

# Potential Health Benefits of Combining Yogurt and Fruits Based on Their Probiotic and Prebiotic Properties<sup>1–3</sup>

Melissa Anne Fernandez<sup>4–6</sup> and André Marette<sup>4,5,7\*</sup>

<sup>4</sup>Quebec Heart and Lung Institute, Quebec, Canada; <sup>5</sup>Institute of Nutrition and Functional Foods, Quebec, Canada; and <sup>6</sup>School of Nutrition and <sup>7</sup>Department of Medicine, Laval University, Quebec, Canada

## ABSTRACT

Fruit and yogurt have been identified individually as indicators of healthy dietary patterns. Fruits are relatively low in energy density and are an excellent source of antioxidants and prebiotic fibers and polyphenols, which can promote digestive health. Yogurt, on the other hand, is a nutrient-dense food that is a good source of dairy protein, calcium, magnesium, vitamin B-12, conjugated linoleic acid, and other key fatty acids. In addition, it contains beneficial bacterial cultures, making it a potential source of probiotics. Yogurt's unique fermented food matrix provides added health benefits by enhancing nutrient absorption and digestion. Combining the intake of yogurt and fruit could provide probiotics, prebiotics, high-quality protein, important fatty acids, and a mixture of vitamins and minerals that have the potential to exert synergistic effects on health. Yogurt consumption has been associated with reduced weight gain and a lower incidence of type 2 diabetes, whereas fruits have established effects on reducing the risk of cardiovascular disease. Yogurt and fruits can be eaten together and may exert combined health benefits through potential prebiotic and probiotic effects. Furthermore, substituting high-energy, nutrient-deficient snacks with fruit and yogurt could reduce the intake of high-calorie obesogenic foods. In light of the positive cardiometabolic impacts of fruit and yogurt and their association with healthy dietary patterns, there is sufficient evidence to warrant further exploration into the potential synergistic health benefits of a combined intake of fruit and yogurt. *Adv Nutr* 2017;8(Suppl):155S–64S.

**Keywords:** yogurt, fruits, prebiotics, probiotics, synbiotics

## Introduction

It has been long understood that fruits, vegetables, and dairy products are healthy components of the diet, as evidenced by their inclusion worldwide in national food guides and nutritional guidelines (1, 2). More recently, it has been suggested that whole plant-based foods, probiotics, and prebiotics can modulate the microbiota, leading to cardiac health (3). From

studies investigating the effects of diet on health, consistent healthy dietary patterns have been elucidated across diverse populations. For example, a fruit and dairy pattern has been linked to a lower risk of metabolic syndrome in Korean adults (4), and a diet high in fruits, vegetables, and low-fat dairy products has been effective in reducing blood pressure in American adults (5, 6). Studying patterns of food consumption will likely better reflect the complex synergistic benefits of eating different foods together, rather than studying the outcomes of individual foods and nutrients on health (7). Diet quality indexes and healthy dietary pattern analyses are important methods that are used to decode the complexity of the diet and its association with health outcomes that go beyond individual nutrients. Given the complex nature of diet variables, multiple analysis approaches are called upon to investigate the relation between food and disease risk (8). Aside from dietary patterns and individual nutrient and food analysis, food combination synergies are an approach to diet analysis that takes in to account the food matrix, thereby warranting investigation. It has been suggested that the food matrix, which combines nutrients into a specific structural arrangement,

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\*To whom correspondence should be addressed. E-mail: andre.marette@criucpq.ulaval.ca.

may endow a food with a synergy of properties that would not be available if the individual nutrients were consumed separately (9).

