Chapter-7

To develop a functional yoghurt by incorporating extract and microencapsulated extract containing bioactive compounds from haritaki

7.1. Introduction

Yogurt is the ideal food to add in your diet to reduce your energy consumption and boost your intake of nutrients, preventing obesity and other cardiovascular issues [16]. Interest in bioavailability and functional foods with additional health advantages has grown in recent years as consumer awareness of their own health has improved. Due to its adaptability, yoghurt is a fantastic way for people to change up their diets and include new, healthy items [52]. Due to the dietary fibre, polyphenol-rich extracts, and nutritional/beneficial qualities of plant-based sources, yoghurt manufacture has become more and more popular in recent years [2, 18, 20, 23, 26] and others are among these sources. The potential utilisation of novel sources of natural food additives as functional components must therefore be thoroughly investigated.

Access to healthcare in developing countries has grown to be a major source of worry due to high costs of medications, healthcare services, including diagnostics. Since ancient times, *Terminalia chebula Retz.* (*T. chebula*) has been used for its medicinal characteristics in a variety of bioactive chemicals to cure geriatric illnesses and enhance memory [4]. Reports state that haritaki organic products contain a number of phytochemicals. The bioactive components of *T. chebula* can be extracted and used to create nutraceuticals or functional meals. Major natural sources of antioxidant chemicals are fruits, vegetables, including plant-based foods including grains and vegetables. They have a variety of bioactive properties that can reduce the oxidative damage connected to many ailments [19]. Numerous studies have demonstrated that incorporating plants, such as bioactive components, increases the amount of phenolic compounds, which in turn increases yogurt's antioxidant activity [26].

Because guar gum has the ability to create highly viscous solutions at very low concentrations, it has been utilised in the food, pharmaceutical, and cosmetic sectors to stabilise emulsions. Guar gum will help stabilise the oils in fortified yoghurt and can aid in consuming the recommended daily amount of fibre [33]. Guar gum was added in various concentrations since it is known to generate extremely viscous solutions at greater concentrations and to degrade consumer acceptability. The purpose of this study is to report the qualitative attributes of yoghurt fortified with haritaki bioactive compounds that have been isolated and encapsulated as well as to further enhance those qualities by utilising guar gum in various quantities.

7.2. Materials and Methods

7.2.1. Raw material

Greek yoghurt starter culture comprising *Lactobacillus bulgaricus* and *Streptococcus thermophillus* was produced, together with extracted and encapsulated beneficial ingredients from haritaki pulp, homogenised standardised milk (Fat= 6.0% and SNF= 9.0%) from Tezpur Market, and Guar gum powder (0.5-1.5%). Chemicals of the analytical grade were utilised during the analysis.

7.2.2. Yogurt preparation

Since yoghurt is widely consumed, easy to obtain, and does not go through heat processing, which reduces the degradation of bioactive compounds, it is chosen as the food model for bioactive chemical integration. It was created using the procedures outlined by Andic et al. [3] and Hematyar et al. [24]. The temperature of the homogenised and standardised milk was heated at 85 °C for 30 mins before being lowered to 42 °C for incubation. During the heat treatment stage (85 °C), guar gum powder (0.5-1.5%), encapsulated extract, and SCF Extract were gradually added to the hydrocolloid. They were then added at 42 °C. *Streptococcus thermophillus* and *Lactobacillus bulgaricus* were introduced to a Greek yoghurt starting culture at 3 g/L concentration. In the initial test, the incubation period was determined until the yoghurt had sufficiently set and the acidity reached 1.20%. The inoculated milk was then incubated in previously sanitised containers for 6 hours at 42 °C. The created yoghurt was obtained and refrigerated at 4 °C until additional testing. Treatments are named accordingly as yoghurt (C1) (Control); (C2) yoghurt with 0.5% guar gum; (C3) yoghurt with 1.5% guar gum; (E1) yoghurt with Encapsulated extract at 42 ℃; (E2) yoghurt with Encapsulated extract at 85 ℃; (E3) yoghurt with Encapsulated extract at 42 ℃ + 0.5% guar gum; (E4) yoghurt with Encapsulated extract at 85 ℃ + 0.5% guar gum; (E5) yoghurt with Encapsulated extract at 42 ℃ + 1.5% guar gum; (E6) yoghurt with Encapsulated extract at 85 ℃ + 1.5% guar gum; (F1) yoghurt with Extract (SFE); (F2) yoghurt with Extract (SFE) + 0.5% guar gum, (F3) yoghurt with Extract (SFE) + 1.5% guar gum shown in **Fig. 7.1**.

