Inclusion of phenolic compounds from different medicinal plants to increase α-amylase inhibition activity and antioxidants in yogurt

Amal Bakr Shori

Faculty of Science, Department of Biological Sciences, King Abdulaziz University, Jeddah, Saudi Arabia

ABSTRACT

Four types of yogurt (Y) were prepared in the presence of rosemary, dill, oregano, and ginger water extracts and refrigerated at 4°C. The effect on post-acidification, α-amylase inhibition activity, total phenolic content (TPC), and antioxidant activity was investigated during 0, 7, 14, & 21 days of storage. All herbal-yogurts showed ~ 5 times higher α-amylase inhibition (74.45%–77.83%) than control (16%) on day 14 of storage. TPC of yogurt was increased significantly in the presence of rosemary and oregano after 14 days of storage. The presence of rosemary, dill, oregano, and ginger increased (p < 0.05) the radical scavenging activity, ferric reducing antioxidant potential (FRAP), and ferrous ion chelating (FIC) ability in yogurt during storage. There were no significant differences in the overall preference score for rosemary and ginger yogurts as compared to control. In conclusion, rosemary, dill, oregano, and ginger yogurts could be an effective treatment for postprandial hyperglycemia with antioxidant activity.

1. Introduction

Type 2 diabetes is generally described by an irregular rise in glucose level after a meal, also known as postprandial hyperglycemia [1]. It develops in middle or later life and affects adults in most modern societies. Most diabetic patients are suffering from type 2 diabetes because of insulin deficiency resulting in cells failed to respond normally to insulin [2].

The main source of blood sugar is dietary starch which is digested by carbohydrate-hydrolyzing enzymes (e.g. pancreatic α-amylase). This hydrolysis produces glucose absorbed by the small intestine, thus contributes to the sharp increase in blood glucose [3]. Therefore, management of Type II diabetes can be done through retarding the absorption of glucose through the inhibition of α-amylase enzyme in the digestive tract [4]. Inhibitors of this enzyme retard carbohydrate hydrolyzing and extend the overall digestion period, leading to a decrease in the level of glucose absorption and subsequently reducing postprandial hyperglycemia [2].

Alpha-amylase is a limiting enzyme that acts by catalyzing the hydrolysis of α-1, 4-glycosidic linkages of polysaccharides such as starch, dextrin, and glycogen. The inhibition of this enzyme in the digestive tract is known to be an effective strategy to manage diabetes [4].

Hyperglycemia stimulates auto-oxidation of glucose to form free radicals. A high concentration of free radicals results in oxidative damage to biological molecules such as DNA, lipids, and proteins [1]. The antioxidant is a substance that prevents or slows the oxidation breakdown of molecules. It works by donating an electron to the free radical and thus converts it into a harmless compound. Therefore, consumption of radical scavengers or antioxidants such as vitamins, melatonin, and polyphenolics are able to support biological resistance against free radicals (active oxygen) and decrease the risk of diseases such as diabetes [5].

Yogurt has long been acknowledged as a health-promoting food and claimed to prevent potential disease beyond the basic nutritional function [6,7]. Bioactive peptides with antioxidant activity in yogurt are essential for enhancing the shelf life and inhibiting the oxidation reactions in the human body [8,9]. The main source of naturally occurring antioxidant is food derived from plant materials such as fruits, vegetables, and grains. They possess anti-diabetes properties and have the ability to reduce oxidative damage associated with many diseases [10].

A total of 16 phenolic compounds have been identified from rosemary (Rosmarinus officinalis) extract which included three major components i.e. carnosic acid, carnosol, and rosmarinic acid. Other phenolic compounds such as diterpenoids, flavonoids, hydroxycinnamic acid derivatives, and some of the essential oil constituents have been also identified from rosemary extract [11]. Carnosic acid from rosemary is well known as a potent antioxidant. It can repeatedly act as a...
reducing agent by sequentially donating hydrogen atoms through a series of phenolic compounds that result from the rearrangement of the initially oxidized species [12].

Dill (Anethum graveolens) is used widely in the traditional herbal medicine for the management and controlling of glucose level and as an antioxidant agent [13]. The antioxidant activity of dill is caused by its phenolic compounds such as limonene, dill ether, α-thujene, sabinene, β-myrcene, α-pinen, p-cymene, α-phellandrene, cis-dihydrocarvone, α-carvone, cadinol, trans-dihydrocarvone, α-copaene, γ-murolene, neophytadiene, n-nonadecane, n-docosane, n-heneicosane, n-tricosane, n-tetracosane, neophytadiene, n-nonadecane, n-docosane, n-heneicosane, n-tricosane, n-tetracosane, n-eicosane, n-pentacosane, n-heptacosane, n-hexacosane [14,15].

Therefore, the main objective of this work was to study the effect of inclusion of different phenolic compounds from rosemary (Rosmarinus officinalis), dill (Anethum graveolens), oregano (Origanum vulgare), and ginger (Zingiber officinale) water extracts in yogurt on post-acidification, α-amylase inhibition activity, total phenolic content, and antioxidant activity of yogurt during 21 days of refrigerated storage at 4°C.