Yogurt and fruit have been identified in isolation as exerting protective effects against specific diet-related diseases (DRDs)<sup>8</sup>, such as type 2 diabetes (T2D) (10, 11). These foods may be consumed together or during the same eating episode (breakfast and snacks). To our knowledge, these 2 foods have never been studied in combination. In fact, common food combinations rarely are reported in scientific literature. Nevertheless, there are indications that consuming certain foods can affect dietary intake of specific nutrients and food groups. For example, in both sexes and across age groups in the United States, ready-to-eat breakfast cereal consumption was associated with higher milk and calcium intake (12). Similarly, in a cross-section of European adolescents (aged 12.5–17.5 y), ready-to-eat cereal consumption was characterized by a better diet quality index, higher micronutrient intake, more frequent fruit consumption, and more milk and yogurt consumption (13). Not only can the intake of one food influence the consumption of another food, but there are also examples from in vitro and animal studies that combining certain nutrients has synergistic and/or complementary effects. An in vitro digestive model tested the antioxidant capacity of a green tea extract added to a dairy matrix (milk, yogurt, or cheese) or a control. It was demonstrated that the dairy matrix enhanced antioxidant activity by protecting the integrity of polyphenols during digestion (14). In an animal study, fermented milk containing yogurt cultures in addition to *Bifidobacterium lactis* CNCM I-2494 was more effective than the pure *B. lactis* CNCM I-2494 strain in normalizing intestinal epithelial barrier junctions and reducing stress-induced visceral hypersensitivity in rats. The efficacy of the fermented milk matrix over the pure probiotic strain was attributed to synergistic interactions between the probiotic strain, yogurt cultures, and metabolites in the fermented milk (15). Yogurts and fruits contain a wide variety of nutrients that have the potential to act in a complementary or synergistic manner on health. The consumption of whole fruits has been recommended over taking supplements for the synergistic activity of bioactive components found in whole foods and their additive effects on health (16). To manage hypertension, the Dietary Approaches to Stop Hypertension diet promotes a dietary mixture, which includes vegetables and fruits for their high potassium content and dairy products for their magnesium and calcium (17). Dietary guidelines and healthy dietary patterns such as the Dietary Approaches to Stop Hypertension diet promote variety and moderation; by consuming different combinations of foods, the types of nutrients ingested are maximized, whereas excesses from one particular food are minimized.

It is largely undisputed that fruits are protective against DRDs (18). These effects are mainly attributed to their high content of fiber and their antioxidant potential. There is increasingly strong evidence supporting yogurt consumption

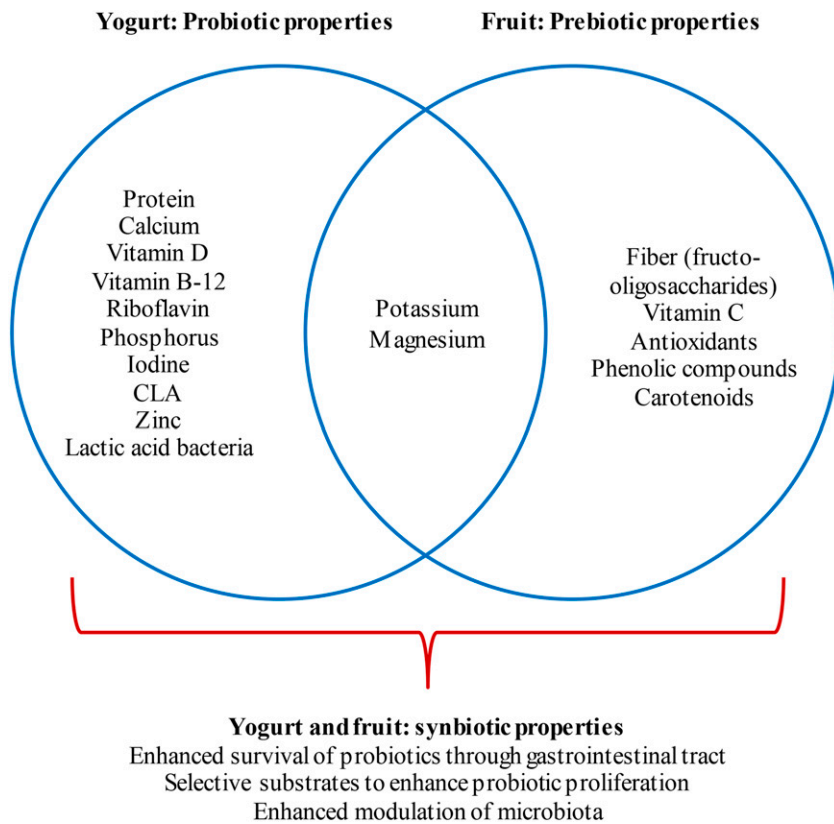
for its protective effect on specific DRDs, such as T2D (10, 19, 20) and obesity (21–23). The mechanisms attributed to yogurt's potential health benefits include its nutrient density, probiotic bacteria content, and fermented properties (24, 25). With the exception of specific supplements, foods and nutrients are rarely consumed in isolation; however, not a great deal is known or understood about food interactions in a dietary context. There is indeed a knowledge gap regarding the potential synergistic impact of combining foods, commonly identified in healthy dietary patterns, on health. This review will explore the potential for the synergistic effects of yogurt and fruit consumption on DRDs, as well as their synbiotic potential as foods with probiotic and prebiotic properties. We hypothesized that the consumption of yogurt and fruit together could exert a synergistic effect on gut health, subsequently affecting DRDs. The present review will question the potential for combining traditional yogurt and whole or minimally processed fruits to exert beneficial effects on health by discussing their synbiotic potential, epidemiologic studies, and their role as indicators of a healthy diet.

