Turkish Journal of Agriculture - Food Science and Technology, 11(12): 2323-2331, 2023
DOI: https://doi.org/10.24925/turjaf.v11i12.2323-2331.6300

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effect of Fenugreek Gum and Eggplant Peel Extract on Physicochemical, Storage, Bioactive, and Sensory Properties of Dairy Dessert

Nalan Yazıcıoğlu[1,a,*]

[1]*Nutrition and Dietetics, Gulhane Health Science Faculty, Saglik Bilimleri University, 06018, Ankara, Türkiye*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 19.08.2023
Accepted : 07.12.2023

Keywords:
Eggplant peel extract
Fenugreek gum
Pudding
Anthocyanin
Antioxidant activity

ABSTRACT

The objective of this research was to examine the impact of fenugreek gum and eggplant peel extract on multiple characteristics of rice pudding, encompassing parameters such as total soluble solids content, pH, color, syneresis index, storage stability, total phenolic content, antioxidant activity, flavonoid, and anthocyanin content, along with a sensory evaluation using a 5-point hedonic scale. Different concentrations of fenugreek gum (0%, 0.2%, 0.4%) and eggplant peel extract (0%, 0.25%, 0.5%) were prepared and incorporated into the rice pudding formulation at varying levels. Higher concentrations of fenugreek gum and eggplant peel extract in the pudding resulted in improved syneresis percentage (68.25±0.42%). This result shows reduced water release and improved storage stability. The addition of fenugreek gum also positively associated with increased storage stability, while eggplant peel extract had no significant effect. Furthermore, while the content of monomeric anthocyanins, total phenolics, total flavonoids, and antioxidant activity in the rice pudding samples increased with higher concentrations of eggplant peel extract, consumer acceptance scores were reported to be very low.

[a] *nalan.yazicioglu@sbu.edu.tr* *https://orcid.org/0000-0001-9569-3361*

Introduction

During production and preparation of food, a large volume of waste is produced by the food industry (Van den Abeele et al., 2017). About one-third of the global food production for human consumption, which is estimated as 1.3-1.6 billion tons of food, is discarded as waste along the entire food supply chain worldwide (Papaioannou et al., 2022). According to the Food and Agriculture Organization (FAO) State of Food and Agriculture (2022) report, after food is harvested in the world, around 14% of it is lost (a value of $400 billion per year). Seeds, peels, pomace, and stems of fruits and vegetables are thrown away even though they possess nutritional compounds such as polyphenols, carotenoids, and dietary fibers. Moreover, for some fruits even the peel contains much more bioactive compounds than the fruit pulp. For example, skins of avocados, lemons, seeds, grapes, jackfruits, and mangoes contain 15% more phenolic compound concentrations than the flesh of the fruit (Gorinstein et al., 2001; Soong and Barlow, 2004; Bhardwaj et al., 2022). Thus, in addition to environmental and economic reasons, recovery of waste in the food industry to obtain useful, cheap, new, high added value and natural products has become increasingly important in scientific research. Moreover, per capita intake of dairy products in Turkey is comparatively lower than that observed in developed nations (Goenenc and Tanrıvermiş, 2008). Thus, there is a pressing need for implementing effective production practices aimed at minimizing additives to augment the demand for this food category in consumer preferences. It is imperative to underscore that this study focuses on a zero waste approach, integrating bioactive nutritional components into the production process.

Eggplant (Solanum melongena L.) is an important vegetable produced in many countries mainly China, India, Egypt, and Türkiye with capacities of 36.6, 12.8, 1.3, and 0.8 million tons, respectively (FAO, 2022). The purple-colored skin of the eggplant is usually peeled off and thrown away in household use and the food industry. Eggplant peel waste was estimated to be around 117,558 tons in Türkiye (Karimi et al., 2021). Eggplant peel is an enormously rich source of anthocyanin with contents varying from 8 to 85 mg per 100 g of peel (Dranca and Oroian, 2016) and pectin (Mauro et al., 2020; Karimi et al., 2021).

Dairy desserts are highly appreciated for their sensory and nutritional properties and are fortified with phenolic extracts in the literature (Kaur et al., 2021; Kaur et al., 2022; Elkot et al., 2022) since they impart a variety of health benefits such as inhibition of cancer and brain cells degeneration, decreasing the risk of inflammatory and circulatory diseases (Yousuf et al., 2015). Blueberry (*Vaccinium myrtillus L.*) and strawberry tree fruits (*Arbutus unedo L.*) were used as a natural ingredient containing high phenolic compounds mainly anthocyanins in ice cream production to increase the nutraceutical potential and nutritive value (Kotan, 2018; Aloğlu et al., 2018). Moreover, when dairy dessert was enriched with beet or ginger or a combination of beet with ginger sensory characteristics and level of acceptance improved as compared to control (Bandyopadhyay et al., 2008).

Rice pudding is one of the most common dairy desserts produced with emulsifiers, and stabilizers like commercial water-soluble gum found in guar seed (Singh and Immanuel, 2022; Toker et al., 2013). Puddings containing carrageenan, alginate, guar and xanthan gums and their combinations were investigated and found that carrageenan was the most effective hydrocolloid on both the steady and dynamic rheological parameters of pudding samples (Toker et al., 2013). Yellow mustard mucilage, fenugreek gum, flaxseed mucilage containing puddings decreased blood glucose and plasma insulin compared to a control pudding, but did not differ from each other (Kay et al., 2017). A creamy mouth feel and smooth texture of a pudding system were achieved by the addition of gums such as xanthan gum (Sanderson et al., 1988). However, in reviewing the literature, no study was found about the investigation of the effect of fenugreek gum and eggplant peel extract in rice puddings in terms of physicochemical, sensory, and bioactive properties. Therefore, in this study, it was aimed to investigate the effect of the addition of fenugreek gum as a thickener, emulsifier and stabilizer and eggplant peel extract as an anthocyanin source in rice pudding. Moreover, the effect of different amounts of fenugreek gum (0%, 0.2% and 0.4%) and eggplant peel extract (0%, 0.25%, and 0.5%) on total soluble solids content, pH, color, syneresis index, storage stability, total phenolic, flavonoid, anthocyanin contents, antioxidant activity and sensory analysis of puddings were investigated. Puddings fortified with eggplant peel extract and fenugreek gum may target consumer groups who generally show interest in healthy eating and natural additives and seek diverse flavor experiences. Particularly, these products could be popular among consumers who prioritize healthy snacks, prefer natural and functional food products, and have an interest in organic and natural ingredients with a consideration for environmental sustainability.