2. Materials and methods

2.1. Preparation of herbal water extracts

Dried and ground leaves of rosemary, dill, and oregano, as well as, dried rhizomes of ginger were bought from local herb supply (McCormick®). All dried herbs were saved in dry airtight containers at 25°C away from heat. Ten gram of each herb was mixed individually with 100 ml of distilled water and incubated in a water bath (70°C) for 12 h. This followed by centrifugation of all mixtures using a centrifuge machine (EppendorfTM Centrifuge 5804 R) at 6682 rpm (5000 g) at 4°C for 15 min and the supernatants were harvested [21]. The supernatants were refrigerated (4°C) and used as herbal water extract within 7 days of preparation.

2.2. Preparation of yogurt

Rosemary- (R), dill- (D), oregano- (O), and ginger- (G) yogurt (Y) were prepared as described by Shori & Baba, [21]. Four herbal-yogurts were prepared separately by inclusion 10 g of water extract from each herb in 85 ml of fresh pasteurized full cream milk, 2 g milk powder (4% fat) and 5 g of starter culture (the starter culture was prepared by mixing 1 L of fresh full cream milk containing 4% fat with a bacterial mixture i.e. Lactobacillus acidophilus LA-5, Bifidobacterium bifidum Bb 12, L. casei LC-01, Streptococcus thermophilus Th-4, and L. bulgaricus in the ratio of 4:4:1:1:1 (Chris-Hansen, Denmark) and incubated at 41°C for 12 h). The mixture of the four samples was incubated at 41°C and the pH was determined every 30 min until reaching pH 4.5 (the milk coagulates at pH ranged between 4.0 and 4.6). After 4 h, the fermentation was stopped by placing all yogurt samples in a cold water bath for 1 h. For plain yogurt (PY; control) preparation, a similar procedure was performed except using 10 ml of distilled water instead of herbal water extract. All yogurt samples were stored in a refrigerator at 4°C for 21 days.

2.3. The pH and titratable acidity (TA) assay

The pH of yogurt samples was determined using a pH metre (Mettler Toledo Delta 320; Shanghai, China). Titratable acidity (TA) was measured as described by Muniandy et al. [22].

2.4. Preparation of yogurt water extract

Yogurt (10 g) and 2.5 ml distilled water were mixed for 10 s using Polytron [3]. Few drops of HCl (0.1 M) were used to acidify the mixture to pH 4.0 and the mixture was incubated at 45°C in a water bath for 10 min. The mixture was centrifuged (6682 rpm; 5000 g) at 4°C for 10 min and the pH of the clear supernatant was adjusted to 7.0 by adding NaOH (0.1 M). The supernatant was further centrifuged (6682 rpm; 5000 g, 4°C) for 10 min and the clear supernatant was used for the analysis.

2.5. α-Amylase inhibition assay

Yogurt extract (500 μl), 500 μl of 0.02M sodium phosphate buffer (pH 6.9), and 0.006M sodium chloride containing 0.5 mg/ml α-amylase solution were mixed thoroughly and incubated at 37°C for 10 min [3]. Later, 500 μl of 1% starch solution in 0.02M sodium phosphate buffer (pH 6.9) with 0.006M sodium chloride was added to the tube. The mixture was further incubated at 37°C for 10 min and 1 ml of the colour reagent (2% dinitrosalicylic acid) was added before incubation at 100°C for 5 min. One millilitre of tartrate solution (18.2% w/v) was added and the mixture was cooling at room temperature for 3 min before diluted with 10 ml of distilled water.
water. The Absorbance of the sample was measured at 540 nm against control (500 μl of buffer solution instead of the extract) using a spectrophotometer (Genesys 10UV). α-Amylase inhibition was calculated using the below formula:

$$\alpha = \frac{\text{Abs}_{\text{control}}@540\,\text{nm} - \text{Abs}_{\text{sample}}@540\,\text{nm}}{\text{Abs}_{\text{control}}@540\,\text{nm}} \times 100$$

2.6. Total phenolic content (TPC) assay

TPC of yogurt samples was determined according to the method described by Muniandy et al. [22]. The mixture consisting of 0.5 ml Folin–Ciocalteu reagent (50% v/v), 5 ml distilled water, 1 ml of 95% ethanol, and 1 ml of the yogurt water extracts, herbal extract, or gallic acid standard solutions (10–60 μg/ml) was allowed to stand at room temperature for 5 min. Sodium carbonate solution (1 ml; 5% w/v) was added to the sample and left for 60 min at 25°C. The absorbance was read at 725 nm using a spectrophotometer (Genesys 10UV). The values were converted to total phenolics by using the gallic acid standard curve and expressed as micrograms gallic acid equivalents per millilitre (μg GAE/ml).