### Nutrient Profiles of Fruit and Yogurt

**Fruit: nutrients, fiber, antioxidants, and potential source of prebiotics.** Fruits are an excellent source of dietary fiber, potassium, antioxidants, phenolic compounds, and carotenoids ( $\beta$ -carotene, lycopene, lutein, and zeaxanthin) (Figure 1), and are very low in energy density and high in water content (26, 27). Most fruits contain negligible amounts of fat and protein and little starch (except for bananas), and have a relatively high percentage of simple sugars, such as fructose and sucrose (26). Fruits are particularly high in insoluble fiber, which has the digestive benefit of adding bulk to the stool (26), and high-fiber diets have been linked to lower incidences of gastrointestinal disease, cardiovascular disease (CVD), and certain cancers (28). Recommendations for fiber intake, set by the Institute of Medicine based on CVD risk, are rarely met in the United States (29). In a standard 2000 kcal/d diet, a single 100-g portion of fruit could provide between 7% and 53% of the recommended daily intake of fiber (28 g/d) (30). High fiber intake protects against DRDs; the prebiotic properties of fruit are thought to contribute to its health-promoting potential (31). Fruits, vegetables, and grains are good sources of oligosaccharides, a dietary prebiotic fiber that promotes the colonization of lactobacilli and bifidobacteria in the colon. High consumption of fruits and vegetables can contribute  $\leq 11.3$  g fructo-oligosaccharides in the human diet (32). Although specific prebiotic fibers have very interesting health benefits and can be isolated to be used as functional additives in processed foods, it is the fiber in the original food matrix that may be responsible for conferring health benefits (31). Increasing fruit consumption would help populations with deficiencies meet recommendations for dietary fiber intake.

Fruit and vegetable intake recommendations vary widely, but international recommendations are generally based on the 1997 joint World Cancer Research Fund/American Institute for Cancer Research report, which recommends

<sup>8</sup> Abbreviations used: CAD, coronary artery disease; CVD, cardiovascular disease; DRD, diet-related disease; T2D, type 2 diabetes.



**FIGURE 1** Nutritive elements found in yogurt and fruit that may have an impact on diet-related disease prevention alone and in combination.

five 80-g portions of fruit and vegetables, or 400 g/d (33). Specific guidelines for fruit have varied between 1 and 5 portions/d in countries such as the United States, Australia, Germany, and China (2). It is recognized that specific cultivars, harvesting, storage, and preparation can result in varying amounts of phytonutrients between different fruits (27), potentially having varying effectiveness on health; however, health organizations have preferred to maintain simple messaging regarding consumption recommendations, likening all fruits and vegetables. This partially reflects modern-day dietary habits with respect to availability and personal preferences, as well as epidemiologic evidence, which rarely distinguishes between the quality or type of fruits and vegetables consumed. Nevertheless, polyphenol-rich fruits have been studied extensively as the most powerful antioxidants for health in the human diet (34); berries and grapes often are set apart from other fruits for this specific attribute (35). Berries in and of themselves, with their high polyphenol and antioxidant content, can be considered to be a naturally occurring functional health food (36). A polyphenol-rich extract from cranberry recently was shown to exert anti-inflammatory properties, reduce weight gain, and improve several features of metabolic syndrome in high fat–fed mice (37). These effects were linked with a markedly increased proportion of the mucin-degrading bacterium *Akkermansia muciniphila* in the gut microbiome of these mice. Similarly, the high polyphenol content of grapes has been pointed to as having beneficial effects on hypertension, T2D, CVD, cancer, and inflammation, among others (34), and a recent study confirmed