Materials and Methods

Materials

Fenugreek seeds (*Trigonella foenum graecum* L., harvested in 2022) and eggplant (*Solanum melongena* L., harvested in 2023) were purchased from a local store. Folin–Ciocalteau reagent, sodium carbonate, 2,2-Diphenyl-1-picrylhydrazyl, and ethanol, HCl were bought from Sigma-Aldrich Chemie GmbH (Darmstadt, Germany). Eggplant peel was chosen as an ingredient for the study due to its abundant availability as a waste product, making it an environmentally sustainable option. It is rich in anthocyanins and pectin, which have potential health benefits. Fenugreek gum, on the other hand, was selected as it can serve as a thickener, emulsifier, and stabilizer in the rice pudding formulation.

Fenugreek Gum Extraction

Fenugreek gum extraction was formulated according to the method described by Hussain et al. (2022) with minor modifications. An amount of 100 g ground fenugreek seeds was soaked in 1000 ml of distilled water at room temperature (22 °C) for 16 h. Then, the swollen seeds were heated to 100 °C in a water bath until a slurry was formed. Thereafter, the solution was kept at 4 °C for the precipitation of any insoluble particle. The seeds were filtered by cheese cloth then the solution was washed with 400 ml of acetone repeatedly and dried at room temperature for 24 h.

Extraction of Eggplant Peel Bioactive Compounds

Fresh, large, elongated, deep purple-colored eggplants with green calyx were peeled using a peeler. The collected peels were dried at room temperature at dark for 48 h. Deep purple colored eggplant peels (100 g) were extracted with 80% ethanol solution with 1% HCl at 4°C for 24 h (Yong et al., 2019). Then, the solution was centrifuged (5000 g) for 15 min, condensed at 35 °C and dried under vacuum.

Preparation of Pudding Samples

The ingredients for the preparation of fenugreek gum-eggplant peel extract incorporated into rice puddings are shown in Table 1.

Table 1. Formula of pudding preparations fortified with fenugreek gum and eggplant peel extract

Sample	Milk (g/100g)	Sugar (g/100g)	Fenugreek gum (g/100g)	Eggplant peel extract (g/100g)	Rice starch (g/100g)
G0E0	81.8	10	0.00	0	8.2
G0E0.5	81.8	10	0.00	0.5	7.7
G0E1	81.8	10	0.00	1	7.2
G0.2E0	81.8	10	0.20	0	8
G0.2E0.5	81.8	10	0.20	0.5	7.5
G0.2E1	81.8	10	0.20	1	7
G0.4E0	81.8	10	0.40	0	7.8
G0.4E0.5	81.8	10	0.40	0.5	7.3
G0.4E1	81.8	10	0.40	1	6.8

Solid and liquid proportions of the samples were kept constant. Fenugreek gum, eggplant peel extract and rice starch amount in total was 8.2% (w/w) of pudding samples. In the abbreviation in Table 1, the letter "G" stands for gum, the letter "E" stands for extract, and the numbers in between represent the percentages of each component in the formulation, respectively. The preparation method was based on Ares et al. (2009). First dry ingredients except eggplant peel extract were mixed then milk was added. The mixture was heated at 90°C for 15 min by using a water bath with agitation. Thereafter, eggplant peel extract was added after cooling to room temperature (25°C) and then stored in a refrigerator (4°C) for 12 h prior to experiments.

Total Soluble Solids and pH Value

Total soluble solids (TSS) were reported as °Brix using a hand refractometer (Loyka ATC 0–50%, Turkey), at ambient temperature (Lee and Choi, 2020). First, pudding samples (10 g) were homogenized with 20 ml of distilled water by magnetic stirrer at 150 rpm at room temperature for 1 h. Samples were centrifuged at 3000 g for 5 min. The Brix and pH value of the supernatant were determined by refractometer and pH meter (Ohaus ST10, NJ, USA), respectively. The measurements were taken in triplicate and the mean value was reported.

Degree of Syneresis (%)

Syneresis is an important undesired defect observed in starch-containing foods such as desserts due to retrogradation. The method described by Kumar et al. (2022) was used with slight modification. Pudding samples (5 g) at 4°C were transferred into a 15 ml centrifuge tube and centrifuged at 4000 rpm (Elektro-Mag M 815, Turkey) for 15 min. The degree of syneresis was calculated using the equation below.

$$\text{Syneresis (\%)} = \frac{\text{Supernatant weight (g)}}{\text{Product weight (g)}} \times 100 \qquad (1)$$

Storage Stability (%)

Storage stability (SS) was determined according to the method described by Fundagül, (2023). Plastic cups containing 10 g of pudding samples were weighed and sealed with aluminum foil. After 72 h of storage at 4°C samples were brought to room temperature. Free water leached from the pudding was drained and storage stability was calculated by the equation below.

$$\text{SS (\%)} = \frac{\text{WSWL}}{\text{WS}} \times 100 \qquad (2)$$

SS : Storage Stability (%)
WSWL : Weight of the sample after water leaching
WS : Weight of the sample

Color

A colorimeter (TES 135A Color Reader, TES, Taiwan) was used to measure color parameters such as L*, a*, b* values. The L* value represents the lightness ranging from black (L* = 0) to white (L* = 100), the a* value measures the redness ranging from green (−60) to red (60), and the b* value represents the yellowness ranging from blue (−60) to yellow (60). For each pudding sample an average of values obtained from five different points were considered.

Determination of Total Phenolic Content of Pudding Samples

Total phenolic content of pudding samples was determined by Folin-Ciocalteu method (Waterhouse, 2002). Although the Folin-Ciocalteu reagent has the potential to react with interfering substances like ascorbic acid, dehydroascorbic acid, and reducing sugars (glucose and fructose) in plant extracts (Sánchez-Rangel et al., 2013), this method was used as a comparative technique in this research to select the best formulation. Pudding samples weighing 10 g were combined with 20 ml of 99.8% ethanol and subsequently centrifuged at 3000 × g for 10 minutes. 20 µL of the supernatant was mixed with 100 µL of Folin-Ciocalteu reagent and 1.58 mL of distilled water. The mixture was incubated for 6 min. Na_2CO_3 stock solution (20%) of 300 µL was added to the mixture. After 2 h of incubation at room temperature in the dark, the absorbance was recorded at 765 nm by using Spectrophotometer (T80+, UV/Vis. spectrometer, PG Instrument Ltd.) with three replications. Blank was prepared using the same procedure but without the sample.

