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Busra Baspinar & Metin Güldaş

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REVIEW

# Traditional plain yogurt: a therapeutic food for metabolic syndrome?

Busra Baspinar[a] and Metin Güldaş[b]

[a]Nutrition and Dietetics, Ankara Universitesi, Ankara, Turkey; [b]Nutrition and Dietetics, Uludag University, Görükle, Bursa, Turkey

**ABSTRACT**

Dairy products have an important role in a healthy diet due to their high-quality protein and rich micronutrients. Yogurt, a fermented milk product, has a similar composition to milk but is a more concentrated product in terms of group B vitamins, minerals, and proteins. It is known that bioactive metabolites and live enzymes that occur by fermentation and digestion, affect the health positively by improving gut microbiota. In recent years, the prevalence of metabolic syndrome, which threatens public health, is increasing rapidly. As with other noninfectious diseases, the diet has an important effect on the prevention and treatment of metabolic syndrome. It has been demonstrated that yogurt has a high-quality amino acid pattern, reduces energy intake by stimulating satiety, and regulates blood glucose level. In addition to the rich protein variety, yogurt also contains peptides that positively affect blood pressure. Unlike milk, increased acidity during the fermentation of yogurt positively affects calcium absorption. Calcium plays an important role in the control of blood glucose and energy metabolism through insulin-dependent and non-insulin-dependent routes. In addition to reducing inflammation, calcium has a positive effect on the regulation of the blood lipid profile by increasing fecal fat excretion. There are many lipid and lipoid nutrients such as saturated fatty acids, phospholipids, sphingolipids, and conjugated linoleic acid that may affect the blood lipid profile in yogurt positively or negatively. There are seen very few randomized controlled studies that are focused on the relationship between yogurt and metabolic syndrome, and these are based on contradictory results. In this review, based on the clinical studies conducted to date, and the nutrient content of yogurt, possible mechanisms of these contradictory results are investigated.

**KEYWORDS**
Bioactive peptides; dairy products; metabolic syndrome; micobiota; type-2 diabetes mellitus; yogurt

## Introduction

Metabolic syndrome (MetS) can be defined as a health problem resulting from the common effect of risk factors that increase an individual's potential for developing chronic disease. MetS is characterized by cluster of several metabolic disorders such as abdominal obesity, elevated blood pressure, hypertriglyceridemia, impaired glucose tolerance and low HDL (high-density lipoprotein) cholesterol (Alberti Zimmet, and Shaw 2005); additionally causes the risk of cardiovascular disease and related mortality (Bonaccio, Iacoviello, and De Gaetano 2012; Feldeisen and Tucker 2007). Metabolic syndrome is a disease that its prevalance increases rapidly all over the world (Saklayen 2018; Sigit et al. 2020) and it is clear that diet and lifestyle are very significant factors in the prevention and the treatment of this disease (Lanktree and Hegele 2017; M. K. Lee et al. 2020; Xu et al. 2019).

In recent years, functional foods are also defined as "superfoods", are added into the diet and thus, it is expected to reduce the risks of some diseases (Proestos 2018). There are various food products among the superfoods including dairy products, kefir and yogurt (van den Driessche, Plat, and Mensink 2018). Milk and dairy products which important part of the healthy diet supplying high quality protein and micronutrients (Astrup 2014; Fernandez et al. 2017). In the past, dairy product consumption has been thought that, is one of the risk factors for cardiovascular diseases and can cause negative effects on health due to their saturated fatty acid content (Lordan et al. 2018).

However, this claim is broken anymore; because dairy products contain functional components (phospholipids, milk proteins and calcium e.g.) with high nutritional value (Table 1), that can act to lower the risk of cardiovascular disease via lipoprotein metabolism, and health benefits, e.g probiotic effects (Buttriss 1997; Şanlier, Gökcen, and Sezgin 2019; Wang et al. 2013). In recent years, it has been found that consumption of dairy products did not lead to cardiovascular diseases, contrarily affects positively (Astrup 2014; Fernandez et al. 2017; Hidayat et al. 2020; Lordan et al. 2018).

In addition, dairy products have been determined to have positive effects on diabetes, obesity and metabolic syndrome (Fernandez et al. 2017; R. A. Gibson et al. 2009; Mazidi et al. 2019; Sonestedt et al. 2011). However, there are also studies stated that may have negative effects and no clear results have been obtained yet (Beydoun et al. 2018; Mena-Sánchez et al. 2018). These different results are thought to be due to the fact that various dairy products have different

CONTACT Busra Baspinar busrabaspinar92@gmail.com Nutrition and Dietetics, Ankara Universitesi, Ankara 06340, Turkey.
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**Table 1.** Nutrient compositions of yogurts with different fat content.