2.7. Antioxidant activity assay

DPPH radical scavenging, Ferric reducing antioxidant potential (FRAP), and Ferrous ion chelating (FIC) ability were determined according to the procedure described by Muniandy et al. [22]. To determine the DPPH radical scavenging, 250 μl of yogurt water extract or herbal extract was added to 3 ml of DPPH reagent (60 mM) dissolved in 95% ethanol. The mixture was incubated at 25°C for 1 h and the absorbance at 517 nm was measured using a spectrophotometer (Genesys 10UV). The presence of rosemary, dill, and oregano water extracts decreased significantly (p < 0.05) the pH in fresh yogurt as compared to control throughout the storage periods (Figure 1). However, the presence of ginger extract did not significantly enhance the pH reduction in yogurt as compared to control during all storage periods. Rosemary yogurt showed the lowest pH value (4.38 ± 0.04) among other herbal extracts.

To determine the FRAP, 400 μl of yogurt water extract, herbal extract, or standard solutions (iron (II) sulfate heptahydrate; FeSO₄·7H₂O; 0.3–1.0 μg/ml) was mixed with 3.6 ml of FRAP reagent (300 mM acetate buffer, 8 mM 2,4,6-tri(2-pyridyl)-s-triazine (TPTZ) reagent, and 20 mM FeCl₃ solutions at a ratio of 10:1:1). The solution was incubated at 37°C for 10 min and absorbance was recorded at 593 nm using a spectrophotometer (Genesys 10UV). The data were estimated from the standard curve (FeSO₄·7H₂O) and expressed as μM Fe²⁺ equivalent/ml (μM Fe²⁺ E/ml).

To determine the FIC, 1 ml of 20 times diluted 2 mM iron (II) sulfate hydrate (FeSO₄·xH₂O), and 1 ml of diluted 5 mM ferrozine solution were mixed with 1 ml of yogurt water extract or herbal extract. The mixture was incubated for 10 min at room temperature and absorbance at 562 nm was measured against control (distilled water instead of the extract) using the spectrophotometer. The FIC ability of samples was calculated using the equation below:

$$\text{FIC ability}(%) = \frac{\text{Abs}_{\text{control}}@562\,\text{nm} - \text{Abs}_{\text{sample}}@562\,\text{nm}}{\text{Abs}_{\text{control}}@562\,\text{nm}} \times 100$$

2.8. Sensory evaluation

The sensory evaluation of yogurt samples was analyzed on the first day of refrigerated storage at 4°C. Untrained panels of 12-member (students and staff) were randomly assigned and the evaluation form was given to each panel. Yogurt samples served in plastic cups (20 g for each) stored at 4°C and labelled with three-digit code. Water was available for panel members to rinse their mouths between samples eating. The evaluation was performed based on a 10-point system (9–10 = Very Good, 7–8 = Good, 5–6 = Satisfactory, 3–4 = Fairly Satisfactory, 1–2 = Unsatisfactory, and 0 = Defective). Five attributes were determined, including texture (presence of whey), consistency (graininess, lumpiness, and firmness), taste, aroma, and overall preference [23].

2.9. Statistical analysis

The experiment was performed in three different batches and in duplicates. Results were presented as mean ± SE. Statistical analysis was achieved using a one-way analysis of variance (ANOVA, SPSS 20.0) and Duncan’s post hoc test for mean comparison at the level of p < 0.05.

3. Results and discussions

3.1. Acidification activity in yogurt

The presence of rosemary, dill, and oregano water extracts decreased significantly (p < 0.05) the pH in fresh yogurt to 4.49 ± 0.03, 4.47 ± 0.01, 4.45 ± 0.06; respectively compared to control (4.54 ± 0.06; Figure 1). However, the presence of ginger extract did not significantly enhance the pH reduction in yogurt as compared to control throughout the storage periods (Figure 1). The pH values of rosemary, dill, and oregano yogurt samples were significantly lower (p < 0.05) than control during all storage periods. Rosemary yogurt showed the lowest pH value (4.38 ± 0.04) among other herbal
yogurts on 21 days of storage whereas both dill and oregano yogurts showed a similar pH value (4.40).

The presence of herbal extracts from rosemary, dill, oregano, and ginger in fresh yogurt increased significantly TA ($p < 0.05$; 0 day) ranged from 0.72% to 0.90% LAE as compared to fresh plain yogurt (0.63 ± 0.02% LAE; Figure 2). Refrigerated storage of yogurt to 21 days resulted in an improvement ($p < 0.05$) in TA of all herbal yogurts compared to plain yogurt (Figure 2). However, ginger yogurt showed no significant difference in TA compared to control (0.81% LAE) on day 7 of storage. Both rosemary and oregano yogurts showed the highest TA% (1.35% LAE) followed by dill and ginger yogurts respectively (1.17% LAE) on 21 days of storage.

The reduction of pH in the presence of rosemary, dill, and oregano in fresh and refrigerated yogurt could be attributed to the active lactic acid bacteria (LAB) that produced lactic acid and other organic acids during their metabolism [24]. Moreover, the initial TA in herbal extracts could affect the reduction of pH in yogurt samples. The present results indicated that the highest TA was shown in oregano water extract (0.09%) followed by dill (0.07%), rosemary (0.05%), and ginger (0.01%); respectively (data not shown).

