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Dietary fibers of fenugreek seeds: Storage stability and food application

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ABSTRACT

This study aimed to determine the storage stability of soluble and insoluble dietary fibers of fenugreek seeds, and their use in yoghurt. Dietary fibers were stored at 25°C - 40% RH for 180 days and 38°C - 90% RH for 90 days, and the changes in their physico-chemical and functional properties were determined, namely water retention, oil holding, and swelling capacities, glucose adsorption index and α-amylase inhibition. All of the physico-chemical and functional properties' values of soluble and insoluble dietary fibers decreased during storage. The reduction of the values was more rapid at 38°C of storage than at 25°C. Insoluble dietary fiber was more stable than soluble dietary fiber in terms of physico-chemical and functional properties during storage. Dietary fiber-fortified yoghurt samples had a higher viscosity than control samples, and the syneresis of yoghurt reduced by 18% when 3% of insoluble dietary fibers were used. The viscosity of the insoluble dietary fiber-added yoghurt samples was higher than that of soluble dietary fiber-added counterparts, which can be related to the higher water retention capacity of insoluble dietary fiber of fenugreek seeds.

Keywords: Dietary fiber, Storage stability, Fenugreek seeds, Yoghurt, Glucose adsorption index

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an old medicinal plant cultivated throughout the world. It has been used as food flavoring agent and traditional medicine for thousands of years (Sarwar et al., 2020). Fenugreek seeds contain soluble and insoluble dietary fiber (DF), protein, and fat as main constituents. Also, volatile oils, sapogenin, trigonelline, thiamine, and folic acid are other constituents present in fenugreek seeds (Srinivasan, 2006; Sarwar et al., 2020). Fenugreek seeds may contain DF over 50%, and defatted fenugreek seeds may contain DF up to 80% (Sarwar et al., 2020; Türker et al., 2022). The antidiabetic and hypocholesterolemic effects of fenugreek have been mainly attributable to the DF found in fenugreek seeds, and these properties and high DF content of the fenugreek seeds increase the nutraceutical value of fenugreek plant (Wani and Kumar, 2018). Even though having a great source of DF, fenugreek seeds' DFs have not been used as food additives frequently.

Physico-chemical and functional properties of DFs are important to demonstrate their positive health effects and their usage areas in the food industry. DFs can adsorb glucose, and this property of DFs can lead to delaying or reducing glucose adsorption in the gastrointestinal tract. Hence, DF consumption can reduce blood sugar (Chu et al., 2019). DFs also have α-amylase inhibition capacity, which can lower postprandial serum glucose, and this property is helpful for the treatment of Type-2 diabetes (Ding et al., 2020). Water retention capacity, oil holding capacity, and swelling capacity are important characteristics in determining the applicability of DFs in the food industry because they provide useful information about optimal usage levels to achieve the desired texture (Requena et al., 2016). The usage of the DFs having desirable physico-chemical and functional properties can be helpful for producing novel functional foods having positive health effects. Recently, DF has been used as a functional ingredient to improve yoghurt properties and produce functional foods having a variety of health benefits (Wang et al., 2019; Dong et al., 2022).

In literature, some studies have been found for the DF fortified yogurts. DFs extracted from seeds, vegetables, and fruits have been used for the production of DF-added yoghurts (Staffolo et al., 2004; Hashim et al., 2009; Tomic et al., 2017). In general, DFs can help yoghurts to have better textural properties. Hashim et al. (2009) reported that adding date fiber into yoghurt significantly affected yoghurt texture and color. Moreover, besides nutritional enhancement, enriched yoghurts with different functional components have been drawing the attention of consumers, and this feature generates a great market demand. For this reason, fenugreek DF can be used as a functional ingredient for DF-fortified yoghurt as a cheap and abundant source. Beyond fenugreek seed DFs' physico-chemical and functional properties, the storage conditions' effect on the physico-chemical and functional properties of fenugreek seed DFs should be investigated. The determination of DF storage stability in terms of their physico-chemical and functional properties can be important for the future of food processing.

The aim of this study is to determine the changes in physico-chemical and functional properties of soluble and insoluble fenugreek seeds' DFs under different storage conditions (25°C, 40% RH, and 38°C, 90% RH). Moreover, the use of isolated soluble and insoluble DFs in yoghurt production was investigated, and some quality characteristics of the produced yoghurt were determined.