that grape polyphenols also can protect against metabolic syndrome by increasing the proportion of *A. muciniphila* in the gut microbiome of mice (38). Given the capability of polyphenols to selectively stimulate the proliferation of beneficial microflora in the gut, it has been strongly suggested that polyphenols are endowed with prebiotic properties (39). Furthermore, polyphenol compounds have been attributed in part with the beneficial effects of fruits on T2D (40). Diets high in fruits contain prebiotic molecules (e.g., polyphenols), which have the ability to rebalance microbial colonization of the gut, thereby promoting metabolic health in the host (41). Overall, the nutrient density, fiber content, and prebiotic activity of fruits justify investments in the public health nutrition promotion of an increased intake of fruits and vegetables as a strategy to diminish chronic diseases (18). However, specific recommendations regarding the selection of fruits with a lower glycemic index may be advisable for individuals with T2D and those at risk of coronary artery disease (CAD) (42). Furthermore, fruit consumption may have a dose-response effect on T2D risk prevention, and there may be no benefits beyond the consumption of 2–3 (106 g) portions/d (11), which should be considered when providing balanced fruit and vegetable recommendations to the public.

**Yogurt: nutrient density and potential source of probiotics.** Traditional yogurt, defined as milk fermented with bacterial strains, is a source of probiotics that has established beneficial effects in vivo for lactose digestion. At this time, however, it is unclear to what extent yogurt cultures have the capacity to act as a probiotic with regard to other health benefits (43).

Nevertheless, yogurt is a nutrient-dense food that is concentrated in energy, containing between 0.2 and 3.8 g fat, 3 and 6.5 g protein, and 47 and 122 kcal per 100-g edible portion (44). It is an excellent source of calcium, vitamin D (in fortified yogurts), magnesium, vitamin B-12, and riboflavin (Figure 1) (45–47). It is also a good source of iodine for vulnerable populations in countries without an iodine-fortified food supply, such as the United Kingdom (48). The primary carbohydrate in yogurt is lactose; however, its ability to be well tolerated by lactose-sensitive individuals is attributed to the presence of viable bacteria (e.g., *Lactobacillus delbrueckii* subspecies *bulgaricus* and *Streptococcus thermophilus*) (49). Besides containing lactose, many marketed yogurts contain sweeteners, making them an energy source, as well as an inconspicuous source of free sugars (45). However, sweetened yogurts may be a substantial source of added sugars only in very young children aged 4 mo to 3 y, which is likely to reflect the limited diet diversity in this age group. Indeed, sweetened yogurts are not a substantial source of added sugars in older children, and they are an important source of key nutrients (45). Yogurt's nutrient density and its contribution to the intake of key nutrients is maintained despite the added sugar content of sweetened yogurts (50). As an excellent source of high-quality protein (from milk), many modern yogurts are further enhanced in protein concentration through manufacturing techniques and the addition of skimmed milk solids (51).

Commercial yogurts are available in a wide range of fat contents, including nonfat and low-fat varieties, which are foods that are promoted in nutritional guidelines as contributing to a balanced diet (47). Despite the popularity of nonfat yogurts, the presence of yogurt lipids has benefits that are often overlooked. Yogurt fat has important organoleptic properties; by maintaining a reasonable amount of fat in yogurt, a reduction in the amount of added sugar can be achieved at the same time that the yogurt remains palatable to consumers (21). The FA profile of yogurt is of particular interest, because it contains SCFAs and medium-chain FAs (10%), as well as CLAs (52), which are thought to confer anticarcinogenic (53), anti-inflammatory (54), and antidiabetic properties (20).