| References | g / 100 g yogurt | Yogurt, whole milk | Yogurt, low fat | Yogurt, nonfat |
|---|---|---|---|---|
| (Chandan 2017; Moore, Horti, and Fielding 2018; USDA, 2019) | Protein, g | 3,47-5,40 | 5,25 | 3,60-5,73 |
| | Fat, g | 1,70,3,50 | 1,55 | 0,10-0,18 |
| (USDA, 2019) | Saturated fatty acids, g | 2,096 | 1,0 | 0,116 |
| | Monounsaturated fatty acids, g | 0,893 | 0,426 | 0,049 |
| | Polyunsaturated fatty acids, g | 0,092 | 0,044 | 0,005 |
| (Florence et al., 2009; Serafeimidou et al., 2012;Serafeimidou et al., 2013) | CLA, mg/ 100 g fat | 2,40-16,50 | 0,13-1,16 | – |
| (USDA, 2019) | Cholesterol, mg | 13 | 6 | 2 |
| (Chandan 2017; Moore, Horti, and Fielding 2018; USDA, 2019) | Carbohydrate, g | 4,66-5,50 | 7,04 | 5,10-7,68 |
| | Ash, g | 0,70-0,72 | 1,09 | 0,70-1,18 |
| (USDA, 2019) | Vitamin A, RAE, mcg | 27 | 14 | 2 |
| | Thiamin, mg | 0,03 | 0,04 | 0,05 |
| | Riboflavin, mg | 0,14 | 0,21 | 0,23 |
| | Niacin, mg | 0,08 | 0,11 | 0,12 |
| | Folate, mcg | 7,0 | 11,0 | 12,0 |
| | Vitamin $B_{12}$, mcg | 0,37 | 0,56 | 0,61 |
| | Vitamin K, mcg | 0,2 | 0,2 | 0,2 |
| | Calcium, mg | 121,0 | 183,0 | 199,0 |
| | Iron, mg | 0,05 | 0,08 | 0,09 |
| | Phosphorus, mg | 95,0 | 144,0 | 157,0 |
| | Potassium, mg | 155 | 234 | 255 |
| | Zinc, mg | 0,59 | 0,89 | 0,97 |
| | Copper, mg | 0,01 | 0,01 | 0,02 |

CLA: Conjugated Linoleic Acid, RAE: Retinol activity equivalents.

degree of processing (such as plain yogurt, flavored or sweetened yogurt) (Jørgensen et al. 2019), compositions, concentration, and properties (Sonestedt et al. 2011).

As a resut of the previous researches, it has recommend that fermented dairy products should be evaluated seperately due to their different health benefits (Fernandez et al. 2017; Mazidi et al. 2019; Sonestedt et al. 2011). As a fermented milk product, yogurt has been proved to have beneficial effects on obesity (Bridge et al. 2019; Panahi et al. 2019), glucose metabolism (Gijsbers et al. 2016; Watanabe et al. 2018), lipid metabolism (Astrup 2014; Buendia et al. 2018; Cormier et al. 2016). Considering these beneficial effects, the effect of yogurt on metabolic syndrome, which threatens public health, has begun to be investigated in recent years. In this study, the effects of yogurt on MetS and concerning mechanisms are reviewed.

## The relationship between yogurt consumption and metabolic syndrome

There are various milk products as fermented and non-fermented milk products. Each milk product has different characteristics and nutrient content (Sonestedt et al. 2011). Especially fermented dairy products, in addition to their chemical characteristics and rich nutrients (Table 1), they have number of mechanisms and interactions that consist of biochemical and microbiological processes. Because of this complex processes occured during the fermentation, new metabolites are composed and affect positively in prevention or to lower the risk of some significant chronic diseases such as cardiovascular diseases, diabetes and cancer (Fernandez et al. 2017; Gibson et al. 2009; Mazidi et al. 2019; Sonestedt et al. 2011; Song et al. 2017).

The qualitative nutrient composition of yogurt is similar to the cow milk, however quantitative distrubution of yogurt constituents are higher than the milk used due to the process steps such as evaporation, dry matter standardization and heat treatment (pasteurization). These process steps cause to evaporate water of milk and rest of the constituents were already solved in the water part, become concentrated. Therefore, the content of some micronutrients such as riboflavin, vitamin B12, calcium, magnesium, potasium, zinc etc. and macronutrients protein e.g. are much higher than its raw material milk (Buttriss 1997; Şanlier, Gökcen, and Sezgin 2019; Wang et al. 2013). In addition to its abundant nutrient composition; yogurt is a fermented milk product that is made by using some starter cultures. It can contain some other beneficial microorganism depending on the region, production method and the milk type (cow, buffalo, goat etc) (Table 2). So, it may contain various microbiological metabolites that can contribute to probiotic effect concerning gut microbiota in the gastrointestinal tract, when it is consumed (Noorbakhsh et al. 2019). Group B vitamins, conjugated linoleic acid (CLA), bioactive peptides, c-aminobutyric acid are some of those metabolites (Fernandez and Marette 2018; Pei et al. 2017). The matrix of dairy products, fermentation process, bioactive metabolites such as peptides and exopolysaccarides that are secreted during the fermentation and the active enzymes, have been thought to responsible from health benefits of yogurt (Fernandez and Marette 2018).

Health benefits of yogurt have been intensively studied in recent years (Fernandez et al. 2017). According to epidemiological studies, it has been mentioned that yogurt has beneficial effects on cardiovascular diseases (Astrup 2014; Buendia et al. 2018; Cormier et al. 2016), Type-II diabetes mellitus (DM) (Gijsbers et al. 2016; Watanabe et al. 2018) and body weight and composition (Bridge et al. 2019; Panahi et al. 2019).