Materials and Methods

Material

Fenugreek seeds' insoluble and soluble DFs (IDF and SDF) were used for the determination of storage stability and yoghurt fortification. DFs were produced using ultrasonic-assisted alkali extraction (1 M of NaOH as a solvent, solid–solvent ratio of 53 g/L, ultrasonic amplitude of 58%, and extraction time of 25 min). The method originated from the method of Türker et al. (2022), and the alkali extraction step was modified using ultrasonic-assisted extraction. After applying the extraction conditions, the samples were centrifuged, the pellet was used for the IDF determination, and the supernatant was used for the SDF determination. Following to the production of DFs, the physico-chemical and functional properties of DFs were determined (initial values) and were shown in Table 1. The raw milk for the yoghurt production was obtained from a local market.

Chemicals

Dinitro salicylic acid (3-5 dinitro salicylic acid, DNS, CAS No: 609-99-4) was obtained from CDH Chemicals (India), and glucose monohydrate (CAS No: 14431-43-7) was purchased from Merck KGaA (Germany). Sodium hydroxide (NaOH, CAS No: 1310-73-2) and α-amylase (*Aspergillus Oryzae*, ~1.5 U/mL, EC No: 232-588-1) were purchased from Sigma-Aldrich (Germany).

Storage Stability of Dietary Fibers

The DFs were stored at two different conditions. The samples were stored at 25°C, 40% RH for 180 days (ambient conditions) and at 38°C, 90% RH for 90 days (accelerated conditions). Three grams of DF sample was hermetically sealed in aluminum-laminated polyethylene (10 µm polyethylene terephthalate + 6 µm aluminum + 40 µm low-density polyethylene) pouches. All physical and functional properties of the DFs were analyzed every 30 days for 180 days of storage (25°C) and every 15 days for 90 days of storage (38°C). All storage trials and analysis results were duplicated.

Physico-Chemical and Functional Properties of Dietary Fibers

Water retention capacity

250 mg of the IDF or SDF were mixed with 15 mL of distilled water in 50 mL of the centrifuge tube, the samples were left at room temperature for 1 hour, and centrifugation was applied for 20 min at 3000 g. After discarding the supernatants, the precipitates were weighed, and the samples' water retention capacity (WRC) was calculated as a gram of water per gram of dry sample (Sun et al., 2018).

Oil adsorption capacity

Similar steps were applied, and similar amounts were used for the WRC to determine the samples' oil adsorption capacity (OAC), only virgin olive oil (Extra Virgin Olive Oil, Kırlangıç, Turkey) was used instead of distilled water. The OAC was defined as a gram of virgin olive oil per gram of dry sample (Sun et al., 2018).

Swelling capacity

The swelling capacity (SC) of the DFs was determined using the method of Ma and Mu (2016), and SC was calculated using Equation (1).

$$\text{SC (mL/g)} = (v_1 - v_0)/w_0 \qquad (1)$$

Here, v_1 is the volume of the hydrated DF, v_0 is the volume of DF prior to hydration, and w_0 is the weight of DF prior to hydration.

Glucose adsorption capacity

The samples' glucose adsorption capacity (GAC) was determined using Chu et al.'s (2019) method. The glucose contents of the supernatants were determined using the DNS method (Miller, 1959). The GAC was calculated using Equation (2).

$$\text{GAC (mmol/g)} = (G_1 - G_2)/W \times V \qquad (2)$$

where G_1 is the glucose concentration before adsorption (mmol/g), G_2 is the glucose concentration after adsorption (mmol/g), W is the weight (g) of the samples, and V is the supernatant volume in mL.

α-amylase inhibition capacity

Ding et al.'s (2020) method was used to determine the α-amylase inhibition capacity (AAIC) of the DFs. AAIC of the samples was determined according to Equation (3).

$$\text{AAIC (\%)} = (A_2 - A_1)/A_2 \times 100 \qquad (3)$$

A_1 is the absorbance of the supernatant containing DF, and A_2 is the absorbance of the supernatant without DF.