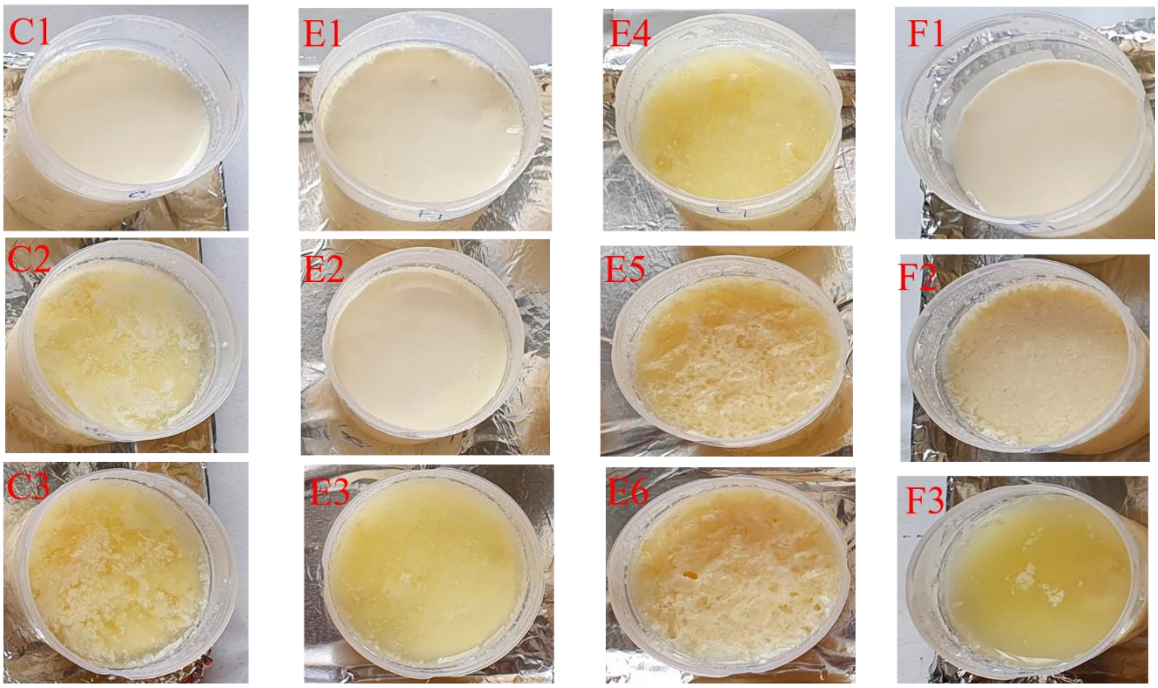


Fig. 7.1. Yoghurt samples (C1) (Control); (C2) yoghurt with 0.5% guar gum; (C3) yoghurt with 1.5% guar gum; (E1) yoghurt with Encapsulated extract at 42 °C; (E2) yoghurt with Encapsulated extract at 85 °C; (E3) yoghurt with Encapsulated extract at 42 °C + 0.5% guar gum; (E4) yoghurt with Encapsulated extract at 85 °C + 0.5% guar gum; (E5) yoghurt with Encapsulated extract at 42 °C + 1.5% guar gum; (E6) yoghurt with Encapsulated extract at 85 °C + 1.5% guar gum; (F1) yoghurt with Extract (SFE); (F2) yoghurt with Extract (SFE) + 0.5% guar gum; (F3) yoghurt with Extract (SFE) + 1.5% guar gum

7.2.3. pH and titrable acidity of yoghurt during storage

The pH including titrable acidity (TA) of the yoghurt samples were measured on the 1st, 12th, and 24th days that they were maintained at 4 °C. The pH was measured using a Eutech 700 pH metre that had already been calibrated. By titrating using 0.1 N NaOH and phenolphthalein as an indicator, the titrable acidity was calculated as a percent of lactic acid.