Determination of Antioxidant Activity of Pudding Samples

DPPH (1, 1-diphenyl-2-picrylhydrazyl) radical inhibition method was used to evaluate the antioxidant activity of pudding samples (González-Aguilar et al., 2007). Due to the higher correlation observed between the DPPH method with other commonly employed techniques for assessing antioxidant activity of eggplant, namely CUPRAC, FRAP, and TEAC (Kaur et al., 2014), the DPPH method was utilized for relative calculations rather than determining absolute values. The supernatant of the with a volume of 0.1 mL was mixed with 3.9 mL of a 0.6 mM DPPH 80% ethanolic solution. The solution was left in the dark for 1 h then the absorbance was measured at 515 nm by using the spectrophotometer with ethanol as control. Percent antioxidant activity was calculated using the formula represented below.

$$\text{AOA (\%)} = \frac{A_c - A_s}{A_c} \times 100 \qquad (3)$$

Where, As is the absorbance of the sample and Ac is the absorbance of control.

Determination of Total Flavonoid Content of Pudding Samples

Total flavonoid content was measured according to the study of Adhikari et al. (2019). 250 µL of extract or standard solution was mixed with 1.25 mL H2O and 75 µL 5% NaNO2 solution. After 6 min incubation, 150 µL of 10% AlCl3 -H2O solution was transferred and 0.5 mL of 1 M NaOH and 275 µL ethanol was added. The absorbance of the mixture was measured at 510 nm using a UV-VIS Spectrophotometer (T80+ UV/VIS Spectrophotometer, PG Instruments Ltd., China). The results were expressed as catechin equivalents (CE) per gram of dry weight (mg CE/g sample).

Determination of the Monomeric Anthocyanin Content of Pudding Samples

The monomeric anthocyanin content (MAC) of pudding samples was determined by pH differential method described by Lee et al. (2005). The supernatant (1 ml) was mixed with two buffer solutions at pH 1.0 and 4.5. Thereafter, the absorbance of solutions was recorded at 510 and 700 nm and monomeric anthocyanin content (MAC) was determined by the formula below:

$$\mathrm{MAC} = \frac{\mathrm{A \times Mw \times Df \times 1000}}{\varepsilon \times \mathrm{L}} \quad (4)$$

$$\mathrm{A} = [(\mathrm{A}_{520} - \mathrm{A}_{700})_{\mathrm{pH1.0}} - (\mathrm{A}_{520} - \mathrm{A}_{700})_{\mathrm{pH4.5}} \quad (5)$$

Mw is molecular weight of delphinidin-3-glucoside (465 g/mol), ε is the molar extinction coefficient of delphinidin-3-glucoside (26,900 L/mol/cm), L is pathlength (1 cm), Df is the dilution factor, 1000 is factor for conversion from g to mg. The results were expressed as mg of delphinidin-3-glucoside equivalents (D3G) per gram of dry extract.

Sensory Analysis

A voluntary sensory evaluation was performed on pudding samples by 20 semi-trained panelists of ages between 18 and 35. An informatory session was provided to the panelists before the analysis. Samples were coded and presented to the panelists at room temperature in a fluorescent-lit room between 09:00 and 15:00. Panelists were supposed to not eat or chew gum for 1 hour beforehand. Between pudding samples, the panelists were asked to wait one minute and drink water as a mouth rinse. Pudding samples (9 samples) were served in plastic clear cups and the panelists were asked whether they liked the appearance, taste, smell, consistency of the appearance, consistency in the mouth and general acceptability with a 5-point hedonic scale ranging from 1 (“dislike extremely”) to 5 (“like extremely”).

Statistical Analysis

The analysis of variance (ANOVA) was conducted on data encompassing various responses, including total soluble solids content, pH, color, syneresis index, storage stability, total phenolic content, antioxidant capacity, flavonoid levels, anthocyanin activity, and sensory evaluation. This analysis aimed to assess the impact of factors such as extract content and gum concentration. Subsequently, the means were compared using the Tukey post hoc test in MINITAB, with a significance level set at P<0.05.

Results and Discussion

Effect of Fenugreek Gum and Eggplant Peel Extract Concentration on Physicochemical Properties of Pudding Samples

Total soluble solids (TSS), measured in °Brix to determine the concentration of dissolved solids in a liquid solution. Brix is a measurement unit used to quantify the soluble solids in a liquid solution. Brix can also be used to measure the total soluble solids content of a solution that may include other dissolved solids besides sucrose, such as other sugars, acids, and other dissolved solids (Cavalcanti et al., 2008). When the concentration of dissolved solids increases in a liquid, the refractive index also increases, and a refractometer measures higher Brix value of a solution. Table 2 shows the total soluble solids of pudding samples ranged from 6.98±0.11 to 9.25±0.07 °Brix being the highest for the G0E0 and lowest for the G0.4E1 samples. Aronia, acknowledged as a source of anthocyanins and phenolic compounds in the diet, contributed to the increase in total soluble solids in the pudding samples from 3.53 ± 0.06 to 4.40 ± 0.00 (Lee and Choi, 2020). It was seen that gum and extract and their interaction cause significant (P<0.05) differences in the Brix values. When 0.4% fenugreek gum and 1% eggplant peel extract were added to the pudding formulas, the TSS decreased from 9.25±0.07 to 6.98±0.11 °Brix (P<0.05). Solids and liquids content in the formulations were kept constant, thus as fenugreek gum and eggplant extract content increases rice starch content decreases. This may have something to do with the fenugreek gum and eggplant extract not dissolving as much as the rice starch.

The pH values of pudding samples ranged from 6.35±0.08 to 6.75±0.08 (Table 2.). The addition of fenugreek gum in the formula did not significantly affect the pH value, on the contrary, eggplant peel extract significantly decreased pH value (P<0.05). The results were in agreement with those reported by Mirani and Goli (2021). The decrease in pH can be due to the antioxidant activity of the anthocyanin in eggplant and its high phenolic content.