Based on these positive effects of yogurt, the effects on MetS, which significantly increases the risk of mortality (Bonaccio, Iacoviello, and De Gaetano 2012; Feldeisen and Tucker 2007), have been discussed in recent years (Table 3). In the cohort study conducted by Beydoun et al. (Beydoun

**Table 2.** Beneficial bacterias isolated from traditional plain yogurt.

| References | Yogurt bacterias |
|---|---|
| (EFSA. European Food Safety Authority, 2010) | *Lactobacillus delbrueckii ssp. bulgaricus* (*Lactobacillus bulgaricus*) |
| | *Streptococcus salivarius spp. thermophilus* (*Streptococcsuc thermophilus*) |
| (Özer, Akin, and Özer 2005) | *Bifidobacterium bifidum* |
| (Aryana and Mcgrew, 2007) | *L. casei* |
| (Paseephol and Sherkat, 2009) | *L. casei* LC-01 |
| (Capela et al., 2006) | *L. rhamnosus* |
| (Shah, 2007) | *L. rhamnosus GG* |
| | *Bifidobacterium animalis BB12* |
| (Khorasgani and Shafiei, 2017) | *L. acidophilus* |
| | *Leuconostoc mesenteroides ssp. cremoris* |
| (Ebrahimi et al., 2011) | *L. brevis* |
| (Zadeh et al., 2014) | *L. fermentum* |
| (Yamamoto, Maeno, and Takano 1999) | *L. helveticus* |
| (Chandan 2017) | *L. lactis* |
| (Islam et al., 2012) | *L. paracasei ssp. Paracasei* |
| (Motahari, Mirdamadi, and Kianirad 2017) | *L. pentosus* |
| (Madhu, Amrutha, and Prapulla 2012) | *L. plantarum* |
| (Ruas-Madiedo et al., 2002) | *L. lactis ssp. Cremoris* |
| (Hill et al., 2017) | *L. casei Shirota* |
| | *L. reuteri DSM 17938* |
| ( Dallal et al., 2016) | *Pediococcus acidilactici* |

et al. 2008) every 100 g yogurt consumption per day was associated with a 2–2.5-fold decrease in the risk of obesity, waist circumference and MetS prevalence. Recently, in a meta-analysis showed that the risk of MetS was reduced by 18% with every 100 g of yogurt added to the daily diet (M. Lee, Lee, and Kim 2018).

In the large-scale cohort study conducted in USA, the consumption of yogurt have been demonstrated to affect all components of Mets, positively (Wang et al. 2013). Similarly, in a cross-sectional study conducted on 4862 Korean, it has been associated that the risk of MetS and the level LDL were decreased, when the amout of yogurt was elevated in the daily diet (J. Kim 2013). In addition to the rich nutrient content of yogurt, this beneficial effect can be attributed to their adoption as a healthy lifestyle, although dairy products are not included in the traditional diet of Korea. In supporting this, another study conducted in Korea, higher yogurt consumption was associated with lower risk of MetS (D. Kim and Kim 2017). In the cross-sectional study conducted on 973 adults in Iran by Falahi et al. (Falahi et al. 2016), plasma high triglyceride level was decreased by consumption of yogurt with full fat, while risk od abdominal obesity and fasting blood glucose level was decreased by consumption of yogurt with low fat.

In a 3-year follow-up study in Spain, higher consumption of yogurt (total, whole-fat and low-fat) were found to be associated with a lower incidence of MetS. However, it has been reported that only low-fat consumption of other dairy products has beneficial effects. The strong correlation between cheese with other fermented products and MetS has been detected, too. In the study, it has been expressed that this benefial effect of yogurt can be related with the high content of calcium and bioactive peptides in yogurt and its effects on the gut microbiota (Babio et al. 2015).

There are also some studies that no significant correlation between MetS and yogurt consumption has been observed (Beydoun et al. 2018; Mena-Sánchez et al. 2018; Sayón-Orea et al. 2015). In a study, only central adiposity as one of the MetS criteria has been found to relate inversely with the high yogurt consumption (Sayón-Orea et al. 2015). It has been thought that the different consequences obtained in the same country, have been affected by different age ranges investigated and certain age groups have lower MetS risk. In the study of Mena-Sánchez et al. (Mena-Sánchez et al. 2018), no association between yogurt consumption and Mets' criteria has been seen, although yogurt increased diet quality due to its beneficial nutrients. Even, in another study, the positive association between yogurt consumption and abdominal obesity has been expressed (Beydoun et al. 2018).

There have been detected some problems in the studies focused on the relation between MetS and yogurt consumption. MetS is a disorder that is caused by more than one reason. These various criteria lead to difficulty for interpretation of the results and standardization of the research methods, in addition to yogurt's rich nutrient composition leading various complex reactions (Figure 1). In order to understand the effects and mechanism of yogurt on metabolic syndrome, it is necessary to consider the rich nutritional composition of yogurt.

## Yogurt composition

The composition of yogurt is mainly changed according to the variety of milk used. Additionally, its nutrient profile can be influenced by number of parameters such as the use of different lactic acid bacteria (Gómez-Gallego et al. 2019) region, season, climate and sort of animal feed was consumed (Verdú, Barat, and Grau 2019). For example, it has been determined that deficiencies of folate and B12 vitamins can be prevented with regular yogurt consumption (Adolfsson, Meydani, and Russell 2004). Moreover, it is argued that yogurt matrix also increases lactose and calcium absorption (Morelli 2014; Parra et al. 2007; van den Heuvel, Schoterman, and Muijs 2000)

