Nutrafoods (2022) 1:337-346 DOI 10.17470/NF-022-0043

Original Research

Characteristics and compositions of commercial digestive health products in Singapore

Rachael Tan [1]

Wai Mun Loke [*1, 2]

[1] School of Applied Sciences, Nanyang Polytechnic, 180 Ang Mo Kio Ave 8, Singapore 569830

[2] Innovprof, Singapore

*Corresponding author:
Wai Mun Loke

27 Orange Grove Road #05-02
Singapore 258356

wai.mun.loke@innovprof.com

Abstract

Information on the characteristics of commercial digestive health products in Singapore is limited. This study examined the prebiotic, probiotic and postbiotic compositions, additives, indications and claims of 146 such products available in major retail (43.8%) and e-commerce stores (56.2%) in Singapore. The results, recorded by trained research personnel, showed that prebiotics, probiotics, and postbiotics were added to 55.9%, 82.9%, and 2.8% respectively of the surveyed products. Prebiotics, probiotics, and postbiotics were identified in the products at 18.5%, 81.5%, and 0.7% respectively. Fructooligosaccharides (FOS) and lactic acid bacteria (*Lactobacillus* and *Bifidobacterium*) were the most used prebiotics and probiotics. The products contained 64.5±50.2 mg prebiotics and 27640±42261 million CFU probiotic bacteria. Additional ingredients added to commercial digestive health products included colourings (13.7% of products), flavourings (21.9% of products), preservatives (2.7% of products), and sweeteners (28.1% of products). Titanium dioxide, lemon flavour, lactic acid, and maltodextrin were the most used colouring, flavouring, preservative, and sweetener respectively. Claims were declared on 68.5% of the products, with half claiming to be gluten-free. Gut/intestinal health was the most prevalent indication among 97.3% products with stated indications. Product characteristics from physical and e-commerce stores were similar. The study concludes that there is limited information available on added prebiotics and probiotics to assess product efficacy. Any efficacies of commercial digestive health products are not well communicated by the manufacturers. Manufacturers should make efforts to investigate the efficacies of their products and communicate these findings to consumers.

Keywords: Digestive health products, prebiotic, probiotic, postbiotic, additives, indications

Introduction

A prebiotic is a selectively fermented ingredient that allows specific changes in the composition and activity of the gastrointestinal microflora and that confers benefits upon the host's well-being and health [1]. Prebiotics are short-chain carbohydrates that are nondigestible by human digestive enzymes [1].
They selectively enhance the activity of some beneficial intestinal bacteria, which ferment prebiotics into short-chain fatty acids [1]. Probiotics are defined as an adequate number of live microorganisms able to confer health benefits on the host [2]. Lactic acid bacteria, *Lactobacilli* and *Bifidobacteria*, are the most studied probiotic strains used in food and supplements [3]. Coincidentally, they are part of the human intestinal microbial flora since birth [2]. Postbiotics refer to dead microorganisms and their components capable of conferring a health benefit to the host [4]. They include enzymes, bacterial peptides and proteins, polysaccharides, and organic acids secreted by live bacteria or released after bacterial lysis [4]. Brick-and-mortar retail outlets have been the mainstream retail channel for decades. They offer customers the opportunity to examine products and/or services before purchasing. E-commerce refers to buying and selling products and services over an electronic network, usually the internet. It also includes an electronic transfer of information and funds between buyers and sellers. These transactions can be either business-to-business (B2B), business-to-consumer (B2C), consumer-to-business (C2B) or consumer-to-consumer (C2C). In Singapore, consumers can purchase digestive health food and supplements at physical retail outlets such as pharmacies and health food shops or through virtual shops such as Lazada and Shopee – two predominant B2C e-commerce platforms serving Singapore residents. At present, there is limited information on the characteristics, compositions, claims, and indications of digestive health products commercially available to Singapore consumers. This study aimed to examine the prebiotic, probiotic, and postbiotic compositions of a selection of such digestive health supplement products and to assess the colouring, flavouring, preservative, and sweetening ingredients added to these products. Their claims, indications, and form of delivery were also studied. The country of manufacture, retail channels and the daily cost of consumption of each product were evaluated. The study also aimed to examine if the compositions, claims, indications, and characteristics of these products differed between physical and e-commerce retail platforms.

Data collection

All digestive health products on the shelves of major pharmaceutical retail outlets (Guardians, Watson, and Unity) and two major e-commerce platforms (Lazada and Shopee) in Singapore were included in this study.

The name of each item and the prebiotic, probiotic, and postbiotic used in its production were recorded by trained research personnel. The presence of added colourings, flavourings, preservatives, and sweeteners in each item was also noted from its product label. Other product information, such as country of manufacture, indications, claims, form of delivery and price were also recorded. This information should be printed on the item's packaging as regulated by the Health Science Authority, Singapore. The daily cost was computed by dividing the product's price by the number of daily doses included in the product. The number of daily doses was calculated as the ratio of the delivery units in the product to the number of delivery units recommended to be taken daily.