Table 2. Physicochemical and storage properties of different pudding samples

	Total soluble solids	pH value	Degree of syneresis (%)	Storage stability (%)
G0E0	9.25±0.07a	6.75±0.078a	74.08±1.25b,c,d	96.06±1.33c,d
G0E0.5	8.51±0.01b	6.55±0.07a,b,c	72.99±0.12c,d	94.97±0.27c,d
G0E1	7.48±0.04d	6.35±0.078c	73.40±0.50c,d	97.20±0.92a,b,c
G0.2E0	8.13±0.04c	6.65±0.078a,b	75.32±0.59b,c	97.15±0.43b,c
G0.2E0.5	8.05±0.07c	6.45±0.07b,c	78.05±0.78a	96.41±0.73c
G0.2E1	7.48±0.04d	6.45±0.07b,c	76.42±0.45a,b	93.22±0.33d
G0.4E0	6.93±0.11e	6.65±0.07a,b	72.57±0.75d,e	99.07±0.28a,b
G0.4E0.5	7.48±0.04d	6.45±0.07b,c	70.09±0.08e,f	99.69±0.08a
G0.4E1	6.98±0.11e	6.45±0.07b,c	68.25±0.42f	99.21±0.23a,b

Results are given as mean ± standard deviation. Different letters in a column refer to significant differences (P<0.05). G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

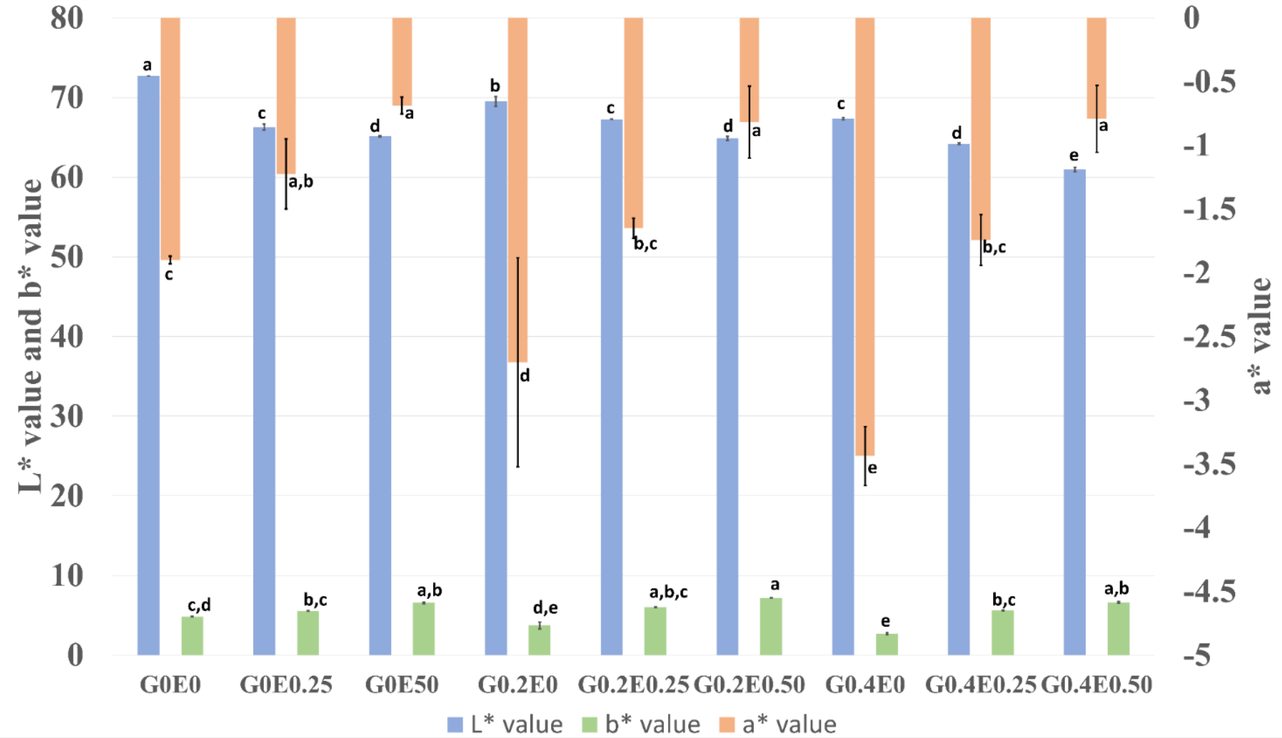

Figure 1. Instrumental color parameters (L*,a*,b*) of pudding samples

Different letters on columns refer to significant differences (P<0.05). G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

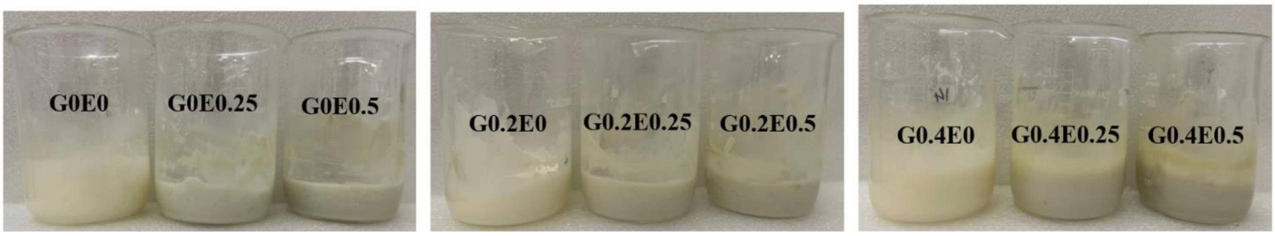

Figure 2. Color of pudding samples

G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

Color is one of the consumer preferred quality parameters for rice pudding. Instrumental color parameters (L*,a*,b*) of pudding samples were presented in Figure 1 and photos of samples were given in Figure 2. The color of pudding samples showed significant ($P\leq 0.05$) variation in color values. The L*values, representing darkness–lightness (from 0 to 100), significantly decrease as fenugreek gum and eggplant peel extract were incorporated into the blends. As fenugreek gum concentration increases and eggplant peel extract concentration decreases, a* and b* values were decreased representing greenness-redness (from negative to positive) and blueness–yellowness (from negative to positive), respectively. However, as there isn't a study specifically addressing the addition of fenugreek gum to dairy products, such comparisons might be done by examining it in relation to a type of bread, chapatti, where fenugreek gum notably affected the lightness value, resulting in a slightly darker color compared to the control sample (Tandon et al., 2021). Mohite and Chandel (2020) utilized the fenugreek mucilage in edible taro starch film packaging and obtained a slightly darker and yellowish-colored film. The chlorophyll pigment leads to the darker color of eggplants whereas the purple color was characterized by the presence of a significant amount of anthocyanins, mainly delphinidin-based pigments (Horincar et al., 2020). A similar change in color was observed as eggplant was introduced into the formula such as the substitution of starch with eggplant flour in edible film decreased L*, while increasing a* and b*, significantly (Nouraddini et al., 2018).