As a fermented product, yogurt has added health benefits over its parent ingredient, milk. Fermentation may increase the bioavailability of nutrients in yogurt, including vitamin B-12, calcium, and magnesium, among others, as well as protein and peptides (especially in Greek-style yogurt), making it ideal for populations with frequent nutrient deficits, and in children and the elderly, who need to develop or maintain their skeletal muscle mass (20, 25). Active bacteria may act as a probiotic, contributing to microbial equilibrium in the host's gastrointestinal tract when it is consumed in sufficient quantities (52). The viability of microorganisms in traditional yogurt remains under dispute (55); however, it continues to be an important vector for added probiotics known to have positive effects on health. The bacterial fermentation of milk to yogurt alters its matrix, improving viscosity, osmolality, and energy density (56), and decreasing pH (57). The unique yogurt matrix results in a longer gastrointestinal

transit time than that for milk, enhancing the absorption of nutrients and reducing gastrointestinal perturbations (58).

Both fruits and yogurt contain an immense variety of bioactive compounds, which may be enhanced or diminished during growth (ripeness), storage, and processing. These minor but sometimes meaningful differences make it very difficult to generalize results when comparing one type of food to all foods in the same category. Furthermore, because of the complex nature of many foods and the fact that foods are not eaten in isolation, it is extremely difficult to ascertain whether potential health benefits are the result of specific foods or compounds within a given food.

### Prebiotic, Probiotic, and Symbiotic Properties

The colonization of the gastrointestinal tract by microorganisms, known as the gut microbiota, creates an important barrier between the environment and the individual that protects against disease (59). The gut microbiota can be enhanced when probiotics, live health-promoting organisms, are ingested in sufficient quantities to remain viable after passage through the gastrointestinal tract (60). On the other hand, prebiotics, which are dietary components—most often nondigestible carbohydrates—that induce the growth and activity of beneficial bacteria, provide fermentable substrate for bacteria in the colon and remain unsusceptible to viability issues during digestion (61). Prebiotics are 100% transferable to the colon, where they can be used to balance the microbiota, thereby providing beneficial systemic effects (62). Both prebiotics and probiotics play a role in modulating the microbiota (63). Research into probiotic foods has established the symbiotic effect of combining probiotic with prebiotic foods (59). Enhancing the health benefits of the microbiota can be achieved with the use of synbiotics, defined by Gibson and Roberfroid (62) as “a mixture of probiotics and prebiotics that beneficially affects the host by improving the survival and implantation of live microbial dietary supplements in the gastrointestinal tract, by selectively stimulating the growth and/or by activating the metabolism of one or a limited number of health-promoting bacteria” (62).

All species of the *Lactobacillus* genus are known to inhibit the growth of pathogenic bacteria, stimulate immune function, and enhance the bioavailability of food ingredients and minerals, including *L. delbrueckii* subspecies *bulgaricus*, typically used in traditional yogurt. Only some species of the *Streptococcus* genus, such as *S. thermophilus*, also found in traditional yogurt, are probiotic. In the book “The Prolongation of Life,” by Nobel Prize-winner Elie Metchnikoff (64), yogurt containing *Lactobacilli* was identified as being able to reduce pathogenic bacteria in the gut, thereby leading to greater longevity (65). However, yogurt bacteria are sensitive to degradation during processing, as well as passage through the acidic environment of the stomach, and need to be viable to be considered probiotic, generally requiring administration of 1–100 million CFU/g food (66). Commercially produced yogurts generally provide adequate concentrations of probiotics in the range of 10 million to 10 billion CFU/g food for a given serving of yogurt



between 125 and 250 ml (65). The benefit of consuming yogurt with fruit is the potential for prebiotics in fruit to help maintain the viability of probiotic bacteria in the yogurt, as well as providing an additional substrate for enhanced activity once they reach the colon (62, 67). Prime prebiotic candidates contain fructo-oligosaccharides (62) and can be found in fruits such as bananas, nectarines, and raspberries (59, 68). In addition, polyphenol-rich fruits can exert prebiotic effects, as evidenced by Anhe et al. (37); a polyphenol-rich cranberry extract administered to animals fed a high-fat, high-sugar diet resulted in a shift in the microbiota toward a marked increase in the relative abundance of *Akkermansia* (37).