Data analyses

Data were statistically described and analyzed using Microsoft Excel (version 2103, April

2021). Differences between two groups were determined by using two-sample independent t-tests. Significance is reached when $p<0.05$.

Results

Product characteristics

All 146 products included in the study declared compositions on their labels. The surveyed products were commercially available to consumers via e-commerce platforms (56.2%) and physical retail (43.8%). The studied products were manufactured in 15 countries. Almost one-third (30.8%) of the products were manufactured in the United States of America. South Korea manufactured 21.2% of the products. Two other major manufacturing countries were the United Kingdom (4.2%) and Australia (4.7%). After stratifying by continents, Asia (36.3%) became the leading manufacturer, followed closely by America (34.9%). Oceania (15.1%) and Europe (13.7%) contributed to the remainder.

Most of the products (52.1%) were delivered as capsules (17.2%) or powder (34.9%). Tablets, gummies, and liquid were less common delivery forms.

Prebiotics, probiotics and postbiotics

Prebiotics were added to 55.9% of the survey products. However, only 18.5% of the products specified the identity of the added prebiotics. Fructooligosaccharides or inulin (FOS), galactooligosaccharides (GOS), isomaltooligosaccharides (IMO) and xylooligosaccharides (XOS) were noted as added prebiotics. Only 2.5% of the prebiotic-labelled products declared the amounts of prebiotics. These products contained 64.5±50.2 mg prebiotics, specifically FOS. The other specified prebiotic products did not state quantities. Prebiotics were added to 50% of the products sold in physical retail stores and to 60.5% of those sold via e-commerce platforms. FOS or inulin was the predominant prebiotic (75.3%) in the store (77.8%) and e-commerce (67.5%) products **(Fig. 1)**. IMO and XOS were completely absent in all store products **(Fig. 1)**. The amounts of prebiotics were declared in 4.1% of the e-commerce (64.5±50.2 mg) products and in none of the retailed products.

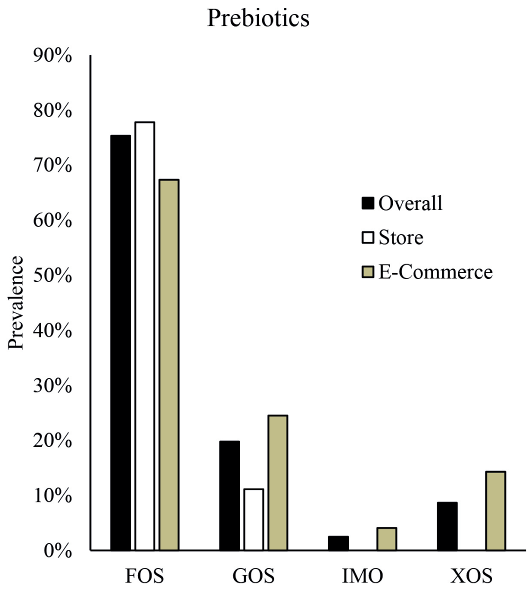

Figure 1 Prevalence (%) of prebiotics added to digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82)

Of the 146 surveyed products, 82.9% were labelled as containing probiotics. Probiotic strains were specified in 81.5% of these products. A total of 26 different probiotic strains were declared **(Table 1)**.

Bacillus coagulans	*Lactobacillus delbrueckii*
Bifidobacterium animalis	*Lactobacillus fermentum*
Bifidobacterium breve	*Lactobacillus gasseri*
Bifidobacterium bifidum	*Lactobacillus helveticus*
Bifidobacterium infantis	*Lactobacillus lactis*
Bifidobacterium lactis	*Lactobacillus paracasei*
Bifidobacterium longum	*Lactobacillus plantarum*
Enterococcus faecium	*Lactobacillus reuteri*
Enterococcus faecalis	*Lactobacillus rhamnosus*
Lactobacillus acidophilus	*Lactobacillus salivarius*
Lactobacillus breve	*Lactococcus lactis*
Lactobacillus bulgaricus	*Saccharomyces boulardii*
Lactobacillus casei	*Saccharomyces cerevisiae*

Table 1 Probiotic strains stated on digestive products (n=121) commercially available in Singapore

The top five probiotics added to digestive health products were all lactic acid bacteria **(Fig. 2)**, making them the predominant probiotics (92.3%). The lactic acid bacteria were *Lactobacillus* (54.2%), *Bifidobacterium* (29.1%), *Enterococcus* (8.3%), *Bacillus* (4.2%), and *Lactococcus* (4.2%). Yeast (7.7%), *Saccharomyces cerevisiae* and *Saccharomyces boulardii* made up the remaining probiotics in the commercial supplements. Probiotics were present in 96.9% of the products sold in the physical store and 72% of the products sold via e-commerce. Of the surveyed products, 3.4% declared the amounts of probiotics. The studied products contained 27640±42261 million CFU (100–100000 million CFU) bacteria. *Lactobacillus rhamnosus* was added at significantly higher doses than the other probiotic strains **(Fig. 3)**. The same five probiotics were widely used in the store and e-commerce products **(Fig. 3)**. Of the e-commerce products (27640±42261 million CFU) 6.1% stated the amounts of probiotics; none of the store products supplied this information.

