



Short Chain Fructo-Oligosaccharide Vs Inulin and longer chain FOS



**Why cannot you ignore
Short Chain FOS in your
formulation?**

Why is chain length important? - Degree of Polymerization (DP)

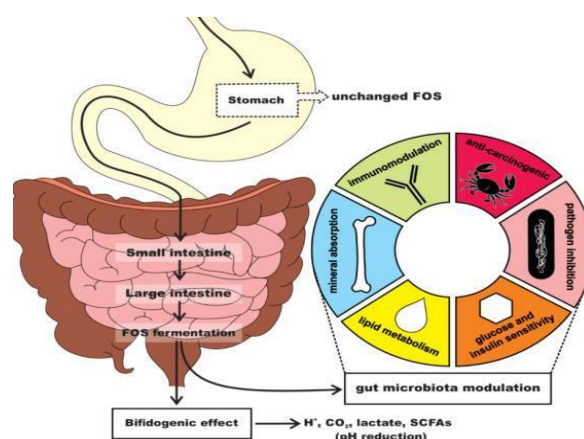
Chain length of fructans or degree of polymerization plays an important role in determining the prebiotic effect and is an important factor in determining physiological effects (Perrin et al, 2002). The DP (chain length) of scFOS is between 3 and 5 while that for Inulin ranges from 2 to 60 (Kathy R. Niness, 1999).

Being shorter in the length, scFOS is fermented readily when compared to longer chain inulin leading to a determining factor in bifidobacterium metabolism of scFOS and thus production of the short chain fatty acids and more probiotic growth (Perrin et al, 2002; Bouhnik et al. 1996).

Metabolism of short chain FOS and Inulin

The scFOS and Inulin are not digested in the stomach and on reaching colon, they are metabolized completely by the colonic microflora, through fermentation, leading to production of Short chain fatty acids (SCFA) and gases (CO₂, H₂, methane) (Bornet et al, 1994, Hosoya, et al 1998 & Bouhnik et al, 2004).

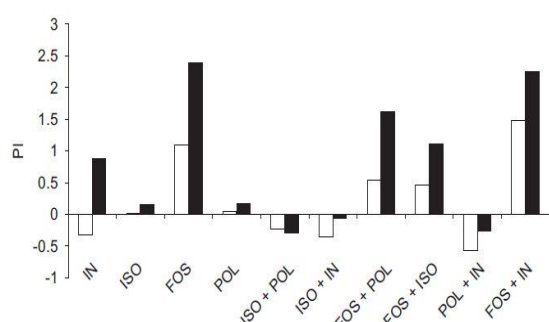
Potentially it has beneficial effects through selective stimulation on growth of good bacteria (e.g. bifidobacteria and lactobacilli) in the colon, thereby improving the gut health (Gibson & Roberfroid, 1995).



Similarities and Differences between Short chain FOS and Inulin

Fermentation Site: Short chain FOS ferments readily in the gut

The short chain FOS, owing to its short chain length are mostly fermented in the initial part of the colon (proximal colon) and Inulin, due to longer chain length in later part of the colon (distal colon). Thus scFOS are rapidly fermented in colon when compared to the longer chains forms (Jennifer et al, 2011). Thereby **increased production of bifidobacteria and consequently increased synthesis of SCFA** (Bouhnik et al, 1996). Inulin alone may not increase the good bacteria growth as whole, however in a longer time span. Therefore, for a steady bacterial growth and metabolite production, a combination of scFOS and inulin could be an appropriate measure to support human health by an overall good bacterial growth.



Prebiotic Index : Short chain FOS has a higher PI

Prebiotic Index (PI) is "the increase in the absolute number of bifidobacteria expressed divided by the daily dose of prebiotic ingested" (Roberfroid, 2007). A greater PI is indicative of a better beneficial bacterial growth in the gut.

In an in vitro study (Ghoddusi et al. 2007), the PI of scFOS was approximately 2.5 which was higher than

that reported for inulin or any other fiber studied in the experiment.

Prebiotic Index score	Short chain FOS	Inulin
PI score at 8 hrs	1	Below 0
PI score at 24 hours	2.5	<1

When a combination of scFOS and Inulin was tested for the PI score, there was an increase in the score, indicating a better growth of beneficial bacteria with the combination compared to Inulin alone (Figure 3) (Ghoddusi et al. 2007). It was evident that in applications, even a partial replacement of inulin with scFOS could provide an improvement in the PI score and thus a possible improved health benefit.