**Table 3.** Characteristics of studies investigating relationship between yogurt consumption and MetS and its components

| Authors (year) | Country | Study design | Gender | Age range or mean | Participants | Diagnosis criteria | Adjustments | Results | Categories of exposure |
|---|---|---|---|---|---|---|---|---|---|
| (Beydoun et al. 2008) | USA | Cross-sectional study | Both | >18 years | 4519 | NCEP-ATPIII | Age, sociodemographic factors, energy intake, physical activity | Each serving of yogurt was associated with a 2- to 2.5 fold reduction in the prevalence odds of obesity, central obesity and MetS. | N/A |
| (J. Kim 2013) | Korean | Cross sectional | Both | >19 years | 4862 (1993 male, 2869 female) | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Age, gender, education level, income, smoking status, body mass index, alcohol intake, physical activity, energy intake, fat intake, calcium intake and fibre intake | High yogurt consumption was associated with higher HDL cholesterol and 29% lower risk of MetS compared to low consumption. | None or rarely, ≤2-3 per month, ≤4-6 per week, ≥once per day |
| (Falahi et al. 2016) | Iran | Cross-sectional | Both | 18-75 y | 1009 (273 male, 736 female) | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Age, gender, cigarette smoking, physical activity, and history of diabetes and heart disease; BMI; energy intake; milk and cheese intake. | High fat yogurt consumption was associated with lower risk of high triglyceride concentration. Low-fat yogurt consumption was associated with a lower risk of abdominal adiposity and fasting plasma glucose. | N/A |
| (Mena-Sánchez et al. 2018) | Spain | Cross-sectional study | Both | Mean age 65 | 6572 | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Gender, age, education level, physical activity, BMI, smoking habit, total energy intake, Mediterranean 17 points questionnaire and use of hypoglycemic, hypolipidemic, antihypertensive, and insulin treatment. | Yogurt was not associated with any of the components of the MetS. | N/A |
| (Wang et al. 2013) | USA | Cohort study | Both | 19-89 y | 6526 | N/A | Age, gender, smoking status, PAI score, total energy intake, DGAI score, BMI, and the use of corresponding dietary supplement | Yogurt consumption was inversely associated with all of the MetS components. | Consumer, nonconsumer |
| (D. Kim and Kim 2017) | Korean | Cohort study | Both | 40-69 y | 5510 (2859 male, 2651 female) | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Age, gender, BMI, residential location, educational level, household income, smoking status, alcohol intake, and physical activity; model 2: further adjusted for nutrient intakes such as energy and energy-adjusted Ca and fibre. | Increased consumption (≥4 servings/week) of yogurt was associated with a lower incidence of the MetS. | None, <1, 1-<4, 4-7, >7 servings/week |
| ( Van Meijl and Mensink, 2011) | The Netherlands | Crossover | Both | Mean age 49.5 y | 35 healthy subjects (BMI > 27 kg/m2) (10 male, 25 female) | N/A | N/A | Consumption of low fat milk and yogurt was not associated with metabolic syndrome component except for systolic blood pressure. | 500 mL low-fat milk and 150 g low-fat yogurt/day for 8 weeks |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ( Dugan, Barona, and Fernandez 2014) | USA | Crossover | Both | Mean age 54.1 y | 37 (14 male, 23 female) adults with MetS | NCEP-ATPIII | N/A | Three dairy servings/day has provided small but significant improvements in a metabolic syndrome population. | 300 mL of 1% milk, 175 mL of nonfat yogurt, 100 g of 2% cheese |
| (Sayón-Orea et al. 2015) | Spain | Longitudinal study | Both | 20-90 y | 8063 | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Age, gender, baseline weight, total energy intake, alcohol intake, soft drinks, red meat, French fries, fast food, Mediterranean diet, physical activity, sedentary behavior, hours sitting, smoking status, snacking between meals, following special diet | All components of MetS except for central adiposity were not significantly associated with high yogurt consumption ($p > 0.01$) | 0-250 g (0-2 servings), $>250$ to $<875$ g ($>2$ to $<7$ servings and $\geq 875$ g ($\geq 7$ servings) per week |
| (Babio et al. 2015) | Spain | Longitudinal study | Both | 55-80 y | 1868 | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Gender, age (years), physical activity, BMI, smoking status; hypoglycemic, hypolipidemic, antihypertensive, and insulin treatment at baseline; Mean consumption during follow-up of vegetables, fruit, legumes, cereals, fish, red meat, cookies, olive oil, nuts, and alcohol; prevalence of MetS components at baseline | All types of yogurt, especially increased consumption of whole fat yogurt was associated with a lower incidence of MetS. However, cheese consumption was associated with an increased risk of MetS. | $\leq 287$, 287-449 and $\geq 450$ g/day |
| (Beydoun et al. 2018) | USA | Longitudinal study | Both | 30-64 y | 1371 | Harmonized criteria (IDF, NHLBI, AHA, WHF, IAS, IASO)* | Age, gender, race, poverty status and education | Yogurt and cheese consumption was associated with an increased risk of central obesity and metabolic syndrome. | N/A |
| (Y. Chen et al. 2019) | China | Randomized controlled trial | Female | 36-66 y | 92 | IDF | Aage, PAL, menopause status, dairy intake and change in energy intake | Yogurt consumption was associated with lower risk of MetS | 220 g yogurt for 24 week |

MetS: Metabolic Syndrome, NHLBI: National Heart, Lung, and Blood Institute, AHA: American Heart Association, IDF: International Diabetes Federation, WHF: World Heart Federation, IAS: International Atherosclerosis Society, IASO: International Association for the Study of Obesity, NCEP-ATPIII: National Cholesterol Education Program Expert Panel (NCEP) and Adult Treatment Panel III, BMI: Body mass index, HDL: High density lipoprotein, PAI: Physical activity index, DGAI: Dietary guidelines adherence index, y: years, PAL: Physical activity level.
* (Alberti et al., 2009).