Effect of Fenugreek Gum and Eggplant Peel Extract Concentration on Storage Properties of Pudding Samples

Degree of syneresis refers to the release of liquid or water from a gel or solid, resulting in the contraction or separation of the gel (Ngamlerst et al., 2022) and represents quality change in pudding products. Texture, appearance, and overall quality of the food product can change as a result of syneresis. Thus, it is generally considered undesirable as it can lead to reduced product quality and shelf life. Syneresis percentage of fenugreek gum-eggplant peel extract incorporated pudding significantly (P<0.05) improved as gum and extract concentration were increased. Total syneresis percentage, after 4000 rpm centrifugal spinning for 15 min, ranged from 68.25±0.42% to 78.05±0.78% corresponding to pudding samples G0.4E1 and G0.2E0.5, respectively (Table 2). Sattar et al. (2017) also reported high syneresis value for rice starch puddings. Increasing the concentration of gum in the pudding matrix resulted in reduced syneresis (P<0.05). When 0.2% fenugreek gum was added, it exhibited increased syneresis compared to samples without gum. This was attributed to the lower water-holding capacity of 0.2% gum in the matrix than rice starch, whereas 0.4% gum indicated greater water-holding capacity than rice starch. Similar results were observed by da Silva Costa et al. (2020) such as 0.50% guar gum and xanthan gum addition on the starch gels made from the arrowroot inhibit the syneresis. Gums promote the establishment of numerous hydrogen bonds between water molecules and hydrophilic groups of gum molecules leading to a decrease in water activity and more restriction of molecular mobility.

Storage stability shows the stability of pudding samples after 72 h of storage at refrigeration temperature (4 °C). Storage stability of samples were in the range of 93.22±0.33% and 99.69±0.08%. It can be concluded that the pudding samples could be considered to have good storage stability. Moreover, fenugreek gum addition from 0.2% to 0.4% significantly increased storage stability (P<0.05) whereas eggplant peel extract concentration had no effect on storage stability. A good negative correlation was found between storage stability and syneresis with a Pearson correlation of 65.4% (P<0.05). Although high syneresis values were observed after 4000 rpm centrifuge for 15 min, their effect on storage stability was less. Without centrifugal force, high concentrations of fenugreek gum can create a more rigid structure, which can absorb water and prevent its release leading to high storage stability.

Effect of Fenugreek Gum and Eggplant Peel Extract Concentration on Bioactive Properties of Pudding Samples

In the flavonoid family, anthocyanins are responsible for purple color in eggplants, as well as in many other fruits, vegetables, and flowers. Anthocyanins are glycosides of polyhydroxy and polymethoxy derivatives of 2-phenylbenzopyrylium or flavylium salts (Kong et al., 2003). Delphinidin, petunidin, and malvidin are some of the common anthocyanins in eggplants found in the skin and flesh of the fruit. The darker the purple color of the eggplant, the higher the anthocyanin content. Anthocyanins are known for their antioxidant properties, which help to neutralize harmful free radicals in the body. MAC of the pudding samples was significantly affected by eggplant peel extract amount in the formulations (P<0.05). The amount of anthocyanin content was increased from 1.23±0.37 to 5.13±0.02 mg CGE/g of sample as eggplant peel amount was increased from 0% to 1%. The presence of slight MAC values in samples without added extract could be attributed to potential interference from certain interfering compounds (antioxidants, reducing sugars, organic acids, minerals, and amino acids) in the MAC analysis (de Oliveira et al., 2017). Eggplant peel anthocyanins were investigated by other researchers. Akhbari et al. (2019) reported that by different extraction conditions anthocyanin content from 6.20 to 434.91 mg CGE/100 g eggplant powder could be extracted, being the highest value was obtained under the following conditions: 90 min extraction time, 37 °C, and solvent/solid ratio of 10 mL/g using 100% acidified solvent. Eggplant peel added food formulations improved the anthocyanin content. The eggplant peel powder was added to the pastry cream in different concentrations (5% and 10%) and MAC of minimum 0.100 ± 0.008 and maximum 0.255 ± 0.017 mg D3G/g DW were obtained (Horincar et al., 2020). Lowbush or wild blueberry and soy protein frozen dessert was found to have an anthocyanin content ranging from 21 ± 4 to 48 ± 6 (mg/100 g) (Teh et al., 2005). Furthermore, MAC had higher Pearson correlation coefficient of 83% and 90.3% with TPC and AOA, respectively (P<0.05). G0E0 had minimum TPC among other pudding samples with an amount of 2.47±0.60 µg/mg, whereas G0E1 had the highest with 33.11±0.30 µg/mg. It is evident that even with the addition of 1% extract, the substantial increase in TPC levels is attributed to the high phenolic content in the eggplant peel extract. This is supported by the fact that TPC of eggplant extract were found to be in the range of 851.67 to 3030.25 mg GAE/100 g extract (Akhbari et al., 2019). Gum content of 0.2% had similar effect on TPC whereas 0.4% gum content significantly increased TPC when eggplant peel extract concentration was 0.5%. Eggplant peel extract significantly affected the TPC with a rapid increase as the content increases from 0.5% to 1% (P<0.05). The AOA analysis relied on the principle of DPPH radical reduction to DPPH2 by receiving a hydrogen atom from an antioxidant. As observed in Table 3, an increase in the extract amount without gum resulted in a significant rise in AOA values from 21.35 ± 1.56% to 54.96 ± 0.87% and total flavonoid content from 0.20±0.001 to 0.26±0.001 catechin equivalents (CE) per gram of dry weight (P<0.05). Similarly, eggplant peel extracts' AOA was found to be in the range of 58.81 ± 1.1% and 63 ± 0.48% (Boulekbache-Makhlouf et al., 2013). The primary source of antioxidant activity within eggplant peel arises from its phenolic compounds, which comprise diverse substances including flavonoids, polyphenols, and anthocyanins. These compounds demonstrate potent antioxidant properties, engaging with free radicals within the body to diminish oxidative stress. Consequently, eggplant peel showcases antioxidant activity, potentially offering health benefits.

Effect of Fenugreek Gum and Eggplant Peel Extract Concentration on Sensory Properties of Pudding Samples

The increasing demand of consumers for healthy and beneficial foods, particularly those with high antioxidant content, has been steadily rising. Nevertheless, the sensory attributes of a food, which greatly impact its acceptance by consumers, remain a crucial factor to consider. As the panelists were unaware of the specific ingredients used in the puddings prior to evaluation, they were unable to correctly identify the flavors of fenugreek and eggplant in the samples.