Postbiotics were present in 2.8% of the studied products. Of the postbiotic-containing products, 14 postbiotic strains were stated on three-quarters of them **(Table 2)**. *Lactobacillus gasseri* (75%) was the most prevalent postbiotic strain, followed by *Lactobacillus fermentum* (50%). None of the postbiotic-containing products declared the amount of postbiotic strains. Postbiotics were completely absent in physical store products and were added to 4.9% of the e-commerce products.

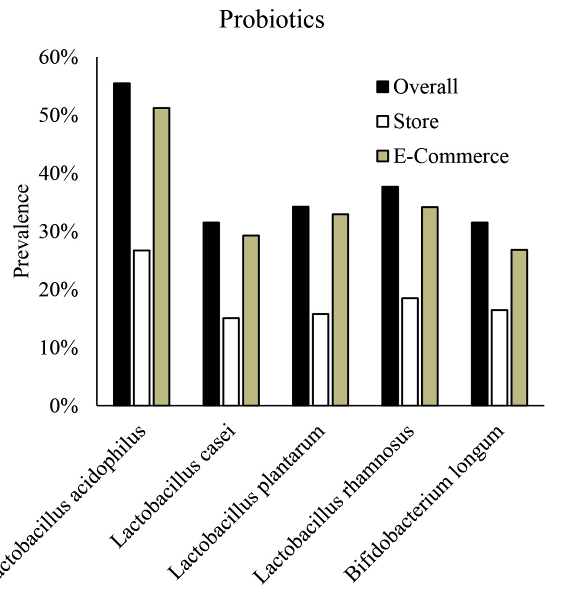

Figure 2 Prevalence (%) of the five most popular probiotics added to digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82) in Singapore

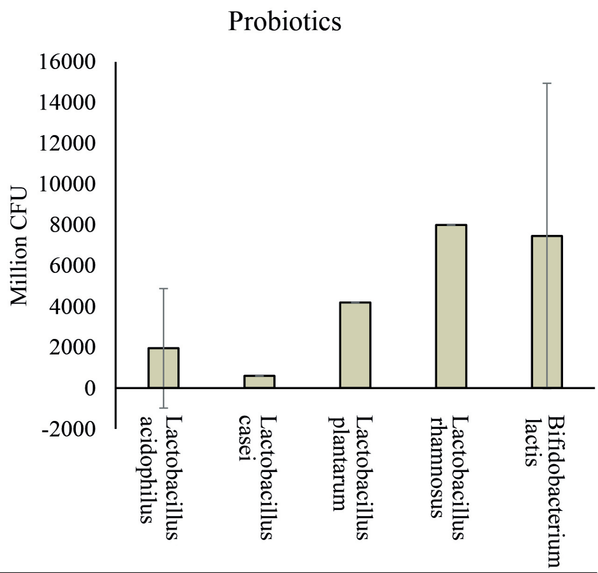

Figure 3 Stated doses (million CFU) of the five most popular probiotics (n=5 for Lactobacillus acidophilus, n=1 for Lactobacillus casei, n=1 for Lactobacillus planterum, n=1 for Lactobacillus rhamnosus, and n=3 for Bifidobacterium lactis) added to digestive health products (n=121)

Bifidobacterium breve	*Lactobacillus bulgaricus*
Bifidobacterium bifidum	*Lactobacillus casei*
Bifidobacterium lactis	*Lactobacillus fermentum*
Bifidobacterium longum	*Lactobacillus gasseri*
Enterococcus faecium	*Lactobacillus helveticus*
Enterococcus faecalis	*Lactobacillus paracasei*
Lactobacillus acidophilus	*Lactobacillus rhamnosus*

Table 2 Postbiotic strains stated on digestive products (n=14) commercially available in Singapore

Colourings, flavourings, preservatives, and sweeteners

Of the studied products, 13.7% contained added colourings. Titanium dioxide (E171) was the most added colouring, followed by β-carotene/arotenoid (E160a) and natural purple/anthocyanins (E163) **(Fig. 4)**. The natural colourings used were β-carotene/carotenoid (E160a), beet (E162) and anthocyanins (E163) **(Fig. 4)**.

Artificial colourants used were sodium copper chlorophyllin (E141), calcium carbonate (E170), and titanium dioxide (E171) **(Fig. 4)**.
Artificial colourants were used more often than natural colourants (Fig. 4). The profiles of colourants in store and e-commerce products were similar **(Fig. 4)**.