Short Chain Fatty Acid Production (SCFA): Short chain FOS leads to acute SCFA

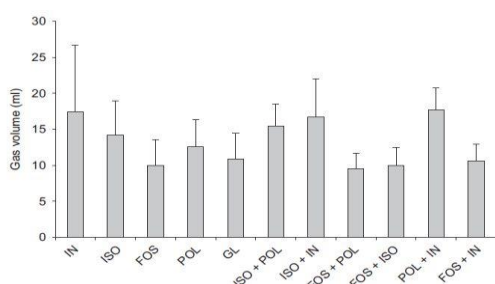
Both Short chain FOS and inulin fibers are not digested / metabolized in the digestive tract and are fermented in the colon. The colonic fermentation of the two fibers leads to production of **SCFA (butyrate, acetate, and propionate)** which are known to have varied health benefits.

Butyric acid inhibits liver cholesterol synthesis and provides a source of energy for human colon epithelial cells. **Propionic acid** helps to inhibit the fatty acid synthesis in liver, thereby lowering the rates of triacylglycerol secretion. **Acetate** is involved in the control of hepatic cholesterol synthesis and it reduces the rate of cholesterol synthesis (Wong et al 2006). A study

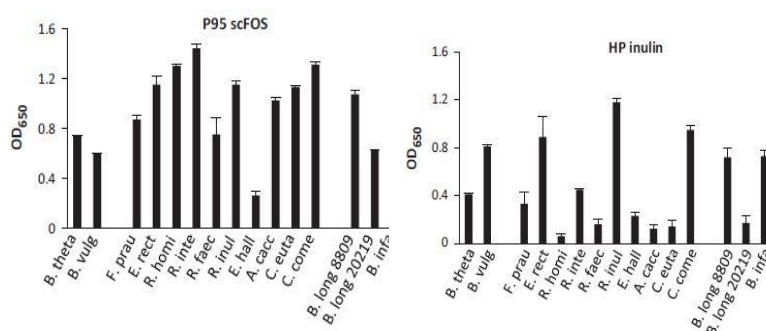
reported that the short chain FOS are rapidly fermented by microbes in the colon and have better effects on growth of bifidobacteria (beneficial microbes) when compared to inulin (Stewart et al. 2008; Kolida et al, 2002). In an in-vitro study (Scott et al. 2013), scFOS showed better bifidobacteria growth than the high performance inulin at 24hrs (Figure 4). Short SCFA of acetate, propionate, and butyrate are produced quickly with scFOS compared to the lcFOS. Similar results were documented on the rate of FOS fermentation in another study where it was higher for scFOS compared to lcFOS during 0 to 4 hours for production of the SCFAs (Maria et al and sucrose, 2008). **ScFOS showed higher SCFA production** at 12 & 24hr time duration compared to the multiple resistance starch in another study (which are similar to the complex structure of inulin) (Erickson et al 2018).

In applications where 100% usage of inulin is present, a partial replacement of inulin with scFOS could improve SCFA production compared to inulin alone. A combination may provide a constant or steady state of SCFA production in 24hours duration (Maria et al, 2008).

Gas Production: Short chain FOS has Lower gas volume production



rapidly than inulin. In a study, even though scFOS produced gas rapidly than other long chain fibers,



the total gas volume production with scFOS in 32hrs was found to be lower than inulin, isomalt and polydextrose. However, when these long chain fibers were combined with scFOS, all showed lower gas production (Figure 5) (Ghoddusi et al. 2007). The study showed that scFOS when combined with inulin and or other long chain fibers, an additional gain may be observed on the reduction of discomforts due to excessive gas production.

pH Reduction in gut environment keeps away pathogenic bacteria

The reduction in high pH values in colon plays an important role for gut health. Increases in SCFAs result in decreased pH, which indirectly influences the composition of the colonic microflora (eg, reduces potentially pathogenic clostridia when pH is more acidic), decreases solubility of bile acids, increases absorption of minerals (indirectly) (Younes et al. 1996; Demigne et al. 1999), and reduces the ammonia absorption (Roberfroid, 2005; Vince et al. 1978; Jackson, 1983; Jenkins et al. 1987).

A decreased colonic pH increases the availability of calcium for binding to free bile acids and fatty acids (Wargovich et al. 1984). The reduced colonic pH due to accumulation of SCFAs decreases the solubility of free bile acids, which may decrease the potential tumor promoter activity of secondary bile acids (Grubben et al. 2001). In other words, a reduced colonic pH possibly helps to reduce in colonic cancer cell proliferation.

