Sudhamani Muddada / Journal of Pharmacy Research 2012,5(1),626-631

Review Article
ISSN: 0974-6943

Available online through
http://jprsolutions.info

Tagatose: The Multifunctional Food Ingredient and Potential Drug

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Received on:20-09-2011; Revised on: 15-10-2011; Accepted on:10-12-2011

ABSTRACT

Diabetes and Obesity have reached epidemic proportions. The treatment of diabetes and Obesity includes life style change. The diet is recommended to be low calorie in order to reduce weight. A low calorie sweetner, tagatose has been approved for food usage since 2003. It is also awaiting clearance for its use as Antidiabetic agent. The review covers the history of tagatose, production and use as food ingredient and refers to its therapeutic potential as anti-diabetic and anti-obesity agent. The present trials for clinical approvals are reported. The use of food as a route of delivery and the requirement of food grade production are discussed.

Key words: Tagatose; low calorie; Obesity; Diabetes; HDL, Hyperglycemia; Prebiotic;

INTRODUCTION

World Health Organization reports Overweight and Obesity as the fifth leading risks for global deaths. Overweight and obesity are linked to more deaths worldwide than underweight. Diabetes causes about 5% of all deaths globally each year. Body weight control is an essential treatment for obesity and diabetes. Treatment of Type II diabetes involves lowering blood glucose levels through oral medication and lowering the levels of other known risk factors (cholesterol, Low Density Lipoproteins) that damage blood vessels. Role of agent of food for health improvement has proposed a new class of foods called Functional Foods. Functional foods can be defined as foods containing significant levels of biologically active compounds that provide specific health benefits beyond the traditional nutrients they contain (Drozen and Harrison 1998). Components with body weight reducing or anti-diabetic potential can be added to traditional foods resulting in functional foods to manage obesity or diabetes. The general reluctance of the consumer to change dietary habits (as required for body weight control) suggests that there is need to select functional components that help in obesity or diabetes management but do not compromise on taste, flavour or other sensory characteristics. Additional functionalities like prebiotic, cholesterol reduction can also be included to give foods the multi-functional character.

D-Tagatose, a natural ketohexose isomer of D-galactose, is currently being introduced as a low-calorie bulk sweetener. The sweetness of this edulcorant is equivalent to sucrose but the caloric value is 30% of the energy content of sucrose (Levin, 2002). Tagatose has been declared GRAS (Generally Regarded as Safe) under FDA food ingredient rules, (Lu et al 2008). Tagatose can be taken without worry or serious side effects. It is reviewed as novel agent (Levien and Baker 2009) for treatment for diabetes but minus the serious side effects of other OAAs (Oral Anti-hyperglycemic Agent; Lu et al 2008). Tagatose is recommended to be administered by inclusion in foods so as to meet its high dosage requirements (up to as much as 15 g tid (three times daily), much larger than a pill of regular OAA, although lesser doses are being investigated. The sweet sucrose-like taste of tagatose is expected to enhance the flavour. Further demonstrated benefits include increased HDL (High Density Lipoprotein) levels, enhanced butyrate production (reported to combat colon cancer), antioxidant and prebiotic properties. In addition, tagatose has been indicated to be a potential treatment for anaemia and hemophilia, for medical problems related to infertility, and appears to have antioxidant and cytoprotective properties (Lu et al 2008).

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History

Tagatose was originally developed by Spherix Incorporated (formerly Biospherics Inc.) as a low-calorie sugar substitute. The discovery of tagatose has its origin in the quest by its discoverer, Gilbert Levin to identify a low calorie analogue to sucrose. Based on the concept that left handed forms of sugars are not recognised by the human enzymes led Levin to test L-glucose. However, L-glucose tasted bitter while some other left handed sugars (L-fructose, l-sucrose) could not be produced economically. However, by accident d-tagatose was found to be sweet and since was structurally similar to L-fructose was tested on rats for calories addition. It was concluded that there was no net gain of calories (Saunders et al 1999). Further research resulted in the FDA recommending a calorific value of 1.5kcal/g (Bar 1998). In 2001, the tagatose was given the GRaS status clearing way for incorporation into foods. It has also been approved for use in Australia, New Zealand, South Korea, Brazil, South Africa, and the European Union (Armstrong et al 2009). Biosperics Inc entered into understanding with Arla Foods (Denmark) to supply technology transfer for tagatose production. Arla and Nordzucker decided to halt their joint venture to produce tagatose from dairy in 2006, despite having novel foods approval but Belgium-based Nutrilab (Damhert) stepped into the breach and bought up existing stocks. Spherix has also investigated the clinical applications of tagatose. The antidiabetic potential of tagatose is being evaluated and is undergoing phase III clinical trials.