Table 3. Antioxidant properties of pudding samples enriched by fenugreek gum and eggplant peel extract

Samples	MAC	TPC	TFC	AOA
G0E0	1.27±0.46e	2.47±0.60f	0.20±0.001g	21.35±1.56d
G0E0.5	3.20±0.08c,d	5.95±0.45e	0.23±0.001e	32.72±1.49c
G0E1	5.13±0.02a	33.11±0.30a	0.26±0.001d	54.96±0.87b
G0.2E0	1.87±0.88d,e	7.63±0.15d	0.26±0.001c	20.00±1.74d
G0.2E0.5	3.65±0.14b,c	8.16±0.15d	0.22±0.002f	34.79±1.37c
G0.2E1	5.01±0.16a,b	25.74±0.30b	0.27±0.001a	71.48±0.61a
G0.4E0	1.23±0.37e	7.42±0.15d	0.26±0.001c,d	21.58±1.66d
G0.4E0.5	3.63±0.06b,c	14.58±0.01c	0.23±0.001f	36.28±0.31c
G0.4E1	4.09±0.04a,b,c	26.26±0.30b	0.26±0.001b	52.88±0.002b

Results are given as mean ± standard deviation. Different letters in a column refer to significant differences (P<0.05). MAC is monomeric anthocyanin content in mg of delphinidin-3-glucoside equivalents/g, TPC is total phenolic content in µg of gallic acid equivalent /mg, TFC is total flavonoid content in mg catechin equivalents/g, AOA is antioxidant activity in percent inhibition. G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

Table 4. Results of sensory analysis

	Appearance	Taste	Smell	Consistency of the appearance	Consistency in the mouth	General acceptability
G0E0	4.70±0.47a	4.8±0.4104a	4.80±0.4104a	4.50±0.827a	4.50±0.827a	4.80±0.4104a
G0E0.5	3.45±1.099b,c,d	3.30±1.129c	3.65±0.933b,c	3.50±0.761c,d	3.40±1.046b,c,d	3.55±1.05b,c,d
G0E1	2.80±0.834d,e	2.95±1.191c,d	2.90±1.119c	3.10±0.788c,d	3.10±1.252c,d	2.90±0.641c,d
G0.2E0	4.05±0.887a,b,c	3.65±0.745b,c	3.40±0.94b,c	3.60±0.754b,c	3.40±0.503b,c,d	3.15±0.813c,d
G0.2E0.5	2.90±0.852d,e	2.75±1.07c,d	2.95±1.191c	3.25±0.716c,d	3.00±0.562c,d	3.05±0.759c,d
G0.2E1	2.65±1.268d,e	2.85±1.137c,d	2.85±1.137c	2.75±1.164d,e	2.60±1.046d,e	2.75±1.164d,e
G0.4E0	4.30±0.733a,b	4.55±0.51a,b	4.25±0.639a,b	4.40±0.681a,b	4.10±0.718a,b	4.30±0.657a,b
G0.4E0.5	3.30±1.218c,d	3.35±1.268c	3.40±1.188b,c	3.65±0.933b,c	3.50±1.1b,c	3.60±0.995b,c
G0.4E1	2.00±0.725e	2.00±0.725e	1.80±0.696d	2.15±0.587e	2.00±0.725e	2.00±0.725e

Results are given as mean ± standard deviation. Different letters in a column refer to significant differences (P<0.05). G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

The results of sensory analysis, as presented in Table 4 and Figure 3, revealed significant differences in appearance, taste, smell, consistency of the appearance, consistency in the mouthfeel, and general acceptability of puddings fortified with fenugreek gum and eggplant peel extract. Based on the data, the G0E0 sample exhibited the most favorable ratings in terms of attributes such as appearance, taste, smell, consistency, mouthfeel, and general acceptability, possibly attributed to its natural and familiar flavor. The substitution of rice starch with eggplant extract resulted in significant adverse effects on various sensory attributes, including appearance, taste, smell, consistency, mouthfeel, and overall acceptability, in the samples of pudding. General acceptance scores decreased significantly in a concentration-dependent manner for puddings fortified with eggplant peel extract. Nonetheless, the utilization of fenugreek gum (G0.4E0) as a substitute of rice starch yielded the most favorable ratings for sensory characteristics such as appearance, taste, smell, consistency, mouthfeel, and overall acceptability, which were closest to those of the control sample (G0E0). The intense bitter taste derived from anthocyanins present in eggplant peel extract has become dominant even at low concentrations, rendering it less preferred by consumers.

Conclusions

Food industry generates significant waste during production and preparation, with an estimated one-third of global food production for human consumption, equivalent to 1.3-1.6 billion tons, being discarded as waste along the entire food supply chain. Eggplant peel, a rich source of anthocyanin and pectin, is often discarded despite its potential nutritional value. Dairy desserts, such as rice pudding, are commonly fortified with phenolic extracts, but there is a lack of research on the use of fenugreek gum and eggplant peel extract in rice puddings in terms of physicochemical, sensory, and bioactive properties. The aim of this study was to investigate the effects of fenugreek gum and eggplant peel extract on various characteristics of rice pudding, including total soluble solids content, pH, color, syneresis index, storage stability, total phenolic content, antioxidant, flavonoid, and anthocyanin activity, as well as sensory evaluation. Results showed that the total soluble solids (TSS) content of rice pudding samples varied depending on the concentration of fenugreek gum and eggplant peel extract used, with higher concentrations resulting in lower TSS values. The pH of the samples was also affected, with eggplant peel extract significantly reducing the pH value, likely due to its antioxidant activity and phenolic content. Increased concentrations of fenugreek gum and eggplant peel extract in the pudding led to improved syneresis percentage, indicating reduced water release and improved storage stability. Furthermore, the addition of fenugreek gum positively correlated with increased storage stability, while eggplant peel extract had no significant effect. Moreover, this study involved a reduction in the product's starch content alongside an augmentation of its bioactive nutrient composition. However, despite the higher content of monomeric anthocyanins, total phenolics, total flavonoids, and antioxidant activity in the rice pudding samples with higher concentrations of eggplant peel extract, consumer acceptance scores were reported to be very low. Interestingly, consumers rated the rice pudding samples with 0.4% fenugreek gum but without eggplant peel extract with similar acceptance scores as the control sample. For future research, the inclusion of encapsulated eggplant peel extract in pudding formulations could be considered as a potential approach to mitigate the issue of bitterness.