In synbiotics, *Lactobacilli* are commonly used as the probiotic component (67), whereas oligosaccharides such as fructo-oligosaccharides are frequently used as the prebiotic component (67). Synbiotics largely have been examined in the context of foods modified through the addition of functional probiotic and/or prebiotic ingredients (69, 70), and not whole, minimally-processed food combinations. The food matrix plays an important synergistic role in enhancing probiotics by providing nutrients in addition to a carrier for delivery into the gut (66), yet food combinations with symbiotic properties have not been examined specifically.

### Epidemiologic Studies: Fruit, Yogurt, and Cardiometabolic Health

Food combinations such as yogurt and fruit have the potential to affect DRD prevention, particularly in developed countries, by offering nutrient-dense (Figure 1), lower-energy alternatives in place of typical nutrient-poor snacks such as desserts and cookies (71). Some epidemiologic evidence illustrates lower all-cause mortality in people who consume high amounts of fruit (72) and yogurt (73). Generally, there is very strong support for the health benefits of fruit consumption in chronic disease prevention (18). Although there is an increasing number of publications relating yogurt to health markers, the case for yogurt in DRDs is less established than that of fruit. Nevertheless, increasing the intake of both fruit and yogurt is among the strategies listed by Mozaffarian (74) as being key dietary evidence-based priorities for cardiometabolic health. Furthermore, there is broad scientific consensus on the benefits of both fruits and yogurt with respect to cardiometabolic health (74). Taken together, dietary pattern analysis suggests that yogurt and fruit are common indicators of healthy dietary patterns that are protective against weight gain (75), T2D (76), and CVD (74, 77).

**Weight gain and obesity.** Both yogurt and fruit have been identified as protective against weight gain (75). Results from examinations 5–8 of the Framingham Heart Study Offspring Cohort (1991–2008) found that participants who consumed yogurt regularly (i.e.,  $\geq 3$  times/wk) had a smaller annual weight gain and waist circumference increase than those consuming  $< 1$  serving/wk (78). A review on yogurt and weight management examined 5 observational studies and found inconsistent results between studies with regards to yogurt's association with BMI, waist circumference, and

sex (79). The Spanish Seguimiento University of Navarra (SUN) cohort was followed for a mean of 6.6 y, and those who had high total and whole-fat yogurt intake had a lower incidence of overweight or obesity. The inverse relation between low-fat yogurt intake, risk of weight gain, and risk of overweight and obesity was only true for participants who also had a high intake of fruit (80). Epidemiologic studies indicate that there are significant associations between yogurt consumption and lower BMI, body weight, body weight gain, and body fat, and smaller waist circumference. However, well-designed randomized clinical trials have yet to provide proof of a cause-effect relation (23).

Current findings suggest that an increased intake of yogurt and fruits reduces the intake of high-calorie foods (81). The influence of yogurt against weight gain may be attributed to the changes in colonic bacteria from the ingestion of abundant yogurt probiotics (75), whey, casein, and bioactive peptides (78). Yogurt consumption may enhance the proportion of beneficial gut microbiota that are thought to be involved in weight maintenance via regulation of energy uptake and extraction (82). In addition, the high fiber content of fruit is purported to increase satiety (75). Fruits are low in energy density and high in fiber and water, a combination that contributes to satiety and helps with weight control (29, 83). Despite expectations that high fruit and vegetable intake is inversely related to adiposity, supporting evidence is weak (84). A systematic review and meta-analysis found only 2 studies that met all criteria and an additional 5 studies meeting all but one criterion. The review did not find any associations between fruit and vegetable intake and weight loss or obesity prevention among these 7 studies (85).

**T2D.** In recent years, there have been numerous high-quality epidemiologic studies and meta-analyses linking fruit and yogurt consumption to a lower incidence for T2D. A Spanish study that followed  $> 3000$  nondiabetic individuals for a mean of 4.1 y found that total yogurt consumption was associated with lower T2D risk after multivariate adjustments for sociodemographic, lifestyle, and dietary factors (20). This study further found a reduced risk of T2D after dietary modeling that replaced commonly consumed sweet snack foods with a serving of yogurt. A British study involving 11 y of follow-up with a subsample of the European Prospective Investigation into Cancer and Nutrition–Norfolk study found a lower risk of T2D with high intake of low-fat fermented dairy foods, mostly with yogurt (19). Similarly, a pooled analysis of 3 large American cohorts (the Health Professionals Follow-Up Study, the Nurses' Health Study, and the Nurses' Health Study II) consistently showed an inverse association between yogurt and T2D risk (10). A meta-analysis that included 7 yogurt studies investigated the association between dairy intake and T2D, revealing a marginally lower risk in the group of consumers of the highest amount of yogurt than in the group consuming the lowest amount (86). Chen et al. (10) updated this meta-analysis with an additional 7 studies, including 3 large cohorts, and found that 1 serving yogurt/d was associated with an 18% lower risk of incident T2D.