The determination of TA is more relevant in the evaluation of post acidification by LAB. The production of organic acids has a positive linear relationship with TA [25–27]. In the present study, the rate of acid production was higher in rosemary, dill, and oregano yogurts than plain yogurt during storage periods. However, the presence of ginger in yogurt did not affect TA during refrigerated storage on day 7 of storage. It is likely that the viability of LAB in yogurt was enhanced in the presence of rosemary, dill, and oregano more than in ginger. Several findings reported that fortified yogurt with herbal extracts such as *Cinnamomum verum*, *Allium sativum*, *Lycium barbarum*, tea (green, white, and black), soybean, and chickpea significantly improved the growth and viability of LAB in yogurt [23,28–31]. Joung et al. [32] found that supplementary plant extracts i.e. *Diospyros kaki* and *Nelumbo nucifera* supported the production of lactic acid by yogurt starter cultures. In addition, Altuntas and Korukluoglu [33], confirmed that aqueous extract of ground garlic or fresh garlic juice has no antimicrobial activity towards selected probiotic strains such as *Streptococcus thermophilus*, *Lactobacillus bulgaricus*, *Bifidobacterium longum* BB536, *Lactobacillus acidophilus* 74–2 and *Lactobacillus rhamnosus*. Further study is needed to verify the viability of LAB in fortified yogurt with rosemary, dill, oregano, and ginger water extracts during refrigerated storage. Since LAB are able to survive at the low pH of yogurt [6], the higher TA in herbal yogurt may help in inhibiting the growth of organisms such as coliform bacteria, yeast, and mould, thus making possible the extension of the shelf life of yogurt [33].

### 3.2. α-Amylase inhibition activity in yogurt

The presence of rosemary, dill, oregano, and ginger improved ($p < 0.05$; 0 day) the inhibition of α-amylase activity in yogurt to 18.70 ± 0.1%, 24.82 ± 0.08%, 13.23 ± 0.1%, and 28.58 ± 1.2% respectively in comparison to control (9.58 ± 0.1%; Figure 3). All herbal yogurts showed a significant increase in the inhibition of α-amylase activity as compared to control during 21 days of refrigerated storage. The four types of herbal yogurts showed approximately 5 times higher in α-amylase inhibition activity ranging from 74.45% to 77.38% than control (16%) on day 14 of storage (Figure 3). Extended storage to 21 days decreased ($p < 0.05$) the inhibition of α-amylase activity to 11.0%, 59.76%, 62.77%, 54.38%, and 64.69% for plain-, rosemary-, dill-, oregano-, and ginger- yogurt respectively. Oregano yogurt showed the lowest inhibition of α-amylase activity among other herbal yogurts (Figure 3).

The inhibition of this rate-limiting enzyme in carbohydrate metabolism could be an effective approach to control postprandial hyperglycemia [34,35].
present study showed that all the four types of herbal yogurts gave pronounced inhibitions on α-amylase activity compared to plain yogurt. A higher inhibitory effect of herbal yogurts is likely to be associated with phenolic compounds since the inhibition of α-amylase activity in rosemary, dill, oregano, and ginger water extracts was 28.74%, 54.10%, 13.04%, and 60.77% respectively (data not shown). The lowest inhibition of α-amylase activity was observed in oregano yogurt. This could be explained by a low α-amylase inhibitory activity effect in oregano extract. The highest α-amylase inhibitory activity of all the four herbal yogurts was shown at day 14 of storage, which ranged from 74% to 78%. Previous studies reported that α-amylase inhibitory activity of phytomix-3+, Mangosteen-, neem-, garlic-, and cinnamon-yogurt was in the range of 9%–16%, 44%–55%, 32%–48%, and 35%–55%; respectively during 21 days of refrigerated storage [3,21,35,36]. Thus, the present study suggested that α-amylase inhibitory activity was improved in the presence of rosemary, dill, oregano, and ginger which indicating that phytochemicals may be more relevant in the evaluation of the potentials of herbal enriched yogurt in the inhibition of this rate-limiting enzyme.

3.3. Total phenolic content (TPC) in yogurt

The TPC of yogurt was increased significantly (p < 0.05) in the presence of rosemary, dill, and oregano water extracts (61.15 ± 1.2, 58.92 ± 1.3, 66.97 ± 0.7 μg GAE/ml; respectively) at 0 day as compared to control (34.79 ± 1.0 μg GAE/ml; Figure 4). However, the addition of ginger water extract did not affect TPC (p > 0.05) in yogurt during 14 days of storage (Figure 4). TPC of yogurt showed a significant increase in the presence of rosemary (80.66–82.89 μg GAE/ml), dill (48.71–53.82 μg GAE/ml), and oregano (85.12–74.90 μg GAE/ml) as compared to control (41.86–39.52 μg GAE/ml) during 14 days of storage. Extended storage to 21 days decreased (p < 0.05) TPC in both herbal- and plain-yogurts (Figure 4).