Components with body weight reducing or anti-diabetic potential can be added to traditional foods resulting in low calorie foods to manage obesity or diabetes. In this context, the importance of tagatose is reviewed from National, International reports and corporate website reports (regarding clinical trials) available.

Low calorie sugar tagatose:

D-Tagatose is a ketohexose, an epimer of D-fructose isomerised at C-4. It was identified as a component of a gum exudate of the cacao tree (*Sterculia setigera*) and also detected as a component of an oligosaccharide in lichens of the *Rocella* species. It is as virtually odourless, white or almost white, non-

hygroscopic crystals and it has almost same sweetness as sucrose and less than half the calories (1.5 kcal / g) of sucrose. It should be noted that tagatose's 1.5 kcal/g (1 kcal ¼ 4.187 kJ) caloric value is calculated upon the assumption of 100% absorption and energy utilization of SCFAs produced by the fermentation of tagatose in the large intestines. This is likely an overestimate, and actual caloric value may be less than1.5 kcal/g (Levin 2002) since all the tagatose is not absorbed. D-Tagatose has a physical appearance and sweetness essentially identical to sucrose and can be found in trace quantities in some milk products (Levin et al. 1995). It has been found as a chief component in generic drugs (Chronulac, Cephulac; Levin 2002). Functional uses of D-tagatose as food additives are used as sweetener, texturizer, stabilizer, humectant, and formulation aid. It is also useful in formulating dietetic foods with a low glycemic index. The 61st JECFA (FAO 2004) recommended the foods and permissible limits for addition of tagatose (See Table 1). Some examples in food formulation are reported (Rosenplenter et al 2006; Lee Thomas 2008; Lee et al 2009; Zehner et al 1988). Several patents suggesting use of tagatose in beverages in combination with other sweeteners have been reported (Anderson and Vigh 1999). Tagatose is being used in chocolate, spreads, cookies, and a home sugar replacer called Tagatesse by Nutrilab (Food navigator.com). Powdered beverages, jams and chocolate bars containing tagatose have recently been introduced to the European market (Damhert, 2008). When sucrose was replaced by tagatose, doughs with similar rheological properties to the control resulted. The tagatose-containing cookies were harder and darker with a lower spread than the control. Sensory data indicated that panelists liked the brown color of the 100% tagatose cookies better than the control, but disliked their sweetness. Recently (Armstrong et al 2009), Sensory panellists could not tell the difference between products containing tagatose and not containing tagatose. In addition, the consumer panel liked products with and without tagatose equally. Therefore, 1 and 2% tagatose can be incorporated into bakery products without harming their flavor while providing the prebiotic effect to consumers. The cookies containing tagatose required a shorter baking time, which would equate to a cost savings from lower energy. Foods containing tagatose were found to be browner (Taylor et al 2008, Armstrong et al 2009). Currently, it has been used in confectionery, beverages and health foods (Talebi et al. 2008; Lu et al. 2008). In addition to the above uses, it could potentially be used as a prescription drug additive to mask unpleasant tastes, and as sweetener, stabilizer and humectants in cosmetics and toothpastes (Ibrahim and Spradlin 2000) and for antioxidant activity (Brands et al. 2000).

Table 1 Proposed food application of D-tagatose and maximum levels of use (as published in 61st JECFA)

Food Category Use	Level (w/w)	Purpose
Ready-to-eat breakfast cereals	15%	sweetener
Diet soft drinks	1%	for improving "mouth feel" flavor enhancement
Hard confectionery	15%	sweetener
Soft confectionery including chocolate	15%	sweetener, humectant
Ice cream and frozen yogurt	3%	sweetener, flavor enhancement
Chewing gum	60%	sweetener
Frostings	15%	sweetener

Production:

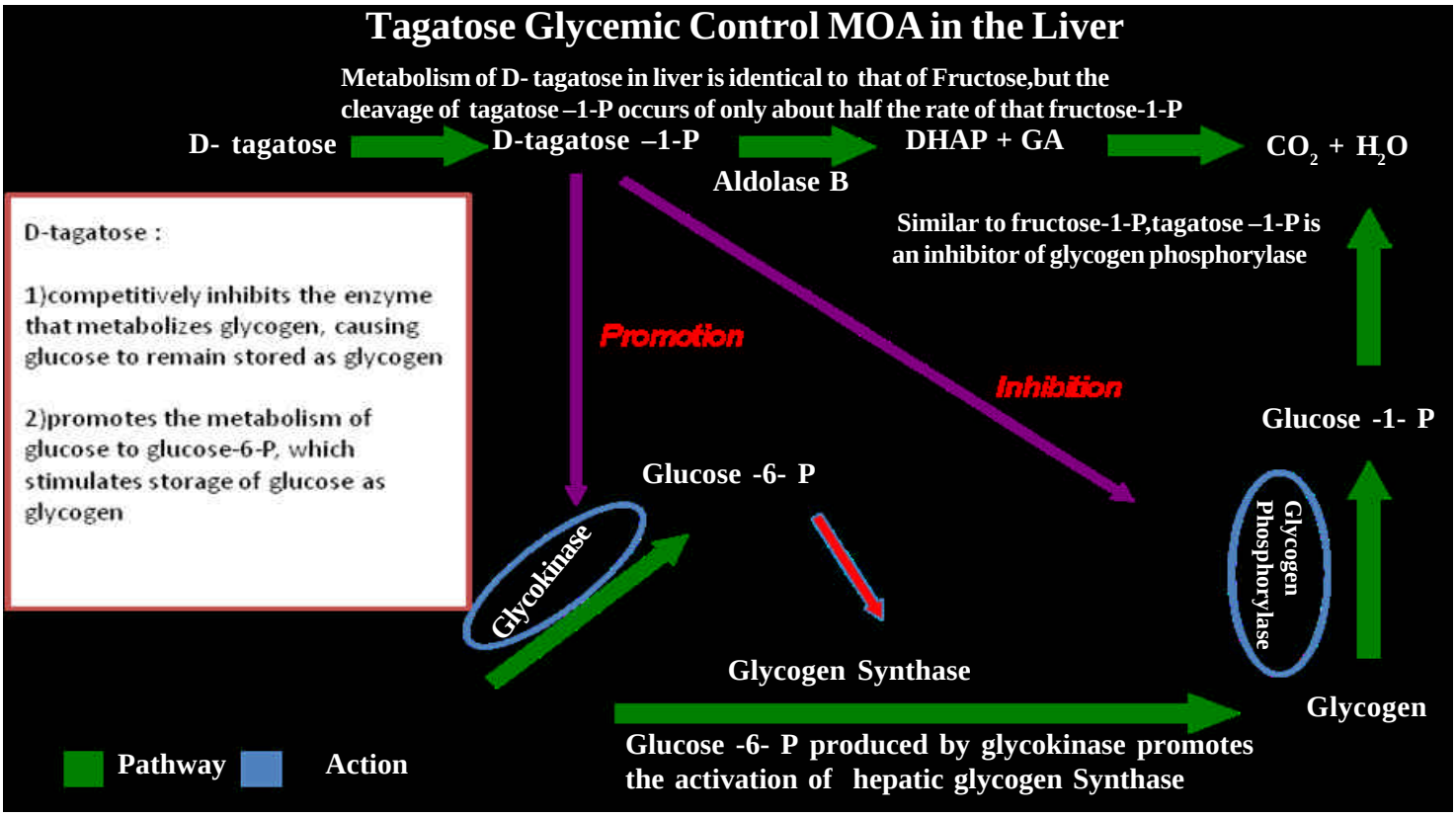
Beadle et al. (1992; WO 92/12263) describes chemical isomerisation of galactose to tagatose; the reaction is performed at pH 12.5 at room temperature for around 2 hours in presence of Ca(OH)2 and CaCl2, thus obtaining conversions of around 85% upon reaching which the reaction is neutralised by CO2 insufflation so as to obtain precipitation of CaCO3, which is removed by filtration. Calcium hydroxide tilts the isomerization equilibrium between galactose and tagatose in the direction of tagatose because it forms an insoluble complex with tagatose at elevated pH. Treatment of the suspension with acid, preferably carbon dioxide, neutralizes the mixture, liberates tagatose and precipitating calcium as calcium carbonate. The tagatose is further purified, crystallized from water and dried. The raw material, galactose, is prepared by the hydrolysis of lactose using immobilized lactase as a biocatalyst, yielding galactose and also glucose as an economic by-product. Lactose is prepared from whey, a by-product of the cheese manufacturing industry. Galactose may be separated from glucose by column chromatography or the glucose may be converted to ethanol (Ibrahim and Spradlin 2000).