A study showed that scFOS maintaining the colonic pH between the range of 5.5 to 5.8 in 4 - 24hr duration. However, other fibers similar to inulin such as polydextrose and resistant starches showed higher pH (6.3) until 12hrs and afterwards reduced to 5.9 at 24 hr (Erickson et al. 2018). Another study (Hernott et al. 2009) showed that the scFOS and other LcFOS /inulin are good at reduction in pH than inulin (Table 2).

Furthermore, FOS + Inulin combination also showed reduced pH levels than the inulin alone model. These studies clearly show that scFOS could be better than inulin and other complex fibers in terms of pH reduction, consequently leading to improved gut health benefits.

Fiber	pH change			
	0 hr	4h	8h	12h
scFOS (<5 DP)	6.52	-1.20	-1.41	-1.32
LcFOS (2-8DP)	6.47	-1.29	-1.35	-1.23
Inulin (≥23DP)	6.51	-0.45	-0.85	-0.90
Inulin +FOS	6.48	-0.88	-1.25	-1.21

Mineral Absorption

In the presence of SCFA in the large intestine, there is a rise in cecal blood flow, (Kvietys et al. 1981) that have trophic effects on epithelial cell proliferation, decrease the cecal pH (Younes et al. 1996; Le Blay et al. 1999), and increase the trans cellular passage of minerals (Trinidad et al. 1996 and Trinidad 1999). The acidic cecal pH leads to greater solubilization of minerals (magnesium) so that the biologically available mineral concentration is increased (Lutz et al. 1991; Remesy et al. 1992) and improved mineral (calcium) absorption through an exchange of intracellular H⁺ for Ca²⁺ in the distal colon (Younes et al. 1996; Demigne et al. 1999). **The SCFA and pH function benefits of scFOS and inulin were discussed in previous sections, thereby the increased SCFA production and reduced pH rate might contribute to increase mineral absorption in the hindgut.**

Physical properties of scFOS and Inulin

Short chain FOS is superior and/or equal to that of inulin properties (Table 1). For example, inulin has been used for formulating a low fat table spread that has a creamy, fat-like mouth feel with no added sweetness. Conversely, scFOS have better sweet profile than inulin and which could enhance the overall flavour profile particularly with the development of low calorie foods without compromising the sweet profile.

Functional Properties	High performance Inulin	Short chain FOS
Chemical Structure	GFn (10 ≤ n ≤ 60)	GFn (2 < n < 5)
Molecular weight	DPn 21–26 - Mn 2499	DPn 4 – 5 - Mn 624–679;
Degree of polymerization	25	4
Calorific value	1.4	1.5
Linkages	β(2,1) linkages	β(2,1) linkages
Solubility	2.5% (w/v)	>75% (w/v) – Readily soluble
Form	Power and liquid	Power and liquid
Appearance	White powder / Liquid transparent	White powder / Liquid transparent
Viscosity	2.4 mPa.s (5% in water at 10°C)	<1mPa.s (5% in water at 10°C)
Sweetness	None	40% that of sucrose (Higher grades)
Functionality in foods	Fat replacer	Sugar Replacer
Synergism	Synergy with gelling agents	Synergy with gelling agents
Prebiotic Effect	Moderate	High
Heat Stability	Between 135 and 195°C	120°C
pH (10% W/v)	5 to 7	4 to 7
Flavour enhancement and bitter note masking ability	No	Yes (Tata has filed a patent where Fossence, short chain FOS is used to mask the bitter notes of Fenugreek extract)
Shelf life (powder grade)	24 months	24 months

Application of scFOS and Inulin

Taste and Calorie Content

scFOS is sweeter than inulin and therefore, without compromising the sweetness profile of a product, sugar replacement can be achieved in a food application. In general, scFOS/FOS is widely used for flavour enhancement and inulin is known for mouth feel enhancement. Therefore, scFOS and inulin combination would provide both benefits. Both scFOS and inulin are low calorie therefore the food application scope may be broader. In addition, both the fibers are low calorie and help to promote a lower rise in post-meal blood glucose when it replaces sugars in foods and beverages as like scFOS since both are contains unavailable carbohydrates. Therefore for better low calorie

products for diabetes platform can be developed by adding the scFOS along with inulin products. Both the fibers health benefits are summarized in Table 3.