7.2.4. Colour analysis of yoghurt samples during storage

The colour properties were calculated as discussed in section 3.2.9. The following equation was used to compute the total colour difference (ΔE*):

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (7.1)$$

7.2.5. Syneresis of yoghurt during storage

Yogurt syneresis was examined using the Garca-Pérez et al. [20] approach, which involved fast pouring 20 g of yoghurt onto a strainer that was connected to a glass beaker. Weighing the whey collected during a 2 h period. After two hours of drainage, whey returned and was represented as a percentage of syneresis.

7.2.6. Total phenol content

The Total phenolic content was calculated as discussed in section 3.2.8.2 [27].

7.2.7. DPPH radical scavenging activity

The total antioxidant activity in terms of DPPH radical scavenging activity was calculated as discussed in section 3.2.8.4 [7].

7.2.8. Textural properties of yoghurt during storage

The back extrusion method of the Texture Analyzer, TA. HD plus (Stable Micro Systems, UK) was employed for evaluation of the textural characteristics of the yoghurt samples [48]. The P-35 cylindrical probe was used to take each measurement. Yogurt samples were allowed to warm up to 25 °C before the measurements. The probe's penetration speed was 1 mm/s, and its depth from the surface was 20 mm. The hardness and adhesiveness values for the textural qualities were extracted using the Exponent Lite 32 application.

7.2.9. Rheological analysis of yoghurt during storage

The rheological parameters of yoghurt samples during storage were evaluated using the Advanced Rheometer System (Anton Paar MCR 72). The samples were heated to 10 °C before the tests. Frequency sweep experiments from 0.1 to 10 Hz were conducted at 10 °C. At 1 Hz, the storage modulus (G′) and loss modulus (G″), were all recorded. Additionally, the behaviour of the yoghurt sample flows was discovered. Shear rate adjustments ranged from 0.02 to 100 s^{-1}[1].

7.2.10. Sensory analysis of yoghurt samples

For the sensory analysis of yoghurt, twelve semi-trained panellists including faculties and research scholars of the department of Food Engineering and Technology were selected. 50 mL cups of yoghurt samples at 8 °C were provided to the panellists for sensory evaluation [32]. Before each serving, panellists were instructed to rinse their mouths with water. The panel evaluated yoghurt based on its overall acceptability, appearance, colour, flavour, taste, texture, and mouthfeel. The acceptability of the product was evaluated using a hedonic scale with a maximum score of 9, where 1 represents a strong dislike and 9 represents a strong like. On the same scale, the samples general acceptability was also graded, with 9 denoting the highest level of acceptance and 1 the lowest or extremely unacceptable.

7.2.11. Statistical analysis

In the present study, IBM SPSS Statistics Version 20.0, Armonk, NY: IBM Corporation package was used for the statistical analysis of data, and the means were separated using Duncan's multiple range test ($p < 0.05$). All the data were presented as the mean with the standard deviation.

7.3. Results and discussions

7.3.1. Physico-chemical properties

Yogurt's semi-solid consistency results from milk proteins being denaturized, which causes a three-dimensional network to develop at a lower pH, depends on the production of acid during yoghurt fermentation. While pH measures the intensity of that acid, titrable acidity gives the measurement of acid amount that is there. Acidity plays a significant role on yoghurt's shelf life and consumer acceptance. In **Table 7.1**, changes in pH and titratable acidity of yoghurts with and without guar gum are shown. The pH levels and acidity were observed to decrease as fermentation times were kept constant across all yoghurts. The pH increased slightly as guar gum concentration was raised. Yogurt acidity had an inverse relationship with pH. The yoghurt sample's pH levels were lowest in the control (C1), whereas they dramatically rose after guar gum was added to the other two samples (C2 and C3). In contrast, guar gum addition (E2) and encapsulated haritaki extract (E1) dramatically lowered the yogurt samples pH value in comparison (E3 to E6). The pH of yoghurt samples was dramatically lowered when haritaki extract