Another patent (US 4273922) describes, tagatose production by addition of boric acid in the presence of tertiary or quaternary amine compounds that changes the equilibrium towards tagatose formation by formation of boric acid-ketose complex. In a different approach (Lim 2007) high production of D-tagatose was obtained by the addition of boric acid and l-arabinose isomerases at pH 8.5-9.0, 60 degrees C, and 0.4 molar ratio of boric acid to D-galactose, and the concentration increased with increase in enzyme concentration. A Chinese patent, CN 1985624 described isomerisation of galactose to tagatose, in presence of NaAlO2 at 10-37° C. for 1-3 hours. After cooling the solution is acidified with the addition of H2SO4 which produces a precipitate containing aluminate which is removed thus providing a tagatose solution. These chemical methods have been found economical but generating hazardous wastes.

Another economical process is through biotransformation by employing l-arabinose isomerases from various microorganisms. L-Arabinose isomerase (L-AI, EC 5.3.1.4) catalyses the conversion of D-galactose to D-tagatose as well as the conversion of l-arabinose to L-ribulose, based on the similarity in configuration of the substrates. This bifunctional activity could be exploited industrially for the production of D-tagatose. L-AI has been identified in various micro-organisms such as *Aerobacter aerogenes* (Yamana and Wood 1966), *Bacillus halodurans* (Lee et al 2005), *Escherichia coli* (Patrick and lee 1968; Yoon et al 2003), *Lactobacillus plantarum* (Chouayeh et al 2007), *Bacillus stearothermophilus* (Rhimi et al 2006;Rhimi et al 2007), *Thermus* sp. (Kim et al 2003), *Thermoanaerobacter mathranii* (Joergensen et al 2004), *Thermotoga neapolitana* (Kim et al 2002) and *Thermotoga maritime* (Lee et al 2004), *Lactobacillus gayonii* (Nakamatu and Yamanaka 1969). Ibrahim and Spradlin 2000 employed AI from *Lactobacillus pentosus*, *B. amyloliquefaciens* and *Arthrobacter* for tagatose production .The AIs show a equilibrium towards tagatose rather than galactose at higher temperatures. Mesophilic AIs from *Lactobacillus gayonii* and *Escherichia coli* have a low affinity for D-galactose (Lee et al 2004). Generally, isomerization performed at higher temperatures (70°C) offers several advantages, such as higher conversion yield, faster reaction rate, and decreased viscosity of the substrate in the product stream. However, higher-temperature and high pH processes introduce undesired effects like browning and unwanted by-product formation. Further, such conditions are not encountered in food or dairy fermentations.

Table 2. Comparison of properties of L-AI from various microbial Origins

Strain	Optimal Temperature (°C)	Optimal pH	Relative activity at pH 6.0 (%)
Thermus sp. IM650115	60	8.0	58
Bacillus stearothermophilus US10013	80	7.5	77b
Geobacillus stearothermophilus	65	7.5	22
Thermotoga neapolitana	85	7.0	Not done
Thermoanaerobacter mathranii	65	7.5–8.0	60
Thermotoga maritime	90	7.5	Not done
Alicyclobacillus acidocaldarius	65	6.0–6.5	83
Lactobacillus plantarum	60	7.5	82
Bacillus stearothermophilus IAM11001d	65	7.5	82
Mycobacterium smegmatisc	45	7.5	NA
Lactobacillus sakei	30-40	7.0	NA
A.flavitherms	95	10.5	NA
Aerobacter aerogenes	50	6.4-6.9	NA
Lactobacillus fermentum	65	6.5	83
Acidothermus cellulolytics ATCC 43068	75	7.5	90
Lactobacillus pentosus	70	5.5-7.0	NA
Bacillus amyloliquefaciens	60	7.0-7.5	NA
Arthrobacter	60	6.5-7.0	NA
Shewanella	15-35 °C.	5.5-6.5	80%