For fruits, the evidence for T2D risk has been less clear. A large cross-European prospective study involving 8 countries through the European Prospective Investigation into Cancer and Nutrition–InterAct did not find any significant associations between fruit intake and T2D risk (87). Similarly, this updated meta-analysis did not note any significant associations between fruit intake and T2D risk. However, this analysis only included 5 studies, which were found to have high heterogeneity, mainly attributed to differences in dietary measures (87). A subsequent meta-analysis of 10 studies did not find any heterogeneity for fruits and concluded that there was a significantly lower risk of T2D with high fruit intake (88). A recent meta-analysis investigating the dose-response of fruit and vegetable consumption found a nonlinear relation between T2D and fruit intake, with the highest reduction in risk being attributed to an intake of two to three 106-g portions/d (11). Given the strength of current evidence, it would be reasonable to speculate that consuming combinations of yogurt and fruit could be beneficial for T2D prevention.

**CVD.** Among DRDs, CVD is a major cause of morbidity worldwide, including in developing nations. It accounts for as high as 23% of deaths in these countries and is the leading cause of death in the United States (89). Low fruit and vegetable consumption is an important risk factor for DRDs (90). It is believed that dietary interventions that promote increased consumption of fruits and vegetables could lead to an important decrease in mortality from CVD (89, 91).

Evidence about the protective effect of fruits and vegetables on cardiovascular health is particularly strong and consistent. The effects of fruits on CVD alone may, however, appear muted. Six prospective cohort studies were examined in a dose-response meta-analysis and found a borderline significant inverse association between CVD mortality and fruit consumption (72). A subsequent meta-analysis examining the association between fruit and vegetable consumption and CAD identified 15 studies with 25 dose-response reports that compared low and high intake of fruit and CAD risk. Of these studies, 6 reported strong inverse relations; pooled analysis revealed a 16% reduction in CAD risk associated with an intake of 300 g fruit/d (91). Several attributes of fruit are credited with heart-protective properties, including nutrient and phytochemical content (e.g., fiber, potassium, and folate), low dietary glycemic load, and energy density (89). Fruits with a high polyphenol content (e.g., berries and grapes) have further heart-protective attributes via mechanisms that have the potential to decrease blood pressure, platelet activation, inflammation, oxidative stress, and LDL oxidation while increasing endothelial function and the HDL-to-LDL ratio (35). Given that dairy products appear to have a beneficial effect on CVD (92), yogurt has the potential to have similar effects. However, too few CVD studies have isolated yogurt consumption from total dairy consumption, making it difficult to draw conclusions. In a meta-analysis that examined the relation between dairy intake and the risk of stroke, CAD, and CVD, no significant relations

were observed between yogurt consumption and stroke ( $n = 3$  studies) or CAD ( $n = 5$  studies). Similarly, with too few studies and no meta-analyses, the relation between yogurt consumption and hypertension remains unclear amid findings demonstrating positive (93), null (94, 95), and inverse (96, 97) relations.

### Challenges and Future Directions

Data on dietary combinations may be difficult to obtain, given that common dietary data collection tools such as FFQs generally are not designed to capture this type of information. FFQs often are used because of their easy application and low cost. The data generated from these tools are generally representative of predefined groups of food items and total daily consumption of nutrients. Although this type of dietary data collection is adequate for most study objectives, it is inflexible and may provide less information than repeated 24-h recalls and food diaries, particularly with regard to eating episodes (98). Tools such as 24-h diet recalls and food diaries can capture meal-by-meal and snack-by-snack information, but analysis of dietary data might not be conducted in a manner that allows foods to be grouped together at specific eating episodes. These collection tools were not designed to capture, enter, and collate information on food combinations. Although epidemiologic studies have provided the best evidence linking dietary measures to health outcomes, they may not be the most appropriate to test the concept of beneficial food combinations. The isolated effects of potential synbiotic food combinations (fruit and yogurt) on predetermined outcomes (glucose metabolism, FA metabolism, antioxidant profiles, and microbiota diversity) can be tested with the use of carefully designed placebo-controlled clinical trials.