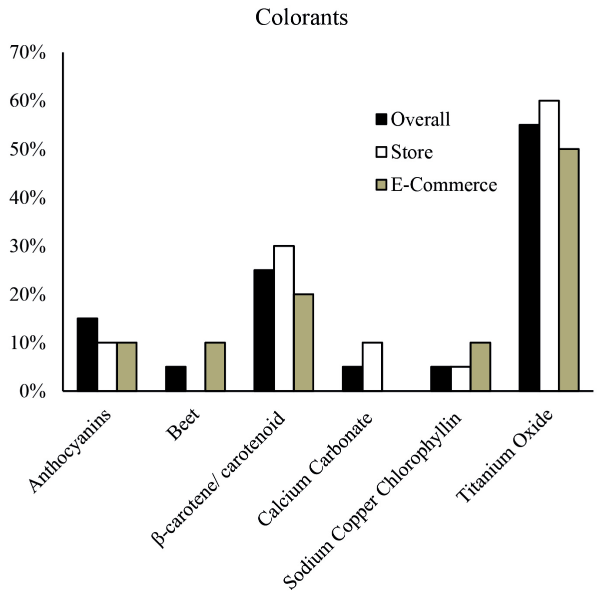

Figure 4 Occurrence (%) of the three most prevalent natural and artificial colourants added to digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82)

Flavourings were added to 21.9% of the products. Lemon (4.1%), grape (3.4%), yoghurt (3.4%), blueberry (2.7%), cranberry (2.1%) and strawberry (2.1%) flavours were the most adopted flavours. Both store (21.8%) and e-commerce (22.0%) products contained flavours. Unspecified flavours were used in a total of 2.7% of the products: store (1.6%) and e-commerce (3.7%).

Preservatives were added to 2.7% of the studied products. Lactic acid (E270, 2.1%) and malic acid (E296, 0.70%) were added as preservatives. The prevalence remained similar for store and e-commerce products.

More than a quarter (28.1%) of the studied products contained artificial or natural sweeteners. Maltodextrin, xylitol, and glucose were the three most prevalent sweeteners **(Fig. 5)**. The most used natural sweeteners included glucose, stevia, and isomalt while the most used artificial sweeteners included maltodextrin, sucralose, and xylitol **(Fig. 5)**.
Store (29.7%) and e-commerce (26.8%) products contained sweeteners and contained a similar profile of added sweeteners **(Fig. 5)**.

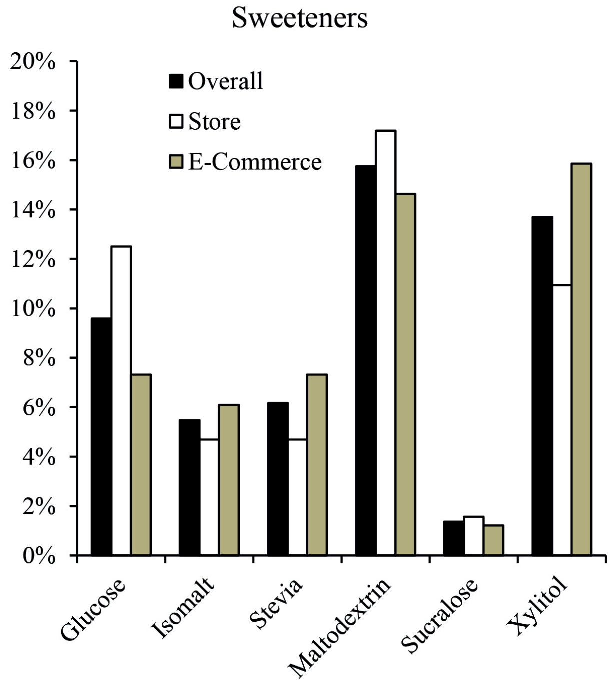

Figure 5 Occurrence (%) of the three most prevalent natural and artificial sweeteners added to digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82)

Claims and indications

Claims were declared on 68.5% of the products. Almost half (48%) of the products claimed to be gluten-free **(Fig. 6a)**. No added flavourings, dairy-free or lactose-free, and preservative-free were claimed by a quarter of the products **(Fig. 6a)**. Other top common claims included no artificial colourings, vegan, soy-free, wheat-free, no artificial sweetener, and no added sugar **(Fig. 6a)**. The top ten claims were similar between the store and e-commerce products and gluten-free was the most prevalent claim.

Product indications were stated on 97.3% of the studied products. Gut/intestinal health was the most prevalent indication, followed by immune health, intestinal flora, and digestive discomfort relief **(Fig. 6b)**. The prevalence trends of store and e-commerce products were similar **(Fig. 6b)**.

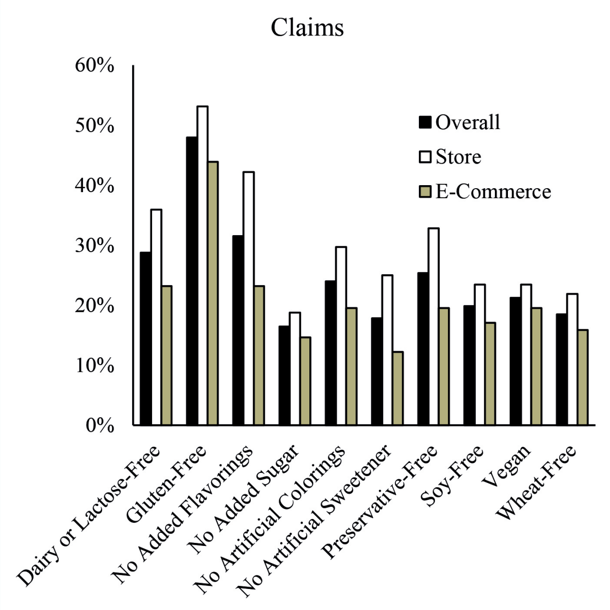

Figure 6a Prevalence (%) of the claims stated by digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82)