In order to overcome these problems, a thermostable AI with an acidic pH optimum and mesophilic temperature optima would be desirable and crucial for industrial fermentations. Working on these lines, Rhimi et al 2006, employed recombinant LAB containing a mutant version of AI from B. *stearothermophilus* US100 in dairy fermentation conditions to develop a fermented food. An AI mutant having lower pH optima, mesophilic optima and low requirement for ions was used. This AI was also found active in milk medium. The AI from *Lactobacillus fermentum* (Zheng Xu et al 2011) and *Lactobacillus sakei* (Rhimi et al 2010a) have also been characterised to have a lower pH optima similar to encountered in dairy fermentations (see Table 3). Similarly, The AI from *Shewanella* sp. ANA-3 showed maximal activity at low temperatures and pH range. Arabinose isomerase from *Alicyclobacillus acidocaldarius* was found to have optima between pH6- pH 7 (Lee et al 2005). The L-arabinose isomerase (L-AI) from *Lactobacillus plantarum* NC8 exhibited optima at pH 7.5 and showed 68% maximum activity at pH 5 (Chouayekh et al 2007).

Additives or organisms used in food need GRaS status. Employing a GRaS organism for tagatose production opens the possibility of *in situ* production in food and avoids the cost/need to add the ingredient in pure form, while also avoiding formation of potential toxic by-products when using other (non-GRaS) hosts. In this context, Rhimi et al 2011, used GRaS host expressing exogenous AI from *B. Stearothermophilus* for tagatose production in the preparation of a dairy product. Similarly, the AI gene from exogenous source *Geobacillus stearothermophilus* (GSAI) was expressed in *Bacillus subtilis*, a GRAS host used in the production of fermented soybean in Korea (Jina Cheon et al 2009). An alternative biological approach for tagatose was suggested by Kumaori et al in 1985 under aerobic conditions at 20-35^{0}C for 1-5 days by *arthrobacter* on dulcitol using NAD (Nicotinamide Adenine Dinucleotide) as cofactor for galactitol dehydrogenase (JP 60248196). The therapeutic benefits of tagatose consumption were reviewed by Lu et al 2007. Some of the reports and recent additions are discussed.

Antidiabetic potential:

Tagatose seems to act by promoting glycogen synthesis, and to decrease glycogen utilization and attenuating intestinal glucose absorption. The intermediate of tagatose metabolism tagatose -1-phophate promotes the activity of glucokinase, resulting in increased phosphorylation of glucose to glucose-1-phosphate which activates glycogen synthase mobilising glucose to glycogen. Tagatose -1-phosphate inhibits the activity of glycogen phosphorylase preventing glycogen breakdown. It is hypothesised that tagatose is metabolised like fructose but at a slower rate. Also, tagatose prevents absorption of sucrose and maltose by inhibiting the action of sucrases and maltases in the small intestine (Lu et al 2008). It was discovered that animals on a tagatose diet showed alleviation of diabetic symptoms including polydipsia in SHR/N-cp rats (Szepesi et al 1996). Studies showed that the pre-administration of tagatose blunted the rise in blood glucose and insulin in both healthy and diabetic subjects (Donner et al 1996; Donner et al 1999). This blunting effect was seen when tagatose was administered 4 h and 15 min before lunch in healthy subjects [Buemann 2000], and in subjects with mild fasting hyperglycaemia (110–140 mg/dl), when tagatose was administered with glucose (Madenokoji et al 2003). Tagatose produced exceptionally low glycemic and insulin responses, only 3% of that ascribed to glucose (Sugirs 2004), and is recommended as sugar substitute in foods for those with diabetes. The daily intake of tagatose by type 2 diabetic patients results in a decline in glycosylated haemoglobin (GlyHb) in both short-term and long-term trials (Donner et al 1996; Donner et al 2006). In comparison to sucrose, a diet enriched in tagatose as a carbohydrate source did not promote obesity or hyperglycemia, adipocyte hypertrophy. Chronic consumption of tagatose did not (Police et al 2009) lower fasting blood glucose or plasma insulin levels compared to sucrose fed mice. Donner et al 2010 conducted a pilot study to explore the metabolic effects of d-tag given daily to 8 human subjects with Type II DM (Diabetes Mellitus) for 1 year. A 2-month run-in period was followed by a 12-month treatment period when 15 g of oral d-tag was taken 3 times daily with food. Mean (SD) body weight declined from 108.4 (9.0) to 103.3 (7.3) kg (P = .001). Glycated haemoglobin fell non-significantly from 10.6% ± 1.9% to 9.6% ± 2.3% (P = .08). It was concluded that this was due to a state of deteriorating glycemic control when they started ingesting tagatose. Recently, Spherix undertook a phase 3 clinical trial and reported encouraging results recommending for glycemic control. Lo

and Lansang 2010 reviewed various therapies available for diabetes and the side-affects. Tagatose was listed as one of the emerging option.