Production of Fortified Yoghurt and Determination of Some Quality Characteristics

The raw milk was pasteurized at 95°C for 10 minutes, and DF was added to the milk and mixed for 2 minutes when the milk temperature cooled down to 65°C. IDF, SDF and the equal portion of IDF+SDF were added as 1, 2 and 3% (w/w). When the temperature got to 40°C, the lyophilized bacterial cell culture containing *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacterium lactis* were added to the samples and the mixtures were incubated at 38°C for 12 hours. 38°C was chosen as the incubation temperature to obtain yoghurt having low syneresis, and incubation was terminated after 12 hours when the pH value of the yoghurt was measured as 4.6. Dry matter, protein, fat and ash contents, pH, titratable acidity, viscosity, syneresis, color, and water holding capacity of the fortified and plain yoghurts (control) were determined after 24 hours of production. All analysis were duplicated.

Dry matter, protein, ash, and fat contents

The dry matter, protein, ash, and fat contents were measured by standard AOAC (2000) methods.

Color measurement

CIE $L^*a^*b^*$ color space was used for the color determination of the yoghurt samples, and a Minolta CR-300 colorimeter (Japan) was used for the measurements (Šeregelj et al., 2021).

Titratable acidity and pH

The pH of the samples was evaluated using a WTW Inolab pH 7110 (Germany) pH meter. For the titratable acidity of the samples, two times diluted (by distilled water) yoghurts were titrated with 0.1 M NaOH to pH 8.1. The titratable acidity of the samples was calculated according to Equation 4, where M is the molarity of the NaOH, V is the volume of the NaOH used for the titration, and W is the sample mass (g). 0.9 is the scaling parameter for lactic acid (Dong et al., 2022).

$$\text{Titratable Acidity (\%)} = M \times V \times 0.9/W \qquad (4)$$

Syneresis, viscosity, and water-holding capacity measurements

The whey amount that drained off was used for the syneresis calculation. 25 g yoghurt samples were poured into 50 mL centrifuge tubes, and the tubes were centrifuged at 500 x g for 10 minutes at 4°C. The supernatant phase (whey) was weighed, and the syneresis of the samples was calculated using Equation 5 (Robitaille et al., 2009). The apparent viscosity of the samples was determined with a single-cylinder type rotating viscometer (Viscotester VT-04E, Japan). The cup having 52.6 mm diameter and 75 mm length, was filled with 170 mL of sample, and the rotor (dta. 45x47x160 mm) of the viscometer was inserted. The force acting on the rotor (torque) that rotating at a constant speed (62.5 rpm) was measured, and the apparent viscosity was determined in Deci pascal-seconds (dPa.s, converted to cp). The scale of the device was calibrated according to the JIS Z 8809 viscosity calibration standard. The water-holding capacity of the yoghurts was determined according to the method of Demirci et al. (2017).

$$\text{Syneresis (\%)} = \text{Whey Drained (g)} / \text{Yoghurt (g)} \times 100 \quad (5)$$

Statistical Analysis

Univariate analysis (Duncan post hoc, 95% confidence interval) was carried out using the SPSS 21.0 (IBM, USA) package program.

Results and Discussion

Storage Stability of Dietary Fibers

In the storage stability study, DFs of fenugreek seeds were stored at two different conditions (25°C, 40% RH, and 38°C, 90% RH). The physico-chemical and functional properties were screened for 90 and 180 days. For all physico-chemical and functional properties, IDF had higher initial values than SDF ($p<0.05$) (Table 1). The results of the storage stability study of DFs showed that different storage conditions affected the physico-chemical and functional properties. All properties' values were reduced by increasing storage time (Figure 1 and Figure 2).

As seen in Figure 1 and Figure 2, a faster decrease of all the physico-chemical and functional properties of IDF and SDF was observed for 38°C storage when compared with 25°C. This phenomenon can be explained by the effect of higher temperatures that affected the structure of the DFs during long storage times. Ozyurt and Ötles (2016) reported that DF composition might undergo some changes when different temperatures were applied as processing conditions, and nutritive value, physico-chemical and functional properties of DF might be affected. The reduction of the values calculated as percentages here is based on their initial values (Figure 1 and Figure 2 showed the actual values of the analysis results). For SDF, at 38°C/90% RH and 90 days, water retention capacity (WRC), oil adsorption capacity (OAC), swelling capacity (SC), glucose adsorption capacity (GAC), and α-amylase inhibition capacity (AAIC) values decreased by ~59%, 53%, 60%, 60%, and 55%, respectively; whereas at 25°C/40% RH and 180 days, these values decreased by ~64%, 61%, 55%, 50% and 61%, respectively. For IDF, at 38°C/90% RH and 90 days, WRC, OAC, SC, GAC, and AAIC values reduced by ~%47, %58, %47, %49, and %55, respectively; whereas 25°C/40% RH and 180 days, these values reduced by ~%58, %54, %50, %55 and %69, respectively. Generally, IDF's physico-chemical and functional properties showed better stability than SDF at both storage conditions. This phenomenon could be related to the bioactivity of the polysaccharides present in the IDF and SDF (Dong et al., 2019).