Health benefits	scFOS	lcFOS
Prebiotic effect	✓	✓
Fiber effect	✓	✓
Acute SCFA production	✓	x
Easy digestion	0-4hrs	>4hr
Tolerability	15g/day	15g/day
Non-cariogenic	✓	✓
Low glycemic effect	✓ (Zero GI)	✓
Low Calories (kcal)	1.5	1.4
Weight management	✓	✓
Mineral absorption	✓	✓
Increase satiety	✓	✓
Gut health	✓	✓

Key comparison aspects between scFOS and Inulin

- Short chain FOS is sweeter than the lcFOS such as inulin. Thereby, any sugar replacement concept product can be used instead of inulin kind of lcFOS (Bornet et al, 1994).
- Short chain FOS are easily fermented by microbes and particularly have better effects on bifidobacteria when compared to inulin and sucrose. (Stewart et al.2008 & Kolida et al, 2002)
- Better rate of Short chain fatty acids (SCFA) production similar to inulin.
- Both Short chain FOS and Inulin are low calorie ingredient and possible for easy replacement.
- Short chain FOS is better on pH reduction that leads to crowding out of pathogenic bacteria
- Short chain FOS has a higher Prebiotic index than Inulin
- Short chain FOS leads to lower volume of gas production compared to longer chain Inulin..

Short chain FOS + Inulin combination would provide additional benefits, without compromising each fiber's own benefits.

Summary

Conclusively, scFOS have additional interesting nutritional and functional attributes than inulin without compromising the inulin's own benefits. Today's consumer's demands the foods that taste great are fatand/or calorie-reduced, and they are interested in foods that provide added health benefits in acute phase. Therefore, scFOS can be used a valuable alternate and /or partial replacement for inulin in products. To be specific, for any energy conscious concept without compromising the sweet profile and to meet the acute demand on SCFA production for metabolic health benefits, short chain FOS is the best choice than long chain FOS or inulin.

References

- Alexandra LJ, Reduction of postprandial glycemia by the novel viscous polysaccharide PGX, in a dose-dependent manner, independent of food form. J.ACN.2010, Vol29,No.2,92-98.
- Bornet, F.R.J. Undigestible sugars in food products. 1994, Am. J. Clin. Nutr.59: 763S–769S.
- Bouhnik Y, Flourié B, Riottot M, Bisetti N, Gailing MF, Guibert A, Bornet F, Rambaud JC Effects of fructo-oligosaccharides ingestion on fecal bifidobacteria and selected metabolic indexes of colon carcinogenesis in healthy humans. Nutr Cancer. 1996; 26(1):21-9.
- Bouhnik Y, Raskine L, Simoneau G, Vicaut E, Neut C, Flourié B, Brouns F and Bornet F. The capacity of nondigestible carbohydrates to stimulate fecal bifidobacteria in healthy humans: a double-blind, randomized, placebo-controlled, parallel-group, dose-response relation study. American Journal of Clinical Nutrition, 2004, 80, 1658–1664.
- Coudray C, Tressol JC, Gueux E, Rayssiguier Y. Effects of inulin-type fructans of different chain length and type of branching on intestinal absorption and balance of calcium and magnesium in rats. Eur J Nutr 2003; 42:91-8. • Demigne C, Remesy C, Morand C. Short chain fatty acids. InColonic Microbiota, Nutrition and Health 1999 (pp. 55-69). Springer Netherlands.
- Dokkum van W, Wezendonk B, Srikumar TS, Van den Heuvel EG. Effect of nondigestible oligosaccharides on large-bowel functions, blood lipid concentrations and glucose absorption in young healthy male subjects. European journal of clinical nutrition. 1999 Jan 1;53(1):1-7.
- Erickson JM , Justin L. Carlson , Maria L. Stewart and Joanne L. Slavin. Fermentability of Novel Type-4 Resistant Starches in In Vitro System. Foods. 2018, 7, 18.
- Ghoddusi HB, M.A. Grandison, A.S. Grandison, K.M. Tuohy. In vitro study on gas generation and prebiotic effects of some carbohydrates and their mixtures. Anaerobe 13 ,2007, 193–199.
- Giacco R, Clemente G, Luongo D, Lasorella G, Fiume I, Brouns F, Bornet F, Patti L, Cipriano P, Rivellese AA and Riccardi G, Effects of shortchain fructo-oligosaccharides on glucose and lipid metabolism in mild hyper-cholesterolaemic individuals. Clinical Nutrition, 2004,23, 331- 340.
- Gibson,G. R. & Roberfroid, MB. Dietary modulation of the human colonic microbiota—introducing the concept of prebiotics. 1995, J. Nutr.125:1401–1412.
- Grubben MJ, van den Braak CC, Essenberg M, et al. Effect of resistant starch on potential biomarkers for colonic cancer risk in patients with colonic adenomas: a controlled trial. Dig Dis Sci. 2001;46:750–756.
- Hernot DC, Thomas W. Boileau, Laura L. Bauer, Ingmar S. Middelbos, Michael R. Murphy, Kelly S. Swanson, And George C. Fahey, Jr. In Vitro Fermentation Profiles, Gas Production Rates, and Microbiota Modulation as Affected by Certain Fructans, Galactooligosaccharides, and Polydextrose. J. Agric. Food Chem. 2009, 57, 1354–1361.
- Hosoya N, Dhorranintra H,Hidaka H. Utilization of [U-14C] fructooligosaccharides in man as energy resources. Journal of Clinical Biochemistry and Nutrition. 1988;5(1):67-74.
- Hosoya, N., Dhorranintra, B. & Hidaka, H. (1988) Utilization of U14-C fructooligosaccharides in man as energy resources. 1998. J. Clin. Biochem. Nutr. 5:67–74.
- Jackson AA. Aminoacids: essential and non-essential? Lancet.1983;1:1034–1037.
- Jenkins DJ, Wolever TM, Collier GR, et al. Metabolic effects of a low-glycemic-index diet. Am J Clin Nutr. 1987;46:968–975.

