart's reference, while those produced with inulin or inulin-derived-oligofructose brown much more intensively and are easily distinguished from the sucrose control. From a marketing and sales point of view if a food producer is seeking to reduce sugar content while wishing to minimize any visual difference between the regular sugar containing version to the reduced one, then using sugar-based sc-FOS fiber (like Galam's GOSFOS™) will result in minimal and almost non distinguishable visual differences.

Nutritional aspects of reducing/non-reducing oligosaccharides and their contribution to the potential of acrylamide (AA) and "advance glycation end-products" (AGE's) production in foodstuff

Acrylamide is an unsaturated amide that has been produced for decades by hydration of acrylonitrile. AA is odorless, highly water soluble having a low MW of 71.08, and melting point of 84.5◦C (*Elbashir et al., Critical Reviews in Analytical Chemistry, 44:107–141, 2014*). AA monomer is readily polymerizable to polyacrylamide and provides a myriad of applications in chemical manufacturing industries (i.e., flocculant, sealant for construction, binder in the paper/pulp industry, dye synthesis). Worries about human exposure to AA arose in 2002

when it was discovered that it may be created in foodstuff during high-temperature cooking, such as frying, baking, roasting during industrial processing at temperatures usually above 120°C and low moisture. AA may be formed in products such as baked or fried carbohydrate-rich foods, bread, biscuits, and coffee. It has been demonstrated that the reaction of the free amino acid asparagine with reducing sugars (naturally occurring or added in foods), via Maillard reaction is the main pathway contributing to AA accumulation in foods. *("ACRYLAMIDE", Safety evaluation of certain contaminants in food, WHO FOOD ADDITIVES SERIES: 63, FAO JECFA monographs 8, 72nd meeting of the Joint FAO WHO Expert Committee on Food Additives (JECFA), Rome, 2011*).

AA is known for its hazardous potential effect on human health, and international organizations including FDA, EFSA and WHO have proposed to take actions to reduce its levels in the food industry supply chain. For example in March 2016 the U.S. Department of Health and Human Services, Food and Drug Administration Center for Food Safety and Applied Nutrition issued a guidance on AA safety (https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-acrylamide-foods).

In view of the above, the reduced browning/Maillard potential related to non-reducing oligosaccharides such as sc-FOS or SOS may be beneficial from a nutritional aspect i.e. – a reduced tendency to participate in Maillard/chemical browning reactions lowers the risk of production of chemical hazardous molecules such as acrylamide (AA).

Recently, results from mouse-model research have reported that "advanced glycation end products" (AGE's) originating from Maillard reaction such as those occurring in the manufacture of processed foods may negatively harm health by contributing to "leaky gut" (Snelson et al., Sci. Adv. 2021; 7). It is therefore hypnotizable that sc-FOS being a non-reducing oligosaccharide may not be able to contribute to the formation such AGE's via Maillard pathways in products which may be consumed daily by humans.

In conclusion, sc-FOS may provide added value in the form of a reduced potential to contribute to AA formation in baked food products, for example, when used to replace sugar in cookies and alike products. In addition, sc-FOS may have reduced effect on excess browning and lower contribution to formation of AGE's in processed food products when compared to other reducing non-digestible oligosaccharides.