Weight loss:
In 1996, Tagatose was concluded to have net zero value by Livesey and Brown. Trials indicated progressive weight loss (Donner et al 2004), or decreased food intake (Beumann et al 2000) on tagatose consumption. Gastrointestinal factors such as the osmotic effects of unabsorbed D-tagatose causing distension of the gut might have mediated the acute appetite-suppressing effect. Recently, Donner et al 2010 reported significant weight loss in Type II DM (Diabetes mellitus) patients fed on 15g of tagatose taken three times daily for 12 months. Results from the study (Police et al 2009) demonstrated that a sucrose-enriched diet promotes the development of obesity in LDLr-/- mice, while TAG did not promote substantial weight gain or enhanced adiposity. Smaller adipocyte size and lower adipose mass was observed in tagatose fed mice compared to sucrose fed mice. Data suggested that tagatose consumption did not affect food intake.

Lee and Storey 1999 reported appetite loss in humans given 20 g D-tag when compared with sucrose in chocolate. Other than reduced food intake due to (loss of apetite or fullness), the decreased absorption of tagatose (26% of that ingested; Johansen and Jensen 1997), the decreased digestibility of sucrose (Laerke and Jensen 1999), and malabsorption of other macronutrients due to speedy transit caused due to osmotic effect of unabsorbed tagatose (Jenkins et al 1994) may be other mechanisms to cause weight loss.

Increase in HDL:
Tagatose helps raise HDL and may prevent heart attack. In a 14-month study on eight type 2 diabetic patients taking tagatose 15 g tid, HDL levels progressively rose from a mean baseline level of 30 to 41.7 mg/dl (p ¼ 0.0001) at month 12 in the 6 subjects who did not have lipid modifying medications added during the study (Donner et al 2006). Reduction in body weight might partially contribute to the improvement in HDL. No significant changes were observed in total cholesterol, LDL or triglycerides during the study period. Police et al 2009 concluded that, in comparison to sucrose, a diet enriched in tagatose as a carbohydrate source resulted in a lesser extent of hypercholesterolemia and atherosclerosis in their experiments on mice. Tagatose fed mice and controls had decreased serum cholesterol and triglyceride concentrations compared to sucrose fed mice. No significant increase in HDL was observed in tagatose fed mice. Reduced pyruvate generation from glycolysis, reducing acetyl CoA through the Krebs cycle as a precursor to cholesterol may have contributed to the observed reductions in serum cholesterol in Tagatose fed mice compared to sucrose fed mice. Atherosclerosis was increased in sucrose fed mice of both genders compared to those on tagatose and CONTROL. Lesions from sucrose-fed mice exhibited pronounced macrophage immunostaining and reductions in collagen content compared to tagatose fed and CONTROL mice. Significant improvements in HDL cholesterol in Type II DM individuals was noted (Donner et al 2010) although no change in LDL and triglycerides was observed. Recently, it was suggested thatD-tagatose blocks absorption of fructose through the gut and can effectively reduce diet-induced dyslipidemia (www.spherix.com;http://www.evaluatepharma.com/Universal/View.aspx?type=Story&id=260274).

Prebiotic effect:
Only 25% of the ingested tagatose is absorbed into the bloodstream through passive absorption while the remaining 75% is fully fermented in the large intestine yielding SCFAs. In animal studies (Laerk et al 1999; Laerk et al 2000), Tagatose altered the composition and population of colonic microflora, as evidenced by changes in the proportion of SCFAs produced. The proportion of butyrate (potential antitumor agent) increases in SCFA obtained from *in vitro* fermentation of tagatose by faecal samples obtained from subjects fed on tagatose than in control (Lu et al 2007). In a human trial, tagatose ingestion of 10 g tid was also characterized by changes in microbial population species and densities. Pathogenic bacteria, such as coliform bacteria, were reduced in numbers, while beneficial bacteria, such as lactobacilli and lactic acid bacteria, were increased (Bertelsen et al 1999). Another study indicated that the daily consumption of 7.5 g or more tagatose may lead to increased production of butyrate at the expense of acetate, to selectively stimulating the growth of lactobacilli and lactic acid bacteria and to reducing the numbers of coliform bacteria, without serious gastrointestinal complaints (Bertelsen et al 2001).