- Jennifer R. Hess , Anne M. Birkett, William Thomas, Joanne L. Slavin. Effects of short-chain fructooligosaccharides on satiety responses in healthy men and women. *Appetite* 56 (2011) 128–134.
- Kathy R. Niness, Inulin and Oligofructose: What Are They? *The Journal of Nutrition*, Volume 129, Issue 7, 1 July 1999, Pages 1402S–1406S.
- Kolida, K. Tuohy, G.R. Gibson Prebiotic effects of inulin and oligofructose. *British Journal of Nutrition*, 87 (2002), pp. S193–S197.
- Kvietys PR, Granger DN. Effect of volatile fatty acids on blood flow and oxygen uptake by the dog colon. *Gastroenterology*. 1981 May;80(5 pt 1):962-9.
- Le Blay G, Michel C, Blottière HM, Cherbut C. Prolonged intake of fructo-oligosaccharides induces a short-term elevation of lactic acidproducing bacteria and a persistent increase in cecal butyrate in rats. *The Journal of nutrition*. 1999 Dec 1;129(12):2231-5.
- Lecerf JM, Clerc E, Jaruga A, Wagner A, Respondek F. Postprandial glycaemic and insulinaemic responses in adults after consumption of dairy desserts and pound cakes containing short-chain fructo-oligosaccharides used to replace sugars. *J Nutr Sci*. 2015; 4:e34.
- Luo J, Van Yperselle M, Rizkalla SW, Rossi F, Bornet FR and Slama G, Chronic consumption of short-chain fructooligosaccharides does not affect basal hepatic glucose production or insulin resistance in type 2 diabetics. *Journal of Nutrition*, 2000,130, 1572-1577.
- Lutz T, Wurmli R, Scharrer E. Short-chain fatty acids stimulate magnesium absorption by the colon. *Lasserre B & Durlach J, John Libbey, London*. 1991; 131:137.
- Maria L. Stewart, Derek A. Timm, Joanne L. Slavin. Fructooligosaccharides exhibit more rapid fermentation than long-chain inulin in an in vitro fermentation system. *Nutrition Research* 28 (2008) 329–334.
- Maria L. Stewart, Derek A. Timm, Joanne L. Slavin. Fructooligosaccharides exhibit more rapid fermentation than long-chain inulin in an in vitro fermentation system. *Nutrition Research* 28 (2008) 329–334.
- Meyer D, Inulin for product development of low GI products to support weight management. In: *Dietary fibre: Components and functions*. Eds Salovaraa H, Gates F and Tenkanen M. Wageningen Academic Publishers, 2007,Wageningen, The Netherlands.
- Perrin S, Fougnes C, Grill JP, Jacobs H, Schneider F. Fermentation of chicory fructo-oligosaccharides in mixtures of different degrees of polymerization by three strains of bifidobacteria. *Can J Microbiol*. 2002;48:759-63.
- Rémésy C, Behr SR, Levrat MA, Demigne C. Fiber fermentability in the rat cecum and its physiological consequences. *Nutrition Research*. 1992 Oct 1;12(10):1235-44.
- Respondek F, Hilpiper C, Chauveau P, Cazaubiel M, Gendre D, Maudet C, Wagner A. Digestive tolerance and postprandial glycaemic and insulinaemic responses after consumption of dairy desserts containing maltitol and fructo-oligosaccharides in adults. *European journal of clinical nutrition*. 2014 1;68(5):575-80.
- Roberfroid M, Prebiotics: The Concept Revisited. *J. Nutr*. 2007; 137: 830S–837S.
- Roberfroid, M. *Inulin-Type Fructans: Functional Food Ingredients*. Boca Raton: 2005, CRC Press.
- Rumessen JJ, Gudmand-Hoyer E. Fructans of chicory: intestinal transport and fermentation of different chain lengths and relation to fructose and sorbitol malabsorption. *Am J Clin Nutr* 1998; 68:357-64.