(F1) was added, compared to (F2 and F3). The pH of yoghurt fluctuated over a 30-day storage period, going from 4.45 to 4.30 [9]. Adding guar gum to yoghurt samples was previously observed to cause a drop in pH [30]. With a storage duration of 24 days at 4 °C, the pH value reduced and the acidity enhanced in all of the samples. Yogurt's pH varied over a storage period of 24 days, going from 4.54 to 4.31. The activity of the bacteria that continue to produce lactic acid may be responsible for the pH drop that occurs with time spent in storage. For yoghurts made with the addition of fibres from diverse sources, Sah et al. [42] similarly showed a comparable pH fall with storage time.

Table 7.1. Acidity, pH and syneresis of the yoghurt during storage period

Sample	1st Day			12th Day			24th Day		
	pH	Acidity (%)	Syneresis (%)	pH	Acidity (%)	Syneresis (%)	pH	Acidity (%)	Syneresis (%)
C1	4.54±0.16^{aA}	1.20±0.23^{aA}	14.16±3.45^{dA}	4.43±0.01^{aA}	1.59±0.54^{aA}	5.51±0.81^{cB}	4.31±0.27^{aA}	1.93±0.85^{aA}	9.55±0.87^{dB}
C2	4.58±0.02^{aA}	1.17±0.16^{aA}	26.12±4.32^{aA}	4.47±0.03^{aB}	1.52±0.45^{aA}	16.69±4.08^{abB}	4.33±0.03^{aC}	1.90±0.80^{aA}	18.97±4.29^{abAB}
C3	4.66±0.05^{aA}	1.09±0.15^{aA}	29.08±2.21^{aA}	4.50±0.08^{aB}	1.48±0.47^{aA}	18.31±3.34^{aB}	4.35±0.04^{aC}	1.84±0.56^{aA}	20.36±3.10^{aB}
E1	4.64±0.09^{aA}	1.11±0.33^{aA}	17.31±4.56^{cdA}	4.47±0.05^{aB}	1.54±0.64^{aA}	12.34±3.17^{abA}	4.34±0.05^{aB}	1.89±0.58^{aA}	14.98±0.49^{bcA}
E2	4.57±0.12^{aA}	1.18±0.41^{aA}	19.89±0.88^{bcdA}	4.45±0.08^{aAB}	1.57±0.63^{aA}	13.88±1.39^{abB}	4.34±0.06^{aB}	1.89±0.25^{aA}	15.49±2.95^{bcB}
E3	4.68±0.02^{aA}	1.02±0.20^{aA}	24.61±4.47^{abA}	4.46±0.08^{aB}	1.56±0.91^{aA}	15.44±4.73^{abB}	4.36±0.04^{aB}	1.81±0.72^{aA}	17.46±1.84^{abcAB}
E4	4.67±0.04^{aA}	1.04±0.09^{aA}	26.63±3.89^{aA}	4.48±0.02^{aB}	1.51±0.85^{aA}	17.46±4.51^{abB}	4.36±0.03^{aC}	1.80±0.40^{aA}	20.50±1.10^{aAB}
E5	4.69±0.19^{aA}	1.01±0.36^{aB}	23.48±1.01^{abA}	4.54±0.13^{aAB}	1.45±0.40^{aAB}	12.42±2.74^{abB}	4.37±0.02^{aB}	1.76±0.27^{aA}	15.66±1.11^{bcB}
E6	4.69±0.15^{aA}	1.00±0.12^{aA}	25.09±1.89^{abA}	4.56±0.14^{aAB}	1.39±0.62^{aA}	13.73±2.89^{abB}	4.37±0.01^{aB}	1.73±0.58^{aA}	17.76±3.77^{abcB}
F1	4.57±0.06^{aA}	1.18±0.18^{aA}	19.94±3.50^{bcdA}	4.45±0.09^{aAB}	1.58±0.73^{aA}	11.21±4.03^{bB}	4.35±0.06^{aB}	1.87±0.19^{aA}	13.48±0.89^{cdB}
F2	4.60±0.12^{aA}	1.14±0.10^{aA}	23.02±0.79^{abcA}	4.47±0.04^{aAB}	1.52±0.52^{aA}	12.54±1.77^{abC}	4.37±0.05^{aB}	1.79±0.25^{aA}	15.32±0.97^{bcB}
F3	4.65±0.07^{aA}	1.10±0.17^{aA}	27.44±4.01^{aA}	4.49±0.04^{aB}	1.50±0.46^{aA}	16.16±3.55^{abB}	4.38±0.07^{aB}	1.71±0.85^{aA}	19.62±3.22^{abB}