Phenolic is a class of chemical compounds consisting of a hydroxyl group, -OH that attach to an aromatic hydrocarbon group. Phenolic compounds are secondary metabolites synthesized by the plant to protect them from predators and environment stress [37]. Certain phenolic compounds possess antioxidant activity and have beneficial properties to human health [38–40]. In the present study, higher phenolic content in rosemary, dill, and oregano yogurts than plain yogurt during storage may be related to phenolic compounds available in these herbs. The current results showed that TPC of rosemary, dill, and oregano water extracts was 219.52 ± 0.7, 220.011 ± 1.5, and 219.52 ± 1.7 μg GAE/ml; respectively (data not shown). A total of 16 phenolic compounds that have been identified from rosemary extract included carnosic acid, carnosol, rosmarinic acid, diterpenoids, flavonoids, hydroxycinnamic acid derivatives, and some of the essential oil constituents [11]. In addition, the health properties of dill are mostly due to the presence of key phenolic compounds such as limonene, dill ether, α-thujene, sabinene, β-myrcene, α-pinene, p-cymene, α-phellandrene, cis-dihydrocarvone, carvone, cadinol, trans-dihydrocarvone, -copiaene, γ-muurol ene [14,15]. Similarly, oregano extract showed a variety of phenolic compounds such as rosmarinic acid, caffeic acid, rutin, gallic acid, quercetin, and p-coumaric [17,18]. Furthermore, it should be noted that the addition of ginger had no significant effect on the TPC of yogurt during 14 days of storage. This could be due to the presence of low TPC in ginger extract (113.98 ± 0.9 μg GAE/ml; data not shown). Some phenolic compounds have been isolated from ginger extract e.g. [6]-gingerol, [6]-shogaol, [6]-azashogaol, [6]-azagingerol Isoxazoline derivative, zingerone, and paradols [20]. Further study is needed to identify the phenolic compounds profiles present in rosemary, dill, oregano, and ginger water extracts.
Figure 5. Changes in radical scavenging activity (%) of rosemary (R), dill (D), oregano (O), and ginger (G) water extracts enriched yogurt (Y) compared to plain (P) yogurt (control) during 21 days of refrigerated storage at 4°C. Data are presented as mean ± SEM. The level of significance was preset at $p < 0.05$ compared to control at the same storage period.

Figure 6. Changes in ferric reducing antioxidant potential (FRAP; μM Fe^{2+}E/ml) of rosemary (R), dill (D), oregano (O), and ginger (G) water extracts enriched yogurt (Y) compared to plain (P) yogurt (control) during 21 days of refrigerated storage at 4°C. Data are presented as mean ± SEM. The level of significance was preset at $p < 0.05$ compared to control at the same storage period.

Figure 7. Changes in ferrous ion-chelating (FIC; %) of rosemary (R), dill (D), oregano (O), and ginger (G) water extracts enriched yogurt (Y) compared to plain (P) yogurt (control) during 21 days of refrigerated storage at 4°C. Data are presented as mean ± SEM. The level of significance was preset at $p < 0.05$ compared to control at the same storage period.

and the composition of these phenolic compounds in yogurt during refrigerated storage.

The decrease in TPC for all herbal yogurts at 21 days of storage may be explained by the action of yogurt bacteria during refrigerated storage to further break down the polymeric phenolics in the presence of these herbal extracts. Similar observations were reported in previous studies [30,36]. Fritsch et al. [41] have reported that *Bifidobacterium animalis* subsp. *lactis* possessed the enzymatic equipment to hydrolyze chlorogenic acid which resulted in an increase of caffeic acid content in fermented sunflower flour. Another study found that *Lactobacillus gasseri* possessed specific enzymes to degrade caffeic acid [42].

3.4. Antioxidant activity in yogurt

The radical scavenging activity of fresh plain yogurt ranged from 58% to 40% during 21 days of storage (Figure 5). However, the addition of rosemary, dill, and oregano water extracts increased ($p < 0.05$) the radical scavenging activity of fresh yogurt to almost 90% (Figure 5). The radical scavenging activity of rosemary and oregano yogurts decreased ($p > 0.05$) to 86% and 88%; respectively whereas dill and ginger yogurts decreased to 73.22% and 58.19%; respectively during 21 days of refrigerated storage.

There were no significant differences ($p > 0.05$) in FRAP values between herbal-yogurts and control during 21 days of storage (Figure 6). However, the inclusion of rosemary, dill, oregano, and ginger significantly increased ($p < 0.05$) the FRAP value in yogurt (5758–5501 μM Fe^{2+}E/ml) compared to control (4465.71 μM Fe^{2+}E/ml) on day 7 of storage.

The FIC ability of plain yogurt was ranged from 45.62% to 58.19% during 21 days of storage (Figure 7). The presence of rosemary, dill, oregano, and ginger showed significant increased ($p < 0.05$) in the FIC ability of yogurt with an average of 76.58%–88.71%, 72.08%–83.23%, 74.29%–85.75%, and 68.53%–87.55% respectively during 21 days of storage.