Table 1. Physico-chemical and functional properties of dietary fibers

Property	Insoluble dietary fiber	Soluble dietary fiber
Water retention capacity (g/g)	10.38 (±0.31)^a	4.93 (±0.13)^b
Oil adsorption capacity (g/g)	4.84 (±0.05)^a	2.69 (±0.10)^b
Swelling capacity (mL/g)	12.35 (±0.19)^a	6.21 (±0.12)^b
Glucose adsorption capacity (mmol/g)	15.74 (±0.14)^a	7.75 (±0.18)^b
α-amylase inhibition capacity (%)	20.30 (±0.48)^a	10.64 (±0.39)^b

$^{a-b}$Means with uncommon superscripts within a line are significantly different ($p<0.05$).

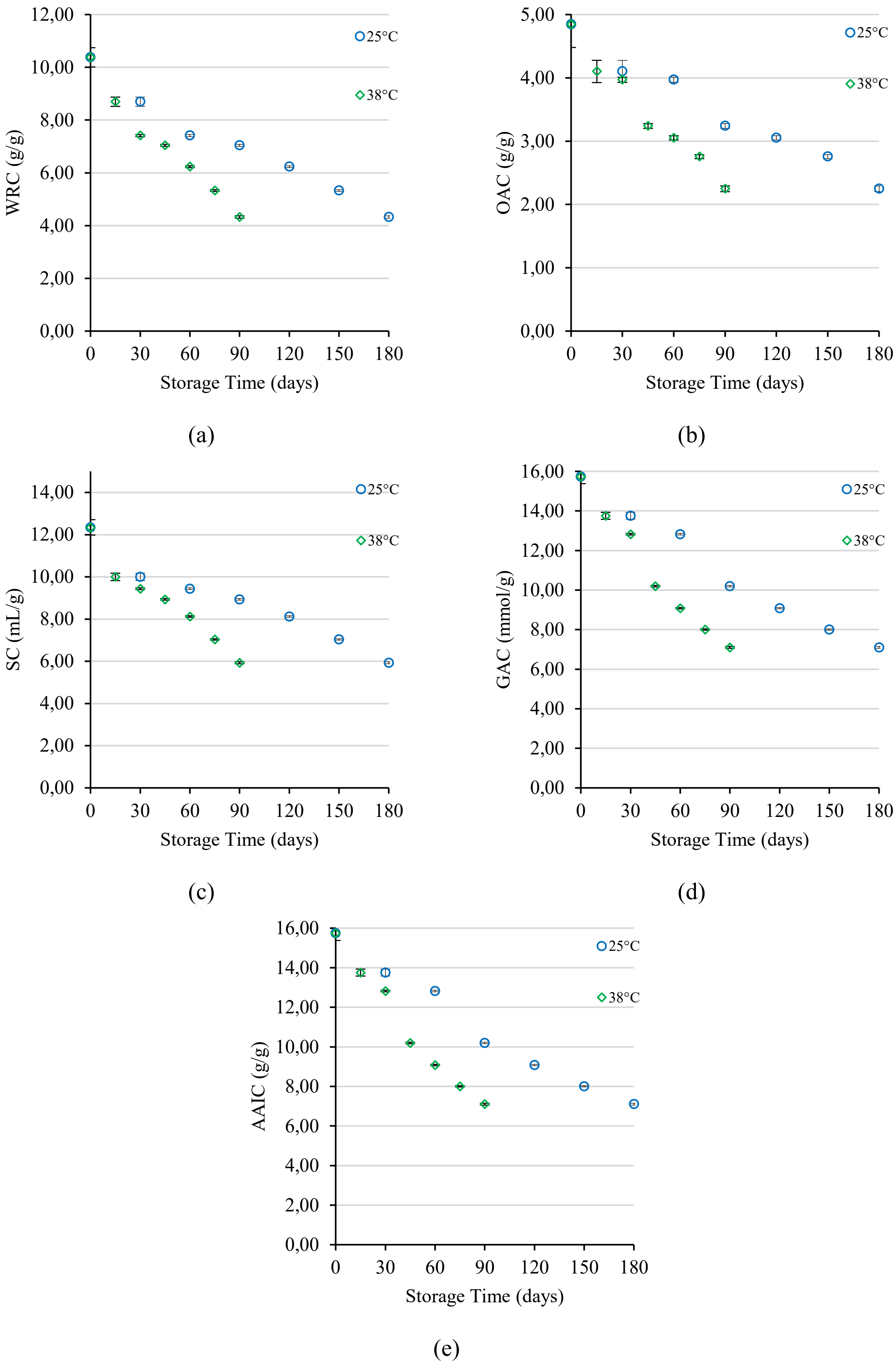

Figure 1. Changes in physico-chemical and functional properties of IDF (a) WRC, (b) OAC, (c) SC, (d) GAC, (e) AAIC