Value reported as Mean ± SD of three replications. Means followed by same capital letter superscripts Within a row for same parameter and small letter superscripts within a column are not significantly different ($p<0.05$).

The separation of liquid or syneresis from the semi-solid product is an obvious fault that reduces the likelihood that a product will be accepted by consumers [31; 37]. The yoghurt samples created for this experiment demonstrated notable variation between samples and also while they were stored (**Table 7.1**). In general, it can be seen that every variation has displayed an irregular syneresis pattern. All of the samples initially had higher syneresis, which decreased on day 12th and then increased once more on day 24th of storage. Acharjee et al. [1] also noted such a pattern of change. This may be caused by the milk protein becoming denaturized with an increase in acidity and the creation of an appropriate protein network, which strengthened the gel structure over time until it was stored for 12 days. Mousavi et al. [32] showed a similar decrease in syneresis for yoghurt fortified with flaxseed during storage. Yogurt gel's inter-aggregate bonds may be strengthened by guar gum, while casein micelles reduced molecular mobility may prevent phase separation [17; 36]. Previous studies have shown that adding hydrocolloids like guar gum, xanthan gum, starch including gelation causes syneresis to decrease [17; 22; 28]. However, successive gum concentration increases (from 0.5 to 1.5%) markedly exacerbated syneresis. After 24 days, syneresis increases when storage time is extended because the gel becomes weaker from high acidity. According to Kiros et al. [28], gelatin syneresis was decreased at 0.25% but dramatically elevated at 0.5% level of supplementation. According to Everett and McLeod [17], depletion flocculation is the cause of higher syneresis with increasing guar gum concentration. Yogurt syneresis may also be increased by guar gum's tendency to demix at higher concentrations because to its poor compatibility with sodium caseinate [34].

7.3.2. Changes in colour of yoghurt

Colour is a crucial element or essential component in food. Customers often have their preferences influenced by this sensory trait because it is the first one, they notice. According to **Table 7.2**, the colour determinants L*, a*, and b* of the control, encapsulated haritaki extract, and haritaki extract with guar gum integrated yoghurts changed over the course of refrigeration. Because haritaki extract has a high yellowness relative to milk, its integration into encapsulated haritaki extract and haritaki extract with guar gum caused a substantial variation in the b* value. Additionally, it should be observed that some of the a* values are positive (+) while others are nearly negative (-), indicating that the samples were greener in hue. L*, a*, and b* values did not significantly change while storing for the control sample, but they did for the other samples.

Throughout the storage period and among the samples, (C1) was shown to be the lightest and the L* value decreased from 90.28±0.2 to 87.52±0.1 as guar gum concentration rose. On the first and twelfth days of storage, (E3) represented the highest degree of lightness. On the 24th day of storage, the greatest a* value was noted in (F1). The highest ΔE was represented by (F3) on the 1st and 12th days of storage. When encapsulate powders were used to create the samples, lightness (L*) decreased and yellowness increased whereas a* values changed from green towards red after storage. The pigments in the haritaki samples may have spread out throughout the samples during storage, which may be why the colour of yoghurt characteristics changed. The results of the present study contrast with Raju and Pal [38], who discovered significant changes in all colour parameters following fibre incorporation, but they are consistent with Dabija et al. [13], who found no evidence of a change in color of yoghurt parameters as a result of fibre incorporation.