The beneficial properties of phytochemicals in herbs have been mainly interpreted on the basis of their antioxidant properties [38,43]. In the present study, all the herbal yogurt samples showed higher DPPH radical scavenging activity and FIC ability than plain yogurt (Figures 5 and 7). It is possible that phenolic compounds from rosemary, dill, oregano, and ginger extracts might be an important contributor to the antioxidant activity. The hypothesis was further supported by high DPPH radical scavenging activity of rosemary, dill, oregano, and ginger extracts (78.07%, 68.78%, 74.37%, and 55.33%; respectively; data not shown). In addition, this study found that the FIC ability of rosemary, dill, oregano, and ginger extracts was 81.07%, 68.99%, 69.38%, and 79.54% respectively (data not shown).

Although FRAP values in rosemary, dill, oregano, and ginger extracts were 3215.71, 3380, 4630, and 4651.43 μM Fe^{2+}E/ml; respectively (data not shown),
Figure 8. Sensory evaluation of rosemary (R), dill (D), oregano (O), and ginger (G) water extracts enriched yogurt (Y) compared to plain (P) yogurt (control) on the first day of refrigerated storage at 4°C. Data are presented as mean ± SEM. The level of significance was preset at $p < 0.05$ compared to control at the same storage period.

all herbal yogurts had higher FRAP values than plain yogurt only on day 7 of storage. This suggests that the profile of individual phenolics in the herbal extracts may be more important in contributing to the FRAP than the total phenolic content [44]. Further study on the isolation and characterization of these phenolics is required to determine their possible bioactivities towards FRAP.

Diabetes mellitus is accompanied by increased formation of free radicals and decreased antioxidant capacity, resulting in oxidative damage of cell components. Antioxidants in dietary products may contribute to a certain level of anti-diabetic properties [45]. Phenolic phytochemicals for instance may inhibit the gradual impairment of pancreatic beta-cell function due to oxidative damage and may thus minimize the occurrence of type 2 diabetes [39, 46]. Therefore, the high antioxidant capacity of rosemary, dill, oregano, and ginger yogurts may be speculated to play a role in the managing of type 2 diabetes.

3.5. Sensory evaluation in yogurt

The sensory evaluation of yogurt in the presence of 4 types of herbal extracts is shown in Figure 8. Rosemary and dill yogurts showed lower scores for texture and consistency (5–6; satisfactory) than control (7–8; good) whereas oregano and ginger yogurts showed no significant difference in the scores of these attributes as compared to control. Ginger yogurt registered a higher taste score (9–10; very good) than control (7–8; good). In addition, the scores of taste and aroma were not affected by the addition of rosemary into yogurt as compared to control (Figure 8). However, the presence of dill in yogurt showed negative effects on the aroma (1–2; unsatisfactory). There were no significant differences in the overall preference scores for rosemary and ginger yogurts in comparison to control (9–10; very good). In contrast, oregano yogurt showed less overall preference score among tested yogurt samples (Figure 8).

A sensory evaluation study is crucial in determining the food quality by accessing the complex sensation resulting from the interaction of our senses [47]. Taste is the most important purchase criterion. The presence of ginger in yogurt improved all the descriptive sensory attributes compared to plain yogurt. This observation is in agreement with another study [48]. The low mean score of dill yogurt in terms of aroma thought to be due to its characteristic aromatic odour such as carvone [49]. Sensory evaluation in this study revealed that ginger and rosemary yogurts were an overall preference (Figure 8). This extra credit is greatly owing to its typical and characteristic flavour.

4. Conclusion

The post-acidification of yogurt has improved in the presence of rosemary, dill, oregano, and ginger during 21 days of storage. In addition, 14 day-old yogurt enriched with all the four herbal water extracts showed ~5 times inhibition toward $\alpha$-amylase activity. All herbal water extracts positively affected the TPC in yogurt compared to control during 21 days of storage. Herbal water extracts were significantly affected radical scavenging activity and FIC ability of yogurt during 21 days of storage. Moreover, all herbal yogurts showed higher ($p < 0.05$) FRAP values than control on 7 days of storage. Rosemary and ginger yogurts have an overall preference score comparable to control. Therefore, functional yogurt enriched with rosemary, dill, oregano, and ginger could be an effective treatment for postprandial hyperglycemia with antioxidant activity.

Disclosure statement

No potential conflict of interest was reported by the author(s).
Funding
This work was supported by King Abdulaziz University [grant number D-321-247-1440].