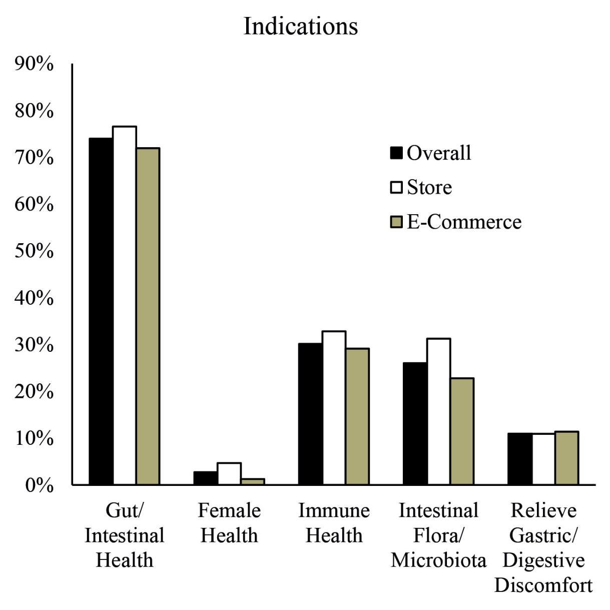

Figure 6b Prevalence (%) of the (a) claims and (b) indications stated by digestive health products (n=146) sold in physical retail stores (n=64) and e-commerce platforms (n=82)

Daily consumption cost

The average daily cost of a digestive health product in Singapore is \$1.94±\$1.20 (mean±SD). The daily cost of the studied products ranged between \$0.13 and \$6.90. Most of the studied products (42.7%) were priced at an average daily cost of \$1.00 and \$2.00. Others cost less than \$1.00 (21.7%) and between \$2.00 and \$3.00 (19.6%) daily. The store products (\$2.26±\$1.21/day) were significantly more costly than the e-commerce products (\$1.69±\$1.14/day) ($p<0.05$ using two-sample independent t-tests).

Discussion

When compared with prebiotics and postbiotics, probiotics were the predominant digestive health nutraceutical product. This is unsurprising due to the longer history of the probiotic concept when compared with prebiotics and postbiotics. However, prebiotics are gaining traction with consumers and manufacturers as scientific evidence is gathered to support their efficacies [1]. Postbiotics are relatively new to the field which explains their placing as the least common of the three biotics in the studied commercial digestive health products. It is understandable why FOS or inulin and GOS are commonly added as prebiotics in commercial products.

They have been scientifically proven to exert the defined biological effects of prebiotics [1]. FOS or inulin consumption, ranging from 4 g to 16 g daily over 14 to 28 days, increased the relative abundance of *Bifidobacterium* in numerous randomized, placebo-controlled studies involving healthy adults [5, 6] and elderly participants [7].

Similar relative increases in faecal *Bifidobacterium* abundance were observed in studies involving GOS intakes (1.5 g to 16 g daily over 21 to 84 days) in healthy adult participants [6, 8] and in overweight adult participants (15 g daily over twelve weeks) [9]. The bifidogenic effect of GOS was reported to be dose-dependent, with a significant impact only observed at doses greater than 2.5 g daily [10]. In addition to *Bifidobacterium*, GOS intervention 1.5 g to 15 g daily over 30 days significantly increased faecal *Faecalibacterium* and *Lactobacillus* in healthy adults.

The results suggest that GOS intake may improve lactose digestion and tolerance [8]. In a randomized, double-blinded, placebo-controlled, parallel-armed clinical trial, GOS consumption (5 g daily) over three weeks increased intestinal barrier permeability in obese adults [11]. A relatively high daily dose of 16 g FOS or GOS interventions reduced the butyrate-producing bacteria and might adversely affect glucose metabolism [6]. XOS is a sugar oligomer of β-1,4-linked xylose molecules, usually two to seven monomer units [12]. XOS similar bifidogenic properties in healthy adults as FOS and GOS [13, 14]. XOS supplementation (8 g daily) over 21 days modulated the immune functions of healthy adults [13]. IMO is a mixture of glucose oligomers with alpha-(1-6)-linkages, usually three to six monomer units [15]. They are naturally found in honey, miso, sake, and soy sauce [15]. IMOs are formed by enzyme-catalyzed hydrolysis of starch followed by saccharification [15]. Limited human clinical results on IMO prebiotic activities were available compared with FOS or inulin, GOS, and XOS. The newer XOS and IMO prebiotics were totally absent in the store products. Only a few products declared the added amounts of FOS or inulin, and the doses were significantly lower than the effective daily doses (1.5 g to 15 g) employed in the clinical studies [6, 8–11, 13, 14].