Miscellaneous Effects:
In addition, tagatose appears to have antioxidant and cytoprotective properties (Valeri et al 1997; Paternal et al 1998) and has been indicated to be a potential treatment for anaemia and haemophilia, for medical problems related to infertility (Levin et al 2002).It does not promote tooth decay (Levin et al 1995). Consumption of tagatose provides multiple health benefits along with the treatment of Type 2 diabetes and the control of obesity, making tagatose a multi-functional food ingredient.

Side effects: Consumption of tagatose has been associated with transitory gastrointestinal upsets. D-tagatose was not found to have toxic effects on renal or hepatic function, measures of which did not change during the 12-month intervention period. No other changes were observed in any of the other biochemical parameters tested during the intervention period (Donner et al 2010). Lower doses (10-30g) resulted in reducing the incidence of gastric discomfort (Donner et al 1999). Reversible liver enlargement was not considered harmful especially at 5% level of tagatose in diet for Crl: CDBR rats. No treatment related side effects were observed at this level of tagatose. Over all, there were no signs of maternal toxicity, embryotoxicity or teratogenicity. Hypoglycaemia is not expected even should an overdose of tagatose be taken (Lu et al 2008).

Present status
Tagatose has entered phase III clinical trials. Phase 3 study demonstrated statistically significant reductions in HbA1c in patients with mild Type 2 diabetes. It provides lipoprotein and glycemic control through a mechanism of action unlike any agent currently marketed in the U.S. It acts as a "Sugar blocker" with potential fat, liver and guts mechanisms that may modify blood lipid and post- prandial glucose levels. Patients with HbA1c levels between 8.0 - 9.0% globally showed 0.7% reduction at 10 months of therapy. It does not cause stimulation of beta cells or insulin secretion. No serious adverse event was deemed treatment related and no episodes of hypoglycemia or pancreatitis were reported among any trial subjects. D-Tagatose did not cause myopathy / rhabdomyolysis. The trials indicated that triglycerides were reduced (VLDL reduced; LDL reduced; HDL essentially unchanged; Total Cholesterol reduced).

The combination of D-tagatose and SPX-106 (naturally synthesized peroxisome proliferator-activated receptor (PPAR) agonist.) reduced dyslipidemia in new studies of apolipoprotein E-deficient mice and Syrian Golden hamsters. SPX-106T is thought to synergistically treat dyslipidemia by simultaneously blocking carbohydrate conversion to lipids and promoting lipid catabolism (as per corporate literature; www.Spherix.com).

Tagatose consumption has transitory and mild side effects (flatulence, diarrhoea, nausea; Lo and Langsang 2010). But the other therapeutic benefits of tagatose will provide additional incentive to consume or adapt to tagatose.
Most studies have used the oral route through diet for administering tagatose (in grams). The large dosage of tagatose to realise the antidiabetic potential combined with its GRaS status suggest the incorporation of tagatose in foods. Pending approval from FDA, the therapeutic benefits of tagatose can be realised anyway in the form of food. The direct production in fermented foods (*in situ* production) by LAB is an attractive option considering the staple consumption of fermented foods across the world. The natural presence in foods, as well as prospects of its biological production will help gain tagatose ready acceptance as sugar and drug. LABS are food-associated microorganisms widely used as starter cultures in fermentations and can be induced for production of tagatose. This avoids the cost of adding the components in purified form. The LAB naturally hydrolyses lactose in milk to glucose and galactose by employing ß-galactosidase activity. The galactose is

unutilised by LAB and may cause galactosemia or cataract in consumers. But LAB, expressing suitable l-arabinose isomerases can transform galactose into tagatose. Hence, an undesirable byproduct of fermentation is not only eliminated but is converted to a multifunctional desirable product tagatose. The functional food product so developed is expected to be preferred/recommended for obese, dieting (weight conscious), diabetic or sports persons. Considering the epidemic nature of diabetes and obesity, foods assuring diabetes /obesity management have a ready market.

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Source of support: Nil, Conflict of interest: None Declared