ORCID
Amal Bakr Shori http://orcid.org/0000-0001-7557-3987

References
[1] Bajaj S, Khan A. Antioxidants and diabetes. Indian J Endocrinol Metab. 2012;16(2):267–271.
[2] Bazzano LA, Song YQ, Bubes V, et al. Dietary intake of whole and refined grain breakfast cereals and weight gain in men. Obes Res. 2005;13(11):1952–1960.
[3] Shori AB, Rashid F, Baba AS. Effect of the addition of phytomix-3+ mangosteen on antioxidant activity, viability of lactic acid bacteria, type 2 diabetes key-enzymes, and sensory evaluation of yogurt. LWT. 2018;94:33–39.
[4] Iid II, Kumar S, Shukla S, et al. Putative anti-diabetic herbal food ingredients: nutra/functional properties, bioavailability and effect on metabolic pathways. Trends Food Sci Technol. 2020;97:317–340.
[5] Shori AB. Screening of antidiabetic and antioxidant activities of medicinal plants. J Integr Med. 2015;13(5):297–305.
[6] Shori AB. The potential applications of probiotics on dairy and non-dairy foods focusing on viability during storage. Biocatagri Biotechnol. 2015;4:423–431.
[7] Shori AB. Influence of food matrix on the viability of probiotic bacteria: a review based on dairy and non-dairy beverages. Food Biosci. 2016;13(1):1–8.
[8] Tamime AY, Robinson RK. Nutritional value of yoghurt. In: Yoghurt science and technology. 2nd ed. Exeter: A. Wheaton and Co. Ltd./Pergamon Press Ltd; 1999. p. 515–534.
[9] Ramchandran L, Shah N P. Influence of addition of Raftiline HP on the growth, proteolytic, ACE- and α-glucosidase inhibitory activities of selected lactic acid bacteria and Bifidobacterium. LWT. 2010;43:146–152.
[10] Forni C, Facchiano F, Bartoli M, et al. Beneficial role of phytochemicals on oxidative stress and age-related diseases. BioMed Res Int. 2019;2019:8748253.
[11] Xie J, VanAlstyne P, Uhlir A, et al. A review on rosemary as a natural antioxidation solution. Eur J Lipid Sci Technol. 2017;119(6):1600439.
[12] El-Massry KF, El-Ghorab AH, Farouk A. Antioxidant activity and volatile components of Egyptian Artemisia judaica L. Food Chem. 2002;79:331–336.
[13] Jana S, Shekhwat GS. Anethum graveolens: an Indian traditional medicinal herb and spice. Pharmacogn Rev. 2010;4(8):179.
[14] Andalibi B, Zehmat SS, Ghaseemi GK, et al. Changes in essential oil yield and composition at different parts of dill (Anethum graveolens L.) under limited irrigation conditions. J Agric Sci. 2011;21(2):11–22.
[15] Radulescu V, Popescu ML, Ilies D-C. Chemical composition of the volatile oil from different plant parts of Anethum graveolens L. (Umbelliferae) cultivated in Romania. Farmacia. 2010;58(5):594–600.
[16] Ozkhan G, Sagdic O, Ozcan M. Inhibition of pathogenic bacteria by essential oils at different concentrations. Food Sci Technol Int. 2003;9:85.
[17] Gonçalves S, Moreira E, Grosso C, et al. Phenolic profile, antioxidant activity and enzyme inhibitory activities of extracts from aromatic plants used in Mediterranean diet. J Food Sci Technol. 2017;54:219–227.
[18] Koldas Ş, Demirtas I, Ozen T, et al. Phytochemical screening, anticancer and antioxidant activities of Origanum vulgare L. ssp. viride (Boiss.) Hayek, a plant of traditional usage. J Sci Food Agri. 2015;95(4):786–798.
[19] Kumar G, Karthik L, Rao KB. A review on pharmacological and phytochemical properties of Zingiber officinale Roscoe (Zingiberaceae). J Pharm Res. 2011;4(9):2963–2966.
[20] Kumar NV, Murthy PS, Manjunatha JR, et al. Synthesis and quorum sensing inhibitory activity of key phenolic compounds of ginger and their derivatives. Food Chem. 2014;159:451–457.
[21] Shori AB, Baba AS. Comparative antioxidant activity, proteolysis and in vitro α-amyrase and α-glucosidase inhibition of Allium sativum-yogurts made from cow and camel milk. J Saudi Chem Soci. 2014;18(5):456–463.
[22] Muniandy P, Shori AB, Baba AS. Influence of green, white and black tea addition on the antioxidant activity of probiotic yogurt during refrigerated storage. Food Pack Shelf Life. 2016;8:1–8.
[23] Shori AB, Baba AS. Viability of lactic acid bacteria and sensory evaluation in Cinnamomum verum and Allium sativum-bio-yogurts made from camel and cow milk. J Asso Arab Univ Basic Appl Sci. 2012;12(1):50–55.
[24] Shori AB, Aboulfazli F, Baba AS. Viability of probiotics in dairy products: a review focusing on yogurt, ice cream, and cheese. In: Datta A, Fakruddin M, Iqbal HMN, Abraham J, editors. Advances in biotechnology. Vol. 3. Las Vegas (NV): Open Access eBooks; 2018. p. 1–25. ISBN: 978-93-87500-23-5.
[25] Baba AS, Najarian A, Shori AB, et al. In vitro inhibition of key enzymes related to diabetes and hypertension in Lycium barbarum yogurt. Arab J Sci Eng. 2014;39(7):5355–5362.
[26] Vénica CI, Wolf IV, Suárez VB, et al. Effect of the carbohydrates composition on physicochemical parameters and metabolic activity of starter culture in yogurts. LWT. 2018;94:163–171.
[27] Marand MA, Amjadi S, Marand MA, et al. Fortification of yogurt with flaxseed powder and evaluation of its fatty acid profile, physicochemical, antioxidant, and sensory properties. Powder Technol. 2020;359:76–84.
[28] Shori AB, Ming KS, Baba AS. The effects of Lycium barbarum water extract and fish collagen on milk proteolysis and in vitro angiotensin I-converting enzyme inhibitory activity of yogurt. Biotechnol Appl Biochem. 2020. DOI:10.1002/bab.1914
[29] Muniandy P, Shori AB, Baba AS. Comparison of the effect of green, white and black tea on Streptococcus thermophilus and Lactobacillus spp. in yogurt during refrigerated storage. J Assoc Arab Univ Basic Appl Sci. 2017;22:26–30.
[30] Shori AB. Antioxidant activity and viability of lactic acid bacteria in soybean-yogurt made from cow and camel milk. J Taibah Univ Sci. 2013;7(4):202–208.
[31] Shori AB. Nutritional and therapeutical values of chickpea water extract enriched yogurt made from cow and camel milk. J Taibah Univ Sci. 2013;7(4):202–208.
[32] Joung JY, Lee JY, Ha YS, et al. Enhanced microbial, functional and sensory properties of herbal yogurt fermented with Korean traditional plant extracts. Korean J Food Sci Anim Resour. 2016;36(1):90.
[33] Altuntas S, Korukluoglu M. Growth and effect of garlic (Allium sativum) on selected beneficial bacteria. Food Sci Technol. 2019;39(4):897–904.