It begs the question of whether these products can exert prebiotic effects. Further studies are needed to ascertain the effects of the relatively low doses of prebiotics in these products.

Commercial digestive health products were predominantly probiotics, with 26 identified strains. Lactic acid bacteria are the most common probiotics, with *Lactobacillus sp.* the most studied. *Lactobacilli* exert significant nutritional benefits to human health. They produce essential vitamins, such as vitamin B2, B9, and B12 [16]. They degrade lactose and solve the problems related to lactose intolerance and maldigestion [17]. *Lactobacilli* break down tannins and phytates and improve the bioavailability of minerals [17]. They prevent the accumulation of pathogenic microbes in the human gut by competing with these pathogens for the same attachment sites on the intestinal mucosal interface [18]. They maintain epithelial barrier integrity by enhancing the function of tight junctions and immune response and preventing epithelial cell apoptosis [19]. *Lactobacilli* metabolites, like lactic acid, phenyl lactic acid, hydrogen peroxide, and bacteriocins, inhibit the growth of pathogens in the human gut [20–22]. *Lactobacillus casei* (10^9 CFU) has been shown to reduce the prevalence of antibiotic-associated diarrhoea during infection treatment in human patients [23]. *Bifidobacteria* are another common lactic acid bacteria probiotic. In vitro studies have reported anti-proliferative, pro-apoptotic, and antioxidative properties of Bifidobacteria and *Lactobacilli* [24]. *Bifidobacteria* has been shown to reduce visceral fat accumulation and improve glucose tolerance in C57BL/6J mice fed a high-fat diet by modulating their gut microbiota and increasing SCFA production [25]. In a systematic review and meta-analysis of 18 randomized controlled trials involving 1,544 participants with metabolic syndrome, *Lactobacilli* and *Bifidobacteria* decreased body fat percentage and low-density lipoprotein cholesterol levels.

Still, they did not significantly influence body fat mass, body mass index, diastolic blood pressure, fasting glucose, fasting insulin, HbA1c, hip circumference, high-density lipoprotein, systolic blood pressure, total blood cholesterol, triglycerides, waist circumference, and waist-to-hip ratio [3].

Bifidobacterium animalis intervention, 10^{10} CFU over three months, decreased the body mass index of abdominal obese women compared with the baseline and the placebo [26].

The extensive clinical evidence may explain that the top five probiotic strains were all lactic acid bacteria **(Fig. 2)**. Yeast can resist the action of gastrointestinal enzymes, bile salts, organic acids, pH and temperature variations, making them good candidates as probiotics [27].

Saccharomyces boulardii and *Saccharomyces cerevisiae* reduce gastrointestinal inflammation, alleviated antibiotic-associated diarrhoea, and protected against intestinal pathogens [27].

The lesser-known probiotic efficacy of yeast to the consumers probably explains their lower occurrence in digestive health products compared to the popular bacteria probiotics.

The negative health influences of food additives such as colourings [28], flavourings [29], preservatives [30], and sweeteners [31] are alarming to nutritionists and health-conscious consumers. Added colourants and flavourings were rare in the commercial digestive health products examined in this study. Artificial colourants, especially titanium dioxide, were used over natural colourants. However, the use of natural colourants is gaining popularity due to the 'natural' and 'free-from' consumer movements. Titanium dioxide is a common, odourless food colourant used to impart or enhance the white colour or opacity of food and pharmaceutical products. It has been traditionally used in pharmaceutical products. The use of colourants may complement the flavourings in numerous products. Dark colourants, like anthocyanins, is likely present in grape-, blueberry-, cranberry-, and strawberry-flavoured products. Carotene/carotenoid may complement the colour of lemon-flavoured products. Preservatives were almost absent in the surveyed products as almost all the products were delivered in solid forms with very low water activities and thus less susceptible to microbial spoilage. Lactic and malic acids were exclusively used in the liquid products. The choice of added sweeteners may be explained by reference to consumer perception of the health benefits of certain sweeteners [31]. Maltodextrin was the predominant added sweetener (15.8%), probably because it is non-caloric and caters to the health-conscious consumer [31]. Xylitol was often added (13.7%) as it inhibits tooth decay [32]. For the same reason, non-caloric stevia is gaining popularity among the natural sweeteners [33]. These supposedly healthier sweeteners were used instead of glucose [31].

Product claims are important to inform and educate consumers on the benefits and strengths of a product. To combat fraudulent claims, product claims are strictly regulated by the local health authority. Gluten-free was the most prevalent claim. Gluten is a group of proteins, prolamin and glutelin naturally found in grains [34]. Gluten triggers adverse inflammatory and autoimmune reactions, which include coeliac disease, non-coeliac gluten sensitivity [34]. All these can be treated by eliminating gluten from the diet [34]. As indicated for digestive health, it becomes critical that the same product must not do the opposite. Thus, it is unsurprising for most of the studied products to be free of gluten. Other less prevalent claims were mainly related to allergens (milk, lactose, soy) and 'free-from additives' concepts.