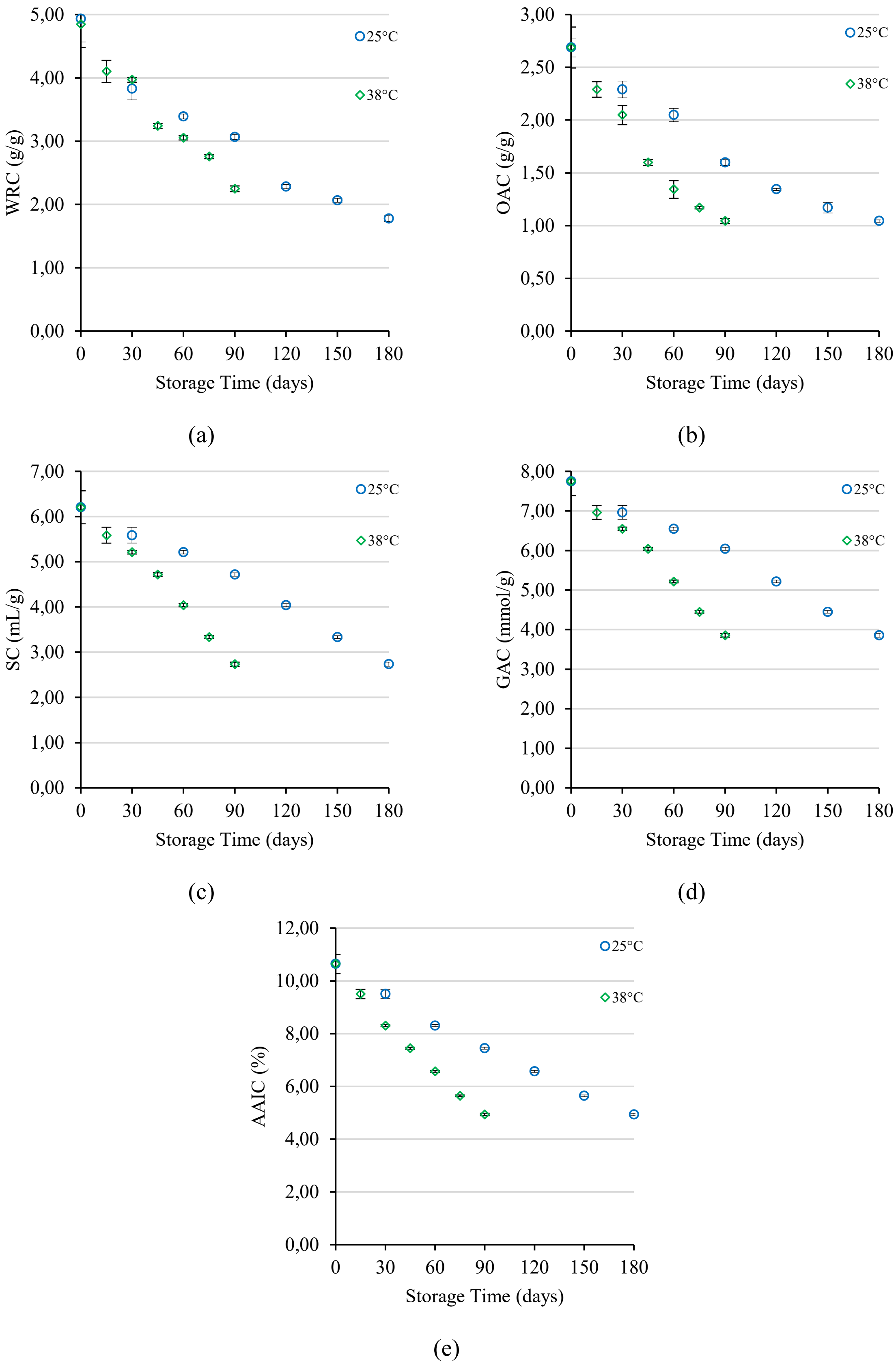

Figure 2. Changes in physico-chemical and functional properties of SDF (a) WRC, (b) OAC, (c) SC, (d) GAC, (e) AAIC

Production of Fortified Yoghurt and Determination of Quality characteristics

The DFs were used for the fortification of yoghurt. Some properties such as pH, titratable acidity, color, protein, dry matter, fat, ash, viscosity, syneresis percentage, and water holding capacity of the IDF and SDF (also the mixture of IDF and SDF) added yoghurt samples were determined, and compared in terms of these properties with additive-free yoghurt (control sample).

pH values of the different samples varied between 4.45 and 4.70. The highest pH was observed when 3% SDF was used, and the sample having the lowest pH value was 3% IDF+SDF. Even though minor pH variations have been found for the different samples, these variations are statistically significant ($p<0.05$) (Table 2). The pH value of the samples was not directly related to the DF type and concentration (Table 2). The pH values proved that the conversion of lactose to lactic acid occurred for all different samples. Mohamed et al. (2014) presented similar results in their study in which they fortified yoghurt with grape pomace. For the titratable acidity, the values of the different samples ranged between 0.97 to 1.15%. The titratable acidity values of the DF-treated samples were significantly higher than that of the control sample ($p<0.05$) (Table 2). There was no correlation between the titratable acidity values and the DF type and/or concentration. Hashim et al. (2009) reported similar findings for the yoghurt produced with date fiber and oat bran. Dong et al. (2022) revealed that there was no statistical difference between the titratable acidity values of the control sample (0.86%) and the SDF extracted by ultrasonic-assisted extraction from the carrot. In our study, the control sample had the lowest titratable acidity value (0.97%), and the DF-treated samples' titratable acidity values were significantly higher ($p<0.05$) (Table 2). Issar et al. (2017) used apple pomace to prepare fiber-enriched yoghurt. They reported that the titratable acidity values decreased when higher apple pomace concentrations were used (0-10%). Researchers explained this phenomenon by dilution effect, and the different results compared to our study can be related to higher concentrations of DFs (Issar et al., 2017).