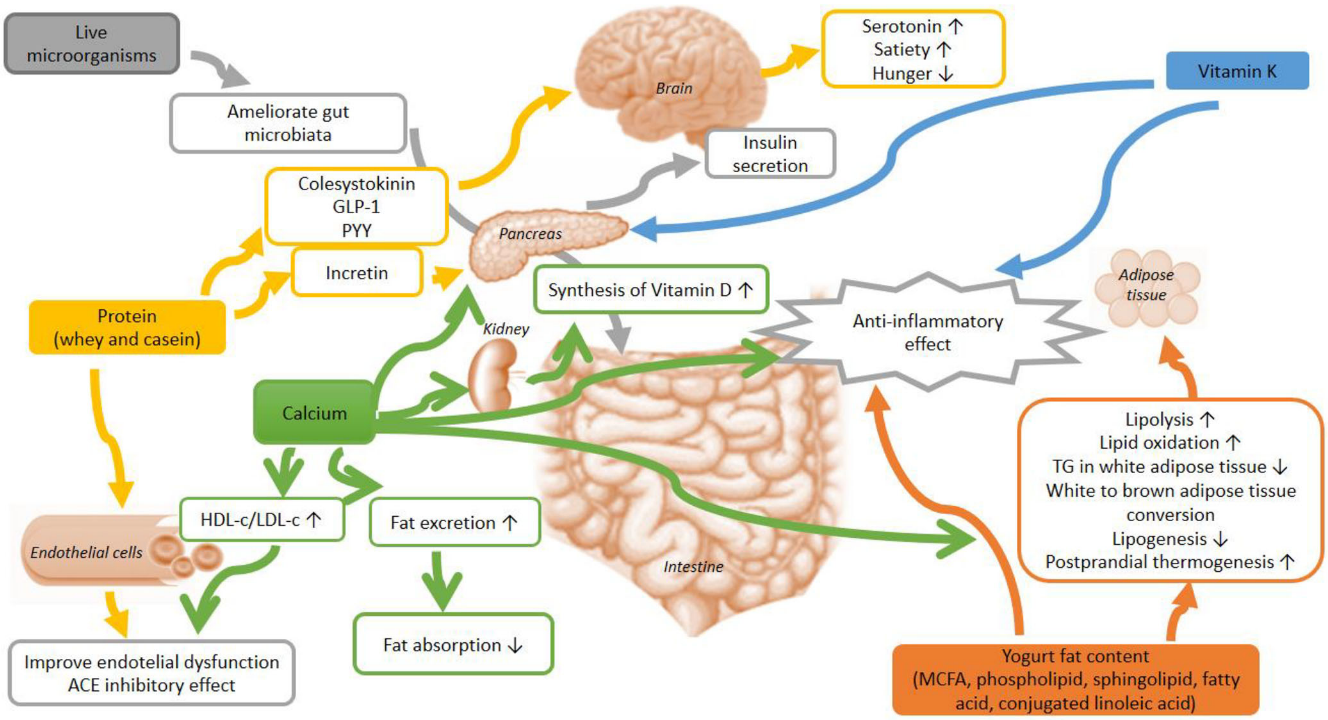


**Figure 1.** The possible effect of yogurt's nutrient content on metabolic syndrome and its components. HDL-c:High Density Lipoprotein; LDL-c: Low Density Lipoprotein; ACE:Angiotensin-converting enzyme; TG:Triglycerides; MCFA:Medium chain fatty acids.

The fat content of yogurt changes between 0.4–3.3% depending of the yogurt type e.g. nonfat or full-fat yoğurt (USDA, 2019) (Table 1). During the yogurt production, water content decreases due to evaporation. Therefore, the content of other nutrients such as protein, vitamin, mineral etc increases. That is why; the nutrient content of yogurt is generally higher than milk. It contains high amount of protein, minerals (calcium) and vitamins (Vitamin B). Some of the vitamins like Vitamin B and pantotenic acid can be used slightly by the yogurt bacteria during fermentation, while folic acid can be produced by the yogurt bacteria, therefore its content can increase slightly (Chandan 2017). The beneficial effects of yogurt on cardiometabolic diseases, obesity, diabetes, and metabolic syndrome are thought to relate with the protein composition, development of a sense of satiety caused by stimulation of the release of the gastrointestinal hormone, and consequently reduced energy intake (Panahi and Tremblay 2016; J. Salas-Salvadó et al. 2017).

## *Milk proteins*

In a study made by Dougkas et al. (Dougkas et al. 2012), yogurt has been consumed by 40 overweight males and found that appetite ratio was decreased significantly. It is thought that the effect of yogurt on satiety is due to its rich protein content. It has been stated that the protein content in the yogurt texture stimulates the release of the gastrointestinal hormones, reduces appetite and thereby short-term food consumption reduces (Fernandez et al. 2017). A large part of the protein content of yogurt consists of whey proteins.

Besides the effect of protein content in yogurt on appetite, protein derivatives that are produced, also have effects (Figure 1). It is stated that the release of aminoacids, plasma cholecystokinin and anorectic peptides such as glucagon-like polypeptide-1 (GLP-1) and peptide YY (PYY) are increased by consumption of whey proteins in the body, thereby stimulates the satiety (Hall et al. 2003; J. Salas-Salvadó et al. 2017; M. Veldhorst et al. 2008). In addition, tryptophan-rich α-lactoalbumin is one of the serum or whey proteins that can increase to serotonin release causing to control food intake (M. A. B. Veldhorst et al. 2009). There has proved that there is a close relationship between serotonin and food intake leading to increase body weight for a long time (Lam et al. 2010). Serotonin is a hormone, which is secreted by the brain signals, inhibits food intake. The deficiency of brain serotonin is a factor that promotes weight gain and hyperphagia (Oussaada et al. 2019).