An indication describes the effect of the product. Most indications on the products examined were justifiably associated with digestive health. Immune health was also one of the top indications. Long-term probiotic consumption reduces systemic inflammation, modulates the immune system, and alleviates immunity-related reactions [35]. The stated indications were justifiable as they truthfully communicated the prescribed benefits of prebiotics, probiotics, and postbiotics.

The daily consumption cost of the studied commercially available digestive health products was affordable and comparable to that of one cup of coffee at a local coffee shop. E-commerce items were generally lower priced than comparable items at physical stores, which have upfront store rental and labour costs to consider.

The study was conducted to preliminarily understand the composition and demographic profiles of digestive health products commer-

cially available to Singapore residents.
The profiles may not represent the preference and perceptions of the consumers. More studies should be conducted to understand preferences and perceptions of consumers.

Conclusions

Digestive health supplements are diverse formulations, but they contain several common prebiotics and probiotics. Limited information on the prebiotic and probiotic concentration is available to assess their efficacies.
Manufacturers should make efforts to investigate the efficacies of their products and communicate these findings to consumers.

Conflict of interest

The authors have no conflict of interest to declare.

References

1. Roberfroid M (2007) Prebiotics: The concept revisited. J Nutr 137(3 Suppl 2):830S–837S

2. Dam B, Misra A, Banerjee S (2019) Role of gut microbiota in combating oxidative stress. In: Chakraborti S, Chakraborti T, Chattopadhyay D, Shaha C (eds) Oxidative stress in microbial diseases. Springer, Singapore, pp 43–82

3. Dong Y, Xu M, Chen L, Bhochhibhoya A (2019) Probiotic foods and supplements interventions for metabolic syndromes: A systematic review and meta-analysis of recent clinical trials. Ann Nutr Metab 74(3):224–241

4. Salminen S, Collado MC, Endo A, Hill C, Lebeer S, Quigley EMM *et al.* (2021) The international scientific association of probiotics and prebiotics (ISAPP) consensus statement on the definition and scope of postbiotics. Nat Rev Gastroenterol Hepatol 17(11):687–701

5. Tuohy KM, Kolida S, Lustenberger AM, Gibson GR (2001) The prebiotic effects of biscuits containing partially hydrolyzed guar gum and fructo-oligosaccharides – a human volunteer study. Br J Nutr 86:341–348

6. Liu F, Li P, Chen M, Luo Y, Prabhakar M, Zheng H *et al.* (2017) Fructooligosaccharide (FOS) and galactooligosaccharide (GOS) increase bifidobacterium but reduce butyrate producing bacteria with adverse glycemic metabolism in healthy young population. Sci Rep 7:11789

7. Guigoz Y, Rochat F, Perruisseau-Carrier G, Rochat I, Schiffrin EJ (2002) Effects of oligosaccharide on the faecal flora and non-specific immune system in elderly people. Nutr Res 22:13–25.

8. Azcarate-Peril MA, Ritter AJ, Savaiano D, Monteagudo-Mera A, Anderson C, Magness ST *et al.* (2017) Impact of short-chain galactooligosaccharides on the gut microbiome of lactose-intolerant individuals. Proc Nat Acad Sci 114(3):E367–E375

9. Canfora EE, van der Beek CM, Hermes GDA, Goossens GH, Jocken JWE, Holst JJ *et al.* (2017) Supplementation of diet with galacto-oligosaccharides increases Bifidobacteria, but not insulin sensitivity, in obese prediabetic individuals. Gastroenterology 153(1):87–97.e3

10. Davis LMG, Martínez I, Walter J, Hutkins R (2010) A dose dependent impact of prebiotic galactooligosaccharides on the intestinal microbiota of healthy adults. Int J Food Microbiol 144(2):285–292

11. Krumbeck JA, Rasmussen HE, Hutkins RW, Clarke J, Shawron K, Keshavarzian A *et al.* (2018) Probiotic Bifidobacterium strains and galactooligosaccharides improve intestinal barrier function in obese adults but show no synergism when used together as synbiotics. Microbiome 6(1):121–132

12. Jordan DB, Wagschal K (2010) Properties and applications of microbial β-D-xylosidases featuring the catalytically efficient enzyme from Selenomonas ruminantium. Appl Microbiol Biotechnol 86:1647–1658

13. Childs CE, Röytiö H, Alhoniemi E, Fekete AA, Forssten SD, Hudjec N *et al.* (2014) Xylo-oligosaccharides alone or in synbiotic combination with bifidobacterium animalis subsp. lactis induce bifidogenesis and modulate markers of immune function in healthy adults: A double-blind, placebo-controlled, randomized, factorial cross-over study. Br J Nutr 111(11):1945–1956

14. Finegold SM, Li Z, Summanen PH, Downes J, Thames G, Corbett K *et al.* (2014) Xylooligosaccharide increases bifidobacteria but not lactobacilli in human gut microbiota. Food Funct 5(3):436–445

15. Plongbunjong V, Graidist P, Knudsen KEB, Wichienchot S (2017) Isomaltooligosaccharide synthesized from rice starch and its prebiotic properties in vitro. Int J Food Sci Technol 52(12):2589–2595