Figure 3. Spider chart of the sensory attributes of pudding samples

G0E0 represents 0% fenugreek gum and 0% eggplant peel extract, G0E0.5 represents 0% fenugreek gum and 0.5% eggplant peel extract, G0E1 represents 0% fenugreek gum and 1% eggplant peel extract, G0.2E0 represents 0.2% fenugreek gum and 0% eggplant peel extract, G0.2E0.5 represents 0.2% fenugreek gum and 0.5% eggplant peel extract, G0.2E1 represents 0.2% fenugreek gum and 1% eggplant peel extract, G0.4E0 represents0.4% fenugreek gum and 0% eggplant peel extract, G0.4E0.5 represents 0.4% fenugreek gum and 0.5% eggplant peel extract, G0.4E1 represents 0.4% fenugreek gum and 1% eggplant peel extract.

References

Taşkın H, Büyükalaca S, Doğan HH, Rehner SA, O'Donnell K. 2010. A multigene molecular phylogenetic assessment of true morels (Morchella) in Turkey. Fungal Genetics and Biology, 47: 672-682. doi: 10.1016/j.fgb.2010.05.004

Adhikari B, Dhungana SK, Ali MW, Adhikari A, Kim ID, Shin DH. 2019. Antioxidant activities, polyphenol, flavonoid, and amino acid contents in peanut shell. Journal of the Saudi Society of Agricultural Sciences, 18(4): 437-442.

Akhbari M, Hamedi S, Aghamiri ZS. 2019. Optimization of total phenol and anthocyanin extraction from the peels of eggplant (Solanum melongena L.) and biological activity of the extracts. Journal of Food Measurement and Characterization, 13: 3183-3197.

Aloğlu HŞ, Gökgöz Y, Bayraktar M. 2018. Kocayemiş (Dağ çileği-*Arbutus unedo L.*) Meyveli dondurma üretimi, fiziksel, kimyasal ve duyusal parametreler açisindan irdelenmesi. Gıda, 43(6): 1030-1039.

Ares G, Baixauli R, Sanz T, Varela P, Salvador A. 2009. The new functional fibre in milk puddings: Effect on sensory properties and consumers' acceptability. LWT-Food Science and Technology, 42(3): 710–716.

Bandyopadhyay M, Chakraborty R, Raychaudhuri U. 2008. Antioxidant activity of natural plant sources in dairy dessert (Sandesh) under thermal treatment. LWT-Food Science and Technology, 41(5): 816-825.

Bhardwaj K, Najda A, Sharma R, Nurzyńska-Wierdak R, Dhanjal DS, Sharma R, Bhardwaj P. 2022. Fruit and Vegetable Peel-Enriched Functional Foods: Potential Avenues and Health Perspectives. Evidence-Based Complementary and Alternative Medicine, 2022.

Boulekbache-Makhlouf L, Medouni L, Medouni-Adrar S, Arkoub L, Madani K. 2013. Effect of solvents extraction on phenolic content and antioxidant activity of the byproduct of eggplant. Industrial Crops and Products, 49: 668-674.

Cavalcanti AL, de Oliveira PS, de Araújo Evangelista AP, Vieria FF, Granville-Garcia AF, Cavalcanti CL. 2008. pH and Total Soluble Solid Content in Concentrated and Diluted in Natura Tropical Fruit Juices. Acta Stomatologica Croatica, 42(3).

da Silva Costa RA, Bonomo RCF, Rodrigues LB, Santos LS, Veloso CM. 2020. Improvement of texture properties and syneresis of arrowroot (Maranta arundinacea) starch gels by using hydrocolloids (guar gum and xanthan gum). Journal of the Science of Food and Agriculture, 100(7): 3204-3211.

de Oliveira IR, Teófilo RF, de Oliveira EB, Ramos AM, de Barros FA, Maia MDP, Stringheta, PC. 2017. Evaluation of potential interfering agents on in vitro methods for the determination of the antioxidant capacity in anthocyanin extracts. International Journal of Food Science & Technology, 52(2): 511-518.

Dranca F, Oroian M. 2016. Optimization of ultrasound-assisted extraction of total monomeric anthocyanin (TMA) and total phenolic content (TPC) from eggplant (Solanum melongena L.) peel. Ultrasonics sonochemistry, 31: 637-646.

Elkot WF, Ateteallah AH, Al-Moalem MH, Shahein MR, Alblihed MA, Abdo W, Elmahallawy EK. 2022. Functional, physicochemical, rheological, microbiological, and organoleptic properties of synbiotic ice cream produced from camel milk using black rice powder and Lactobacillus acidophilus LA-5. Fermentation, 8(4): 187.

FAO, IFAD, UNICEF, WFP and WHO. 2022. The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO. https://doi.org/10.4060/cc0639en

Fundagül E. 2023. Physicochemical, Sensory, and Bioactive Properties of Gluten-Free Puddings Produced with Aronia Derivatives. Gıda, *48*(2): 243-255.

Goenenc S, Tanrıvermiş ŞH. 2008. An overview of the Turkish dairy sector. International journal of dairy technology, 61(1): 3-10.

González-Aguilar GA, Villegas-Ochoa MA, Martínez-Téllez MA, Gardea AA, Ayala-Zavala, JF. 2007. Improving antioxidant capacity of fresh-cut mangoes treated with UV-C. Journal of Food Science, 72(3): S197-S202.

Gorinstein S, Zachwieja Z, Folta M. 2001. Comparative contents of dietary fiber, total phenolics, and minerals in persimmons and apples, Journal of Agricultural and Food Chemistry, 49(2): 952–957.

Horincar G, Enachi E, Barbu V, Andronoiu DG, Râpeanu G, Stănciuc N, Aprodu I. 2020. Value-added pastry cream enriched with microencapsulated bioactive compounds from eggplant (Solanum melongena L.) peel. Antioxidants, 9(4): 351.

Hussain HR, Bashir S, Mahmood A, Sarfraz RM, Kanwal M, Ahmad N, Nazir I. 2022. Fenugreek seed mucilage grafted poly methacrylate pH-responsive hydrogel: A promising tool to enhance the oral bioavailability of methotrexate. International Journal of Biological Macromolecules, 202: 332-344.

Karimi A, Kazemi M, Samani SA, Simal-Gandara J. 2021. Bioactive compounds from by-products of eggplant: Functional properties, potential applications and advances in valorization methods. Trends in Food Science & Technology, 112: 518-531.