Table 2. Properties of the fortified yoghurt samples

Analysis	Control	IDF			SDF			IDF+SDF		
		1%	2%	3%	1%	2%	3%	1%	2%	3%
pH	4.63 (±0.05)^{b}	4.55 (±0.00)^{c}	4.51 (±0.00)^{de}	4.49 (±0.01)^{e}	4.53 (±0.00)^{cd}	4.51 (±0.01)^{de}	4.70 (±0.01)^{a}	4.53 (±0.00)^{cd}	4.50 (±0.00)^{de}	4.45 (±0.01)^{f}
Titratable acidity (%)	0.97 (±0.01)^{e}	1.09 (±0.01)^{cd}	1.11 (±0.00)^{bc}	1.14 (±0.00)^{ab}	1.08 (±0.02)^{d}	1.09 (±0.01)^{cd}	1.15 (±0.02)^{a}	1.08 (±0.01)^{d}	1.11 (±0.02)^{bcd}	1.14 (±0.03)^{ab}
L*	87.02 (±1.76)^{a}	80.48 (±0.81)^{cd}	78.12 (±1.23)^{e}	74.91 (±2.48)^{f}	86.74 (±0.87)^{a}	84.17 (±0.57)^{b}	83.21 (±0.52)^{b}	83.51 (±0.53)^{b}	81.02 (±0.97)^{c}	78.86 (±0.22)^{de}
a*	-3.07 (±0.18)^{d}	-3.57 (±0.20)^{g}	-4.18 (±0.09)^{i}	-4.25 (±0.02)^{i}	1.99 (±0.04)^{c}	2.85 (±0.07)^{b}	3.13 (±0.11)^{a}	-3.36 (±0.03)^{f}	-3.35 (±0.07)^{e}	-3.77 (±0.18)^{h}
b*	8.89 (±0.10)^{a}	-1.24 (±0.08)^{f}	-1.66 (±0.10)^{g}	-1.73 (±0.10)^{g}	7.31 (±0.23)^{b}	6.76 (±0.10)^{c}	6.05 (±0.07)^{d}	-0.90 (±0.05)^{e}	-1.27 (±0.06)^{f}	-1.57 (±0.07)^{g}
Protein (%)	3.82 (±0.20)^{e}	3.98 (±0.03)^{cde}	4.01 (±0.05)^{cd}	4.19 (±0.04)^{ab}	3.85 (±0.02)^{de}	4.03 (±0.07)^{bcd}	4.31 (±0.00)^{a}	4.00 (±0.06)^{cd}	4.15 (±0.03)^{abc}	4.21 (±0.04)^{a}
Dry Matter (%)	12.77 (±0.06)^{e}	13.58 (±0.21)^{d}	14.45 (±0.13)^{bc}	15.73 (±0.37)^{a}	13.96 (±0.14)^{cd}	14.55 (±0.21)^{b}	15.61 (±0.45)^{a}	13.89 (±0.09)^{cd}	14.79 (±0.38)^{b}	15.96 (±0.14)^{a}
Fat (%)	1.80 (±0.05)^{a}	1.73 (±0.03)^{b}	1.63 (±0.03)^{cd}	1.47 (±0.03)^{f}	1.68 (±0.03)^{bc}	1.53 (±0.03)^{e}	1.47 (±0.03)^{f}	1.68 (±0.06)^{bc}	1.62 (±0.03)^{d}	1.47 (±0.03)^{f}
Ash (%)	0.80 (±0.01)^{f}	1.08 (±0.08)^{d}	1.28 (±0.00)^{b}	1.44 (±1.44)^{a}	0.97 (±0.05)^{e}	1.08 (±0.02)^{d}	1.17 (±0.01)^{c}	1.04 (±0.02)^{de}	1.11 (±0.00)^{cd}	1.34 (±0.00)^{b}
Viscosity (cp)	840.00 (±26.46)^{f}	1076.67 (±23.09)^{d}	1193.33 (±15.28)^{b}	1273.33 (±25.17)^{a}	996.67 (±20.82)^{e}	1123.33 (±25.17)^{c}	1213.33 (±32.15)^{b}	1043.33 (±20.82)^{d}	1206.67 (±20.82)^{b}	1313.33 (±32.15)^{a}
Syneresis (%)	32.47 (±0.66)^{a}	20.98 (±0.06)^{c}	19.25 (±0.14)^{d}	14.29 (±0.12)^{f}	22.02 (±0.05)^{b}	19.36 (±0.12)^{d}	15.26 (±0.10)^{e}	20.61 (±0.14)^{c}	19.43 (±0.20)^{d}	14.68 (±0.10)^{f}
Water holding capacity (%)	17.29 (±1.18)^{e}	27.03 (±0.61)^{cd}	33.89 (±2.95)^{b}	38.90 (±1.86)^{a}	24.87 (±0.67)^{d}	29.11 (±0.98)^{c}	33.18 (±0.19)^{b}	27.95 (±0.95)^{cd}	34.46 (±1.06)^{b}	38.40 (±0.79)^{a}

IDF: Insoluble Dietary Fiber, SDF: Soluble Dietary Fiber

$^{a-h}$Means with uncommon superscripts within a line are significantly different ($p<0.05$).