- Scott KP , Jennifer C. Martin, Sylvia H. Duncan & Harry J. Flint. Prebiotic stimulation of human colonic butyrate-producing bacteria and bifidobacteria, in vitro. FEMS Microbiol Ecol 87 (2014) 30–40.
- Sheth M, Thakuria A, Chand V and Paban Nath M. Fructooligosaccharide (fos)- a smart strategy to modulate inflammatory marker and lipid profile in non-insulin dependent diabetes mellitus (NIDDM) subjects residing in Assam, India- a randomized control trial. World J Pharma Res, 2015; 4 (5): 2673-2678.
- Slavin J. Fiber and prebiotics: mechanisms and health benefits. Nutrients. 2013; 5(4):1417-35.
- Stewart ML1, Timm DA, Slavin JL. Fructooligosaccharides exhibit more rapid fermentation than long-chain inulin in an in vitro fermentation system. Nutr Res. 2008 May;28(5):329-34.
- Thornton, JR. High colonic pH promotes colorectal cancer. Lancet. 1981;1:1081–1083.
- Trinidad TP, Wolever TM, Thompson LU. Effect of acetate and propionate on calcium absorption from the rectum and distal colon of humans. The American journal of clinical nutrition. 1996 Apr 1;63(4):574-8.
- Trinidad TP, Wolever TM, Thompson LU. Effects of calcium concentration, acetate, and propionate on calcium absorption in the human distal colon. Nutrition. 1999 Aug 31; 15(7):529-33.
- Van den Heuvel EG, Muijs T, Brouns F, Hendriks HF. Short-chain fructo-oligosaccharides improve magnesium absorption in adolescent girls with a low calcium intake. Nutr Res, 2009; 29(4):229-37.
- Vandenplas Y, Zakharova I, Dmitrieva Y. Oligosaccharides in infant formula: more evidence to validate the role of prebiotics. Br J Nutr, 2015; 113, 1339–1344.
- Velazquez M, Davies C, Marett R, Slavin JL, Feirtag JM. Effect of oligosaccharides and fibre substitutes on short-chain fatty acid production by human faecal microflora. Anaerobe 2000;6:87-92.
- Vince A, Killingley M, Wrong OM. Effect of lactulose on ammonia production in a fecal incubation system. Gastroenterology. 1978;74:544–549.
- Wargovich MJ, Eng VW, Newmark HL. Calcium inhibits the damaging and compensatory proliferative effects of fatty acids on mouse colon epithelium. Cancer Lett. 1984;23: 253–258.
- Wong JMM, Russell de Souza, Cyril W. C. Kendall, Azadeh Emam, and David J. A. Jenkins, Colonic Health: Fermentation and Short Chain Fatty Acids. J Clin Gastroenterol 2006;40:235–243.
- Yamashita K, Kawai K, Itakura M. Effects of fructo-oligosaccharides on blood glucose and serum lipids in diabetic subjects. Nutr Res, 1984; 4(6):961-6.
- Younes H, Demigné C, Rémésy C. Acidic fermentation in the caecum increases absorption of calcium and magnesium in the large intestine of the rat. British Journal of Nutrition. 1996 Feb;75(2):301-14.

ⁱ Tuhoy KM, Fava F, Viola R. 'The way to a man's heart is through his gut microbiota' –dietary pro-and prebiotics for the management of cardiovascular risk. Proceedings of the Nutrition Society. 2014 May;73(2):172-85.

ⁱⁱ Walsh CJ, Guinane CM, O'Toole PW, Cotter PD. Beneficial modulation of the gut microbiota. FEBS letters. 2014 Nov 17;588(22):4120-30.