Kaur G, Sharma N, Singh A, Kapoor S, Khatkar SK. 2022. Ultrasound-assisted microemulsions of anthocyanins extracted from black carrot pomace and its utilisation as functional component in kulfi: implication on in vitro release, bio-functional components and rheological characteristics. *International Journal of Food Science & Technology*. 58: 2744–2753.

Kaur N, Kaur A, Sridhar K, Sharma M, Singh TP, Kumar S. 2021. Development and quality characteristics of functional Kulfi fortified with microencapsulated betalains. International Journal of Food Science & Technology, 56(10): 5362-5370.

Kaur C, Nagal S, Nishad J, Kumar R. 2014. Evaluating eggplant (Solanum melongena L) genotypes for bioactive properties: A chemometric approach. Food Research International, 60: 205-211.

Kay BA, Trigatti K, MacNeil MB, Klingel SL, Repin N, Goff HD, Duncan AM. 2017. Pudding products enriched with yellow mustard mucilage, fenugreek gum or flaxseed mucilage and matched for simulated intestinal viscosity significantly reduce postprandial peak glucose and insulin in adults at risk for type 2 diabetes. Journal of Functional Foods, 37: 603-611.

Kong JM, Chia LS, Goh NK, Chia TF, Brouillard R. 2003. Analysis and biological activities of anthocyanins. Phytochemistry, 64(5): 923-933.

Kotan TE. 2018. Mineral composition and some quality characteristics of ice creams manufactured with the addition of blueberry. Gıda, 43(4): 635-643.

Kumar N, Sahu JK, Kumar A, Naik S. 2022. Numerical optimization approach for the development of Giloy stem (Tinospora cordifolia) extract based functional yoghurt. Journal of Food Processing and Preservation, e17214.

Lee JH, Choi IS. 2020. Physicochemical characteristics and consumer acceptance of puddings fortified with Cudrania tricuspidata and Aronia melanocarpa extracts. Food Science & Nutrition, 8(9): 4936-4943.

Lee J, Durst RW, Wrolstad RE, & Collaborators: Eisele T, Giusti MM, Hach J, Hofsommer H, Koswig S, Krueger DA, Kupina S, Martin SK, Martinsen BK, Miller TC, Paquette F, Ryabkova A, Skrede G, Trenn U, Wightman JD. 2005. Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative study. Journal of AOAC international, 88(5): 1269-1278.

Mauro RP, Agnello M, Rizzo V, Graziani G, Fogliano V, Leonardi C, Giuffrida F. 2020. Recovery of eggplant field waste as a source of phytochemicals. Scientia Horticulturae, 261: 109023.

Mirani A, Goli M. 2021. Production of the eggplant-fiber incorporated cupcake and evaluating its chemical, textural and colorimetric properties over a ten-day storage time. Journal of food processing and preservation, 45(4): e15311.

Mohite AM, Chandel D. 2020. Formulation of edible films from fenugreek mucilage and taro starch. SN Applied Sciences, 2: 1-9.

Ngamlerst C, Prangthip P, Leelawat B, Supawong S, Vatthanakul S. 2022. A Vital Role of High-Pressure Processing in the Gel Forming on New Healthy Egg Pudding through Texture, Microstructure, and Molecular Impacts. Foods, 11(17): 2555.

Nouraddini M, Esmaiili M, Mohtarami F. 2018. Development and characterization of edible films based on eggplant flour and corn starch. International journal of biological macromolecules, 120: 1639-1645.

Papaioannou EH, Mazzei R, Bazzarelli F, Piacentini E, Giannakopoulos V, Roberts MR, Giorno L. 2022. Agri-Food Industry Waste as Resource of Chemicals: The Role of Membrane Technology in Their Sustainable Recycling. Sustainability, 14(3): 1483.

Sánchez-Rangel JC, Benavides J, Heredia JB, Cisneros-Zevallos L, Jacobo-Velázquez DA. 2013. The Folin–Ciocalteu assay revisited: improvement of its specificity for total phenolic content determination. Analytical methods, 5(21): 5990-5999.

Sanderson GR, Bell UL, Brtgun DR, Clark RC, Ortega D. 1988. In: Phillips GO, Wedlock DJ, Williams PA (eds) Gums and stablizers for the food industry, vol 4, I.R.L. Press, Washington, DC, pp 165–172.

Sattar DES, Ali TM, Hasnain A. 2017. Effect of nongerminated and germinated legumes on antioxidant, functional, and sensory characteristics of rice puddings. Cereal Chemistry, 94(3): 417-423.

Singh K, Immanuel G. 2022. Physico–Chemical, Nutritional and Sensorial Characteristics of Ragi Pasta Enriched With Rice And Guar Gum. Asian Jr. of Microbiol. Biotech. Env. Sc. 24(4) :803-806.

Soong YY, Barlow PJ. 2004. Antioxidant activity and phenolic content of selected fruit seeds, Food Chemistry, 88(3): 411–417.

Tandon N, Sachan S, Kumar V. 2021. Isolation, characterization of fenugreek gum and its effect on quality of chapatti (Indian unleavened flat bread). Materials Today: Proceedings, 43, 2091-2097.

Teh YH, Dougherty MP, Camire ME. 2005. Frozen blueberry-soy dessert quality. Journal of food science, 70(2): 119-122.

Toker OS, Dogan M, Canıyılmaz E, Ersöz NB, Kaya Y. 2013. The effects of different gums and their interactions on the rheological properties of a dairy dessert: a mixture design approach. Food and Bioprocess Technology, 6: 896-908.

Van den Abeele L, Smets T, Derden A, Huybrechts D, Nevens F. 2017. Feasibility study for the food processing industry inFlanders (Belgium) to become water neutral by 2030. J. Clean.Prod. 141: 1376–1390.

Waterhouse AL. 2002. Determination of total phenolics. Current protocols in food analytical chemistry, 6(1): I1-1.

Yong H, Wang X, Zhang X, Liu Y, Qin Y, Liu J. 2019. Effects of anthocyanin-rich purple and black eggplant extracts on the physical, antioxidant and pH-sensitive properties of chitosan film. Food Hydrocolloids, 94: 93-104.

Yousuf B, Gul K, Wani AA, Singh P. 2016. Health benefits of anthocyanins and their encapsulation for potential use in food systems: A review. Critical reviews in food science and nutrition, 56(13): 2223-2230.