Color properties of the yoghurt samples fortified with different concentrations of DFs were determined. Results showed that the brightest sample was the control, and the darkest sample was the yoghurt enriched with 3% fenugreek seed IDF. It was also determined that the L^* values decreased when the IDF or SDF concentration was increased ($p<0.05$, Table 2). Hashim et al. (2009) reported similar findings for the yoghurt fortified with date fiber. When a^* values were examined, it was observed that the increment in IDF percentage decreased the a^* values of the samples ($p<0.05$, Table 2). On the other hand, a^* values increased when the SDF percentage was increased ($p<0.05$). b^* values of the samples also showed a difference, and the yellowness of the control sample decreased by adding DFs. The decline in IDF samples was the most significant, and both DFs reduced the yellowness of the yoghurt at increasing concentrations ($p<0.05$, Table 2). In general, researchers reported that the color of DF-fortified yoghurt samples is mainly dependent on the color of the fiber source (Staffolo et al., 2004; Sanz et al., 2008; Tomic et al., 2017).

Protein, dry matter, and ash contents of the control yoghurt samples, and the samples fortified with DFs were determined, and all values of the fortified samples were higher than that of the control ($p<0.05$, Table 2). On the other hand, the highest fat content was observed for the control sample, and this phenomenon can be explained by the dilution effect of the DFs on yoghurt ($p<0.05$, Table 2). The Food and Drug Administration standards define low-fat yoghurt as having <0.20% fat before adding other ingredients (Chandan et al., 2006). Hence, our yoghurt products (both DFs added) can be considered low-fat yoghurt, and quite similar results were reported by Issar et al. (2017).

The viscosity, syneresis, and water-holding capacity of the samples are given in Table 2. When compared with the control, the viscosity, and water-holding capacity of the samples having DFs increased at increasing percentages of DFs, and the syneresis of the samples decreased ($p<0.05$, Table 2). Syneresis of the control sample reduced by 18.18% when 3% IDF was used. Yildiz and Ozcan (2019) reported similar observations for the vegetable DF-added yoghurts, and they revealed that the highest syneresis observations were done for the samples having the lowest viscosity. The protection mechanism of DFs from syneresis can be explained by their binding water capacity to trap whey casein gel (Wang et al., 2019). Moreover, DFs also can prevent the aggregation of casein due to the electrostatic interaction between casein and pectin, and the gel network of the yoghurt can be stabilized (Dong et al., 2022). DFs obtained from food matrices have ability to affect the stability of the foods that they are added to due to their water binding capacities. When DFs added to yoghurt, the interactions within the protein can be enhanced, and the viscosity of yoghurt increases (Staffolo et al., 2004; Yildiz and Ozcan, 2019). IDF-added yoghurt samples showed higher viscosity, water-holding capacity, and lower syneresis than SDF-added yoghurt samples. This phenomenon can be related to the physico-chemical properties of DFs, and individual IDF samples showed higher water retention capacity than that of SDF samples (Table 2). Dong et al. (2019) studied the structural properties of the IDF and SDF from foxtail millet (*Setaria italica*) bran, and they reported that IDF had a higher water retention capacity than the SDF. Ding et al. (2020) also reported higher water retention capacity values for IDF from *Nannochloropsis oceanica* compared to its SDF.

Conclusion

In this study, DFs obtained from fenugreek seeds were stored at two different conditions, and some quality properties of fortified yoghurt were investigated. The changes in the physico-chemical and functional properties were determined for 90 and 180 days of storage times. Moreover, yoghurt was fortified with isolated DFs, and some quality characteristics of DF-fortified yoghurt were determined. Results showed that the physico-chemical and functional properties of DFs were changed under different storage conditions, and these data can be useful for the production and storage planning of DFs from fenugreek. Fortified yoghurts showed better gel formation when viscosity, syneresis, and water-holding capacity values were examined. A new and cheap source was introduced, and the daily intake of DFs can be increased by usage of them in a frequently consumed product such as yoghurt. Its advantages, such as having good physico-chemical and functional properties and being natural, inexpensive, and long-lasting stability and abundance, make fenugreek DFs appropriate alternative for the commercial use. The results obtained for the yoghurt having DFs can be useful for commercial applications which produce enriched or fortified functional foods.

Compliance with Ethical Standards

Conflict of interests: The authors declare that for this article, they have no actual, potential, or perceived conflict of interest.

Ethics committee approval: The Authors declare that this study does not include any experiments with human or animal subjects.

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Disclosure: -

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