16. Crittenden R, Martinez N, Playne M (2003) Synthesis and utilization of folate by yoghurt starter cultures and probiotic bacteria. Int J Food Microbiol 80(3):217–222

17. de Vrese M, Stegelmann A, Richter B, Fenselau S, Laue C, Schrezenmeir J (2001) Probiotics – compensation for lactase insufficiency. Am J Clin Nutr 73(2 Suppl):421s–429s

18. Prado Acosta M, Ruzal SM, Cordo SM (2016) S-layer proteins from Lactobacillus sp. inhibit bacterial infection by blockage of DC-SIGN cell receptor. Int J Biol Macromolec 92:998–1005

19. Kozakova H, Schwarzer M, Tuckova L, Srutkova D, Czarnowska E, Rosiak I *et al.* (2016) Colonization of germ-free mice with a mixture of three lactobacillus strains enhances the integrity of gut mucosa and ameliorates allergic sensitization. Cell Mol Immunol 13(2):251–262

20. Shokryazdan P, Sieo CC, Kalavathy R, Liang JB, Alitheen NB, Faseleh Jahromi M *et al.* (2014) Probiotic potential of lactobacillus strains with antimicrobial activity against some human pathogenic strains. Biomed Res Int. doi:10.1155/2014/927268

21. Chew SY, Cheah YK, Seow HF, Sandai D, Than LTL (2015) Probiotic lactobacillus rhamnosus GR-1 and lactobacillus reuteri RC-14 exhibit strong antifungal effects against vulvovaginal candidiasis-causing candida glabrata isolates. J Appl Microbiol 118(5):1180–1190

22. Yang H, Deng J, Yuan Y, Fan D, Zhang Y, Zhang R (2015) Two novel exopolysaccharides from bacillus amyloliquefaciens C-1: antioxidation and effect on oxidative stress. Curr Microbiol 70(2):298–306

23. Dietrich CG, Kottmann T, Alavi M (2014) Commercially available probiotic drinks containing lactobacillus casei DN-114001 reduce antibiotic-associated diarrhoea. World J Gastroenterol 20(42):15837–15844

24. Nowak A, Paliwoda A, Błasiak J (2019) Anti-proliferative, pro-apoptotic and anti-oxidative activity of lactobacillus and bifidobacterium strains: A review of mechanisms and therapeutic perspectives. Crit Rev Food Sci Nutr 59(21):3456–3467

25. Aoki R, Kamikado K, Suda W, Takii H, Mikami Y, Suganuma N *et al.* (2017) A proliferative probiotic bifidobacterium strain in the gut ameliorates progression of metabolic disorders via microbiota modulation and acetate elevation. Sci Rep 7:43522

26. Pedret A, Valls RM, Calderón-Pérez L, Llauradó E, Companys J, Pla-Pagà L *et al.* (2019) Effects of daily consumption of the probiotic bifidobacterium animalis subsp. lactis CECT 8145 on anthropometric adiposity biomarkers in abdominally obese subjects: a randomized controlled trial. Int J Obes 43(9):1863–1868

27. Palma ML, Zamith-Miranda D, Martins FS, Bozza FA, Nimrichter L, Montero-Lomeli M *et al.* (2015) Probiotic Saccharomyces cerevisiae strains as biotherapeutic tools: Is there room for improvement? Appl Microbiol Biotechol 99(16):6563–6570

28. Leo L, Loong C, Ho XL, Raman MFB, Suan MYT, Loke WM (2018) Occurrence of azo food dyes and their effects on cellular inflammatory responses. Nutrition 46:36–40

29. World Health Organization (2011) Evaluation of certain food additives and contaminants. World Health Organization technical report series 966:1-136.

30. Loong C, Tsen SY, Ho XL, Raman MFB, Loke WM (2018) Common food antimicrobials: effects on cellular inflammation and oxidative damage and their estimated occurrence in Singapore. Asia Pac J Clin Nutr 27(1):113–120

31. Sylvetsky AC, Rother KI (2016) Trends in the consumption of low-calorie sweeteners. Physiology & behavior 164:446–450

32. Gasmi Benahmed A, Gasmi A, Arshad M, Shanaida M, Lysiuk R, Peana M *et al.* (2020) Health benefits of xylitol. Appl Microbiol Biotechnol 104(17):7225–7237

33. Samuel P, Ayoob KT, Magnuson BA, Wölwer-Rieck U, Jeppesen PB, Rogers PJ *et al.* (2018) Stevia leaf to stevia sweetener: Exploring its science, benefits, and future potential. J Nutr 148(7):1186S–1205S

34. El Khoury D, Balfour-Ducharme S, Joye IJ (2018) A review on the gluten-free diet: Technological and nutritional challenges. Nutrients 10(10):1410–1418

35. Maldonado Galdeano C, Cazorla SI, Lemme Dumit JM, Vélez E, Perdigón G (2019) Beneficial effects of probiotic consumption on the immune system. Ann Nutr Metab 74(2):115–124