Determinants of food choice are based on availability, sensory preferences, satiety, and social transmission (30). Fruits are widely available regardless of season or proximity to harvesting location; a large variety of common and exotic fruits can be found in and out of season in Westernized countries (27). Both yogurt and fruit have a relatively low cost per kilo compared with other animal-based foods (99). However, despite the widely available nature of fresh fruits, their affordability is still a barrier to some (100). Lifestyle factors are important contributors to dietary choices. Socioeconomically disadvantaged women tend to have a lower intake of both fruit and yogurt and poorer diet quality than their more privileged peers (101). In one study, active boys and girls consumed more fruits than their sedentary peers and girls also consumed more yogurt (102). Inverse associations between yogurt and DRDs have been hypothesized to be partially linked to the likelihood that yogurt consumers lead more healthy lifestyles (24). Public health agencies promote canned fruits in place of fresh fruits when accessibility or price are barriers; however, alarm has been raised over the appropriateness of these recommendations, given recent findings associating the frequent consumption of canned fruit to cancer (103). Fruits are generally sweet and respond to innate taste preferences (26), likely making them more palatable

than certain vegetables. Although fruit is low in energy density, its fiber and water content give it satiating properties (83). Finally, fruits and yogurt are generally positively viewed (100), giving them high social transmission potential. According to the determinants of food choice, both fruit and yogurt would be selected and consumed readily by individuals who are given appropriate means and accessibility. However, it is unclear whether current recommendations for fruits, vegetables, and dairy products are in fact sustainable, should the majority of the population begin to eat according to dietary guidelines (104).

The intake of fruits, vegetables, whole grains, milk products, and seafood is suboptimal in the American diet, resulting in specific nutrients of concern: potassium, dietary fiber, calcium, and vitamin D (105). Consuming yogurt and fruits in combination regularly would assist in increasing the intake of all the nutrients of concern, helping close nutrient gaps. Yogurt is concentrated fermented milk, making it a nutrient-dense macro- and micronutrient source, as well as a potentially high source of energy. This is particularly important when considering foods for populations that are vulnerable to malnutrition. For example, the elderly often have suboptimal protein and energy intake, and yogurt is a viable source of nutrients for this population in a concentrated format that is less expensive than most commercial nutrient supplements. In addition, yogurt is an excellent source of vitamin D, calcium, and magnesium, nutrients that are important for maintaining bone health and preventing fractures in the elderly (106). Specific dietary patterns combining a variety of foods are known to be protective against DRDs. The prudent dietary pattern, which includes fruit and yogurt intake among its attributes, was strongly associated with a lower risk of both CVD mortality and all-cause mortality (107). The Mediterranean diet, characterized in part by high fruit and vegetable intake and moderate dairy intake, has been known to have anticancer and antiobesity health properties (108).

## Conclusion

To our knowledge, the synbiotic properties of combining foods such as yogurt and fruit have never been examined. Separately, both groups of foods are nutrient dense and have demonstrated protective associations against DRDs in epidemiologic studies. There is reasonable evidence to suggest that, in combination, the probiotic properties of yogurt and prebiotic properties of fruit warrant examination. In practice, foods more often are eaten in combinations in meals and snacks rather than individually, and in countries in which dairy products, fruits, and vegetables are consumed in suboptimal quantities, interventions that promote a combined intake of these food groups would be of added value to encourage the consumption of healthy foods that are associated with both healthy dietary patterns and lifestyles. Given that public health nutrition has had little success with increasing the intake of fruits and vegetables to optimal levels, marketing breakfast or snack combinations such as yogurt and fruits that require little preparation is a worthwhile strategy

for DRD prevention, particularly T2D. However, the validation of the specific synergistic benefits of combining foods is needed. Finding solutions to ensure that these specific food combinations are affordable and accessible year-round is particularly important to equitable DRD prevention.

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