The whey proteins have also role to prevent metabolic syndrome that is one of the components of diabetes (Dougkas et al. 2012; Fernandez et al. 2017). The small amount of whey protein consumed before a daily meal helps to control appetite and plasma glucose levels through insulin-dependent and non-insulin-dependent pathways (King et al. 2018). Whey proteins affect the release of incretin, one of the gastrointestinal hormones that regulate gastric emptying, increase insulin function (Karamanlis et al. 2007) and secretion (Hidayat, Du, and Shi 2019).

It is believed that the beneficial effects of yogurt on blood pressure are mainly due to milk proteins (Astrup 2014; Fernandez et al. 2017). It is thought that casein and whey proteins, which are found in yogurt, can regulate blood pressure by inhibiting angiotensin, a vasoconstrictor via converting angiotensin-1 to angiotensin-2 (Choi et al. 2012;

Mizuno et al. 2005; Pal and Ellis 2010). In a recent randomized controlled trial; 54 (27 participants in both group) adults with pre and mild hypertension have been given 30 g of whey protein or maltodextrin for 12 weeks. It was reported that the group in which the whey protein is consumed, had improved endothelial function and decreased systolic blood pressure, significantly. It was emphasized that this effect may be due to its positive effects especially on body weight and composition. (J. Yang et al. 2019). In particular, the antihypertensive effects of lactotripeptides as IPP (isoleucine-proline-proline) and VPP (valine-proline-proline) that occur after fermentation and digestion of whey and casein are emphasized (Cicero et al. 2011). In the meta-analysis of randomized controlled studies by Chanson et al. (Chanson-Rolle et al. 2015) IPP and VPP lactotripeptides have been found to reduce systolic blood pressure significantly in all Japanese individuals with and without hypertension.

### Calcium

From another point of view, the positive effect of yogurt on obesity parameters is due to calcium. (Panahi et al. 2018). Calcium in yogurt increases the inhibition of lipogenesis, lipolysis, lipid oxidation, and thermogenesis and thus affects adiposity (Panahi et al. 2018; Zemel 2005). In addition, acidity increases significantly during yogurt fermentation, which is different from other dairy products, and this provides an ideal environment for mineral absorption (Allen 1982; Jeon, Jang, and Park 2019). Calcium in yogurt matrix compared to isolated and taken calcium alone protects other nutrients and bioactive components against degradation (Fernandez et al. 2017; Jacobs, Gross, and Tapsell 2009), and calcium available in yogurt coagulum is absorbed better (Smith et al. 1985). Calcium in the yoghurt matrix is more stable to deteriorate than its independent/free form. Thus, when yoghurt is consumed, calcium can be benefited more than in free form and its bioavailability is higher in yoghurt (Fernandez et al. 2017). The calcium concentration in the blood is not just diet-dependent and is regulated by a hormonal response. Calcium intake affects vitamin D production and hormonal response (Fernandez et al. 2017).

The calcium is a concentrated mineral found in yogurt and is thought to be responsible for its beneficial effects on glucose metabolism. In a meta-analysis conducted in recent years, supporting this, it has been reported that yogurt significantly reduces the risk of Type-2 diabetes (Godos et al. 2020). Calcium affects insulin metabolism by more than one mechanism (Muñoz-Garach, García-Fontana, and Muñoz-Torres 2019; Szymczak-Pajor and Śliwińska 2019). Secretion of insulin is a calcium-dependent process (Llanos et al. 2015; Milner and Hales 1967). Calcium increases insulin release from B-cells (Bartlett et al. 2014; García-Delgado et al. 2018; Mears 2004; Zemel 1998) and modifies cytokines to reduce systemic inflammation (Bartlett et al. 2014; Llanos et al. 2015; Muñoz-Garach, García-Fontana, and Muñoz-Torres 2019); that's why, glucose metabolism can be impaired in hypocalcemic individuals (Pittas et al. 2007).

Although the effects of yogurt on the risks of cardiovascular diseases are controversial; it is obviously seen that calcium has many beneficial effects (Das and Choudhuri 2019; Mert et al. 2018; Umesawa et al. 2006; Zhang et al. 2019).

Although the effects of yogurt on the risks of cardiovascular disease are controversial, the beneficial effects of calcium have been proved with the recent studies (Das and Choudhuri 2019; Mert et al. 2018; Umesawa et al. 2006; Zhang et al. 2019). In a cohort study of 110 792 adults in Japan, it was determined that dietary dairy calcium intake was associated with lower risk of death due to cardiovascular causes (Umesawa et al. 2006). In a randomized controlled trial, in the rats fed on a high-fat diet, it has been determined that inflammation decreased in the group with calcium supplementation (Das and Choudhuri 2019). These beneficial effects of calcium can be attributed to various reason. It is suggested that calcium forms insoluble calcium-fatty acid soaps and increases fecal fat excretion by interacting with fatty acids (Zhang et al. 2019). Therefore, plasma TG concentration decreases as fatty acid absorption is inhibited (Mert et al. 2018). In addition, the ratio of HDL cholesterol to LDL cholesterol is thought to improve with calcium intake (Heshmati et al. 2019).