[34] Apostolidis E, Kwon VI, Shetty K. Fermentation of milk and soymilk by Lactobacillus bulgaricus and Lactobacillus acidophilus enhances functionality for potential dietary management of hyperglycemia and hypertension. Food Biotechnol. 2007;21:217–236.

[35] Shori AB, Baba AS. Cinnamomum verum improved the functional properties of bio-yogurts made from camel and cow milks. J Saudi Soc Agri Sci. 2011;10(2):101–107.

[36] Shori AB, Baba AS. Antioxidant activity and inhibition of key enzymes linked to type-2 diabetes and hypertension by Azadirachta indica-yogurt. J Saudi Chem Soc. 2013;17(3):295–301.

[37] Amirdivani S, Baba SB. Changes in yogurt fermentation characteristics, and antioxidant potential and in vitro inhibition of angiotensin-1 converting enzyme upon the inclusion of peppermint, dill and basil. LWT. 2011;44(6):1458–1464.

[38] Scalbert A, Manach C, Moret C, et al. Dietary polyphenols and the prevention of diseases. Critical Rev Food Sci Nutr. 2005;45(4):287–306.

[39] Cheplick S, Kwon Y, Bhownik P, et al. Phenolic-linked variation in strawberry cultivars for potential dietary management of hyperglycemia and related complications of hypertension. Bioreasour Technol. 2010;101(1):404–413.

[40] Belfeki H, Mejri M, Hassouna M. Antioxidant and α-amylase inhibitory activities of some Tunisian aromatic plants. J New Sci Agri Biotechnol. 2016;31(6):1775–1782.

[41] Fritsch C, Heinrich V, Vogel RF, et al. Phenolic acid degradation potential and growth behavior of lactic acid bacteria in sunflower substrates. Food Microbiol. 2016;57:178–186.

[42] Couteau D, McCartney AL, Gibson GR, et al. Isolation and characterization of human colonic bacteria able to hydrolyse chlorogenic acid. J Appl Microbiol. 2001;90(6):873–881.

[43] Atta EM, Mohamed NH, Abdelgawad AAM. Antioxidants: an overview on the natural and synthetic types. Eur Chem Bull. 2017;6(8):365–375.

[44] Chen PX, Tang Y, Marcone MF, et al. Characterization of free, conjugated and bound phenolics and lipophilic antioxidants in regular and non-darkening cranberry beans (Phaseolus vulgaris L.). Food Chem. 2015;185:298–308.

[45] Lin SY, Wang CC, Lu YL, et al. Antioxidant, anti-semicarbazide-sensitive amine oxidase, and antihypertensive activities of geraniin isolated from Phyllanthus urinaria. Food Chem Toxicol. 2008;46:2485–2492.

[46] McCue P, Shetty K. Phenolic antioxidant mobilization during yogurt production from soymilk using Kefir cultures. Process Biochem. 2005;40:1791–1797.

[47] Marathe SA, Deshpande R, Khamesra A, et al. Effect of radiation processing on nutritional, functional, sensory and antioxidant properties of red kidney beans. Radiat Phys Chem. 2016;125:1–8.

[48] Yang G-H, Guan J-J, Wang J-S, et al. Physicochemical and sensory characterization of ginger-juice yogurt during fermentation. Food Sci Biotechnol. 2012;21(6):1541–1548.

[49] Naidu MM, Vedashree M, Satapathy P, et al. Effect of drying methods on the quality characteristics of dill (Anethum graveolens) greens. Food Chem. 2016;192:849–856.