### Milk fat

In addition to the protein content, the fatty acid content of yogurt also has a significant effect on adiposity. It has been reported that medium-chain fatty acids naturally present in yoğurt (Sumarmono, Sulistyowati, and Soenarto 2015), can increase postprandial thermogenesis (Baba, Bracco, and Hashim 1987), fat oxidation, and energy expenditure (Dulloo et al. 1996), thereby reduce fat accumulation (Schönfeld and Wojtczak 2016).

### Fatty acids, phospholipids and sphingolipids

World Health Organization (WHO) still recommends the consumption of reduced-fat dairy products instead of whole fat ones to limit the intake of saturated fatty acids (such as myristic and palmitic acids) from dairy products (Ada 2020; WHO, 2018; World Health Organization 2003). However, there have been found in many studies that fermented milk products especially have beneficial effects on cardiovascular diseases (Aihara et al. 2005; Anderson and Gilliland 1999; Liu et al. 2019; Ramchandran and Shah 2011).

In a study conducted by Liu et al on Australian elderly people, high total fat and saturated fat from dairy products have found to be associated with higher HDL-C levels and lower TC/HDL-C levels (Liu et al. 2019). In a systematic review and meta-analysis examining 9 cohort studies conducted on 291 236 participants in recent years, the relationship between yogurt consumption and cardiovascular disease have been evaluated. It has been declared that daily consumption of more than 200 g of yogurt has been associated with significantly lower risk of CVD (Wu and Sun 2017). According to the results of the two cohort studies given in this reference Buendia et al. (2018), it has been observed that the individuals who consume 2 or more portions of yogurt weekly have healthier diet patterns and lower risk of cardiovascular diseases.

In a study conducted by Ivey et al. (Ivey et al. 2011) on 1080 participants over 70 years of age living in Western Australia, increased consumption of yogurt was associated with lower common carotid artery intima-media thickness (CCA-IMT). But, in the same study, no effect has been observed if any other dairy products were consumed.

However, there are controversial findings, too. For example, in a meta-analysis, no significant relationship has been reported between yogurt consumption and cardiovascular disease risk (Alexander et al. 2016). Due to these contrasts, the relationship between yogurt and cardiovascular disease has not been clarified, precisely (Lordan et al. 2018). Therefore, possible mechanisms that can cause positive effects are as follows.

The low-grade systemic inflammation has been considered as an important etiological factor in the development and progression of many chronic diseases such as atherosclerosis (Thiagarajan 2019), metabolic syndrome (Huang et al. 2018; Thomas et al. 2018), type 2 diabetes (Everett et al. 2018) and cardiovascular diseases (Nakou et al. 2008). For example, high plasma concentrations of C-reactive protein (CRP) and proinflammatory cytokines TNF-a and IL-6, have been associated with a high risk of cardiovascular disease (Ito and Ikeda 2003; Kelishadi 2010; McLaren et al. 2011). Therefore, in order to explain the potential cardiometabolic protective effects of yogurt, at first, its effects on inflammatory biomarkers are emphasized (Lordan et al. 2018). From this point of view, phospholipids and sphingolipids are lipoid compounds found in milk fat, which are thought to have anti-inflammatory properties (Phan et al. 2016).

In addition, sphingolipids that are present in the dairy fat and bacterial cell walls are thought to be an effective factor to increase level of HDL-C (Fabian and Elmadfa 2006; Kiessling, Schneider, and Jahreis 2002; Vesper et al. 1999). On the other hand, sphingolipids are the compounds that play a role in cholesterol metabolism and transport (Sadrzadeh-Yeganeh et al. 2010). In studies on rats, it has been determined that sphingolipid intake lowers total plasma cholesterol (Imaizumi et al. 1992; Kobayashi et al. 1997).

### Conjugated linoleic acid (CLA)

Conjugated linoleic acid (CLA) is a compound highly found in fats produced by ruminants. It plays a role to modify body composition and cardiometabolic risk factors (Rainer and Heiss 2004). It has been reported that CLA has significant functions to decrease the body fat accumulation, atherosclerosis, and cancer (Yang et al. 2015). It also helps to regulate glycemic profile (Salas-Salvadó, Márquez-Sandoval, and Bulló 2006). In addition, CLA intake could elevate the level of lipolysis and thus, the accumulation of fats in the adipose tissue lowers (Ares-Yebra et al. 2019; Bulut et al. 2013). Moreover, it is thought that it probably causes to provoke some mechanisms that are responsible for reducing the lipase enzyme activity (Virsangbhai et al. 2019).

Milk fat is one of the richest sources of conjugated linoleic acid (CLA) (Chin et al. 1992). However, how CLA in milk is affected by the fermentation process and its related mechanism has not been clarified yet (Fernandez and Marette 2018; Gutiérrez 2016). Due to conjugated linoleic acid, which is a specific fatty acid in milk, it is suggested that yogurt consumption with high-fat content is beneficial on adiposity and therefore in cardiometabolic diseases (Parodi 2016; Sumarmono, Sulistyowati, and Soenarto 2015). Studies in animal models have shown that conjugated linoleic acid increases lipolysis and fat oxidation, leading to fat loss and reducing triglyceride amounts in white adipose tissue (Park et al. 1997, 1999; Yamasaki et al. 1999). In a study on rats, a diet with CLA led to the browning of white adipose tissues and increase energy expenditure (Den Hartigh et al. 2017). In a recent review, it has been stated that adding CLA to an individual's diet has beneficial effects on body weight and body fat parameters without causing any negative metabolic results (van den Driessche, Plat, and Mensink 2018).

### Vitamin K

Another component that indirectly affects glucose metabolism in yogurt is vitamin K; especially fermented milk products contain two vitamin K derivatives, phylloquinone (Vitamin K1) and menaquinone (Vitamin K2) (Manna and Kalita 2016; Walther et al. 2013). Vitamin K is thought to play a role in osteocalcin metabolism, a vitamin K-dependent protein (Li et al. 2018) and thus, improve glucose metabolism (Bourron and Phan 2019; Dahlberg et al. 2019). In a long-term follow-up study conducted by Ibarrola-Jurado et al. (Ibarrola-Jurado et al. 2012), the risk of T2DM has been found to reduce 17% with a daily intake of each 100 mcg of vitamin K. In a recent review, it has been argued that vitamin K has positive effects on dyslipidemia, oxidative stress and inflammation as well as glycemic control (Karamzad et al. 2020).

### Microbial cultures

Gut microbiota is accepted as an important health indicator (Power et al. 2014). The microbiota in the gut not only affect the strength of the immune system but also includes various complex interactions having microbiological, chemical, biochemical and neurochemical pathways. Disruption of gut microbiota is called dysbiosis and this triggers metabolic disorders such as obesity, inflammation, T2DM (Anhê et al. 2015).

Live cultures in yogurt are thought to play a role in maintaining a healthy gout microbiota (Alvaro et al. 2007; Donovan and Shamir 2014; Fernandez et al. 2017; García-Albiach et al. 2008; Ross et al. 2017). Although only 1% of L.bulgaricus and S.thermophilus reach the duodenum, their beneficial effects on health should not be underestimated (Morelli 2014).

Yogurt is a fermented milk product consisting of a network/coagulum that includes kappa casein, beta-lactoglobulin, alfa lactoalbumin, and rod shape yogurt bacteria and their extracellular polysaccharide by-products secreted by these bacteria (Sfakianakis and Tzia 2014) (Table 2).

Fermentation of yogurt and some milk products are conducted by the help of live bacteria that can also be called the starter cultures. In this process; bioactive peptides, bacteriocins, and many metabolites can be produced (Ross et al. 2017) according to the fermentation conditions and variety of milk used. It has been determined that peptides released with traditional yogurt cultures can increase mucin release (Plaisancié et al. 2013). Increased mucin secretion plays a role to protect the intestinal mucosa barrier. Thus, colonization of pathogenic bacteria, high acidity, and mechanical damage are not allowed and the intestinal inflammation is decreased (P. R. Gibson and Muir 2005).

It is argued that consumption of yogurt, can be effective in the prevention or treatment of metabolic diseases by restoring inflammation-induced intestinal barrier dysfunction, which plays a role in the pathophysiology of inflammatory diseases such as obesity (Putt et al. 2017). In a study with rats receiving high-fat diet, it was determined that yogurt supplementation prevented metabolic syndrome by reducing oxidative stress (Lasker et al. 2019). In a recent large-scale study, it has been reported that obese women consuming yogurt have a lower risk of hypertriglyceridemia, and this may be due to improvements in gut microbiota.

In a study conducted by Chen et al. (M. Chen et al. 2014) it has been stated that the gut microbiota of the group consuming yogurt was changed and an improvement in insulin resistance was observed. In a prospective study conducted on 4074 adults, aged between 40–69 by Jeon et al. (Jeon, Jang, and Park 2019), the effects of calcium-containing foods on T2DM were evaluated and it was concluded that only yogurt had positive effects. In this beneficial effect, it has been expressed that the high concentration of protein and other nutrients in yogurt may play a role as well as the presence of living microorganisms.

In an intervention study conducted on 92 obese, women with nonalcoholic fatty liver disease and metabolic syndrome aged 36–66 in recent years; participants have been divided into two groups to be consumed 220 g of yogurt or milk daily for 24 weeks. In the group that was consumed yogurt, it was determined that lipid metabolism, insulin resistance, and fatty liver improved, inflammation and oxidative stress decreased, and the composition of gut microbiota changed, positively (Y. Chen et al. 2019). Apart from the other dairy products, these beneficial findings can be attributed to yogurt that is a fermented dairy product, having a high number of live microorganisms with a high concentration of protein and micronutrients (Gómez-Gallego et al. 2019).

## Conclusion

Yoghurt is a very healthy fermented milk product that has high protein content with high protein quality. It has been seen that beneficial effects of yoghurt on MetS have been correlated with its calcium, conjugated linoleic acid, live microorganisms, whey proteins and casein. According to the literature survey, positive effects of yoghurt on MetS have found to relate the various factors such as study design, differences among the target populations, amount of yoghurt consumed by the test individuals, milk type (cow milk yoghurt, buffalo milk yoghurt and sheep milk yoghurt) and fat content (full fat, semi-fat and skimmed yoghurt) of yoghurt. The controversial results can probably be related to these factors their study design used in the previous studies.

However, the general consideration obtained from the literature is that yoghurt improves diet quality significantly, suppress the appetite that helps to obesity control, and regulates glucose metabolism. In spite of the low level of saturated fatty acids and cholesterol, yoghurt closes the gap regarding all these negative aspects with its rich nutrient composition composed of many vitamins and minerals that play a role to prevent and treatment of metabolic diseases. Additionally, it has been found that yoghurt supports the development of gut microbiota that is a key factor to prevent many chronic diseases based on inflammation and thus, is able to reduce the risk of metabolic syndrome.

## ORCID

Busra Baspinar http://orcid.org/0000-0003-0584-2568
Metin Güldaş http://orcid.org/0000-0002-5187-9380

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