Table 7.2. Colour parameters of yoghurt samples during storage period

Sample	1st Day				12th Day				24th Day			
	L*	a*	b*	ΔE	L*	a*	b*	ΔE	L*	a*	b*	ΔE
C1	90.40±2.10^{aA}	0.19±0.28^{abA}	6.22±2.20^{fB}	0.00±0.00^{f}	89.10±0.98$^{a}_{AB}$	0.31±0.47^{aA}	10.70±0.47$^{d}_{eA}$	0.00±0.00^{i}	87.00±0.17$^{a}_{B}$	-1.02±0.13^{efB}	10.59±0.60$^{d}_{eA}$	.00±0.00^{e}
C2	90.28±0.25^{aA}	0.32±0.05^{aA}	8.82±0.04$^{bcd}_{B}$	3.37±1.23^{eB}	88.92±0.43$^{a}_{A}$	0.59±0.02^{aA}	15.07±0.66$^{a}_{bA}$	4.45±0.38^{gB}	80.95±2.72$^{b}_{B}$	0.59±0.22^{bcA}	17.06±1.58$^{b}_{A}$	9.26±1.01^{cdA}
C3	87.52±0.18$^{b}_{A}$	0.02±0.03^{bcB}	9.24±0.11$^{bc}_{C}$	4.73±1.13^{eB}	84.94±0.68$^{c}_{A}$	0.63±0.47$^{aA}_{B}$	14.23±2.04$^{a}_{bB}$	5.69±0.51^{fgB}	77.73±5.37$^{b}_{cB}$	1.05±0.25^{abA}	21.81±0.42$^{a}_{A}$	15.24±2.77$^{ab}_{A}$
E1	89.45±0.27^{aA}	-0.13±0.08^{cB}	8.25±0.21$^{cde}_{C}$	3.28±0.88^{eB}	87.22±0.10$^{b}_{B}$	-0.38±0.21^{bB}	14.98±0.64$^{a}_{bA}$	4.80±0.17^{gA}	86.78±0.46$^{a}_{B}$	0.34±0.08^{cA}	12.49±0.22$^{d}_{eB}$	2.37±0.39^{eB}
E2	83.25±0.04$^{d}_{A}$	-0.47±0.06^{dA}	7.07±0.07^{efB}	7.48±2.03^{dA}	82.52±0.10$^{d}_{B}$	-0.57±0.13$^{bA}_{B}$	13.25±1.51$^{b}_{cA}$	7.23±0.62^{efA}	81.73±0.27$^{b}_{C}$	-0.91±0.30^{eB}	11.90±3.75$^{d}_{eA}$	6.09±1.26^{dA}
E3	84.66±0.15^{cA}	-0.12±0.00^{cA}	9.96±0.07^{bC}	7.18±1.30^{dB}	82.69±1.20$^{d}_{A}$	-0.21±0.02^{bA}	15.34±0.68$^{a}_{B}$	8.04±1.53^{deB}	77.08±3.70$^{b}_{cB}$	0.20±0.59^{cdA}	16.88±1.07$^{b}_{A}$	12.05±2.68$^{bc}_{A}$
E4	81.09±0.02^{eA}	-0.52±0.02^{dA}	7.67±0.16$^{de}_{A}$	9.66±1.99^{dB}	79.77±0.34$^{e}_{A}$	-0.56±0.03^{bA}	9.87±0.55^{eA}	9.45±1.09^{dB}	70.76±1.66$^{d}_{eB}$	-0.20±0.38^{dA}	10.10±2.37$^{e}_{B}$	16.39±1.82$^{a}_{A}$
E5	75.84±0.17$^{g}_{A}$	-0.46±0.05^{dB}	12.16±0.08$^{a}_{C}$	15.87±1.40^{bA}	73.68±0.52$^{g}_{AB}$	-0.55±0.04^{bB}	14.71±0.69$^{a}_{bB}$	15.98±1.31$^{b}_{A}$	71.29±2.44$^{d}_{eB}$	0.23±0.30^{cdA}	17.16±0.75$^{b}_{A}$	17.16±1.93$^{a}_{A}$
E6	78.63±0.57^{fA}	-1.99±0.14^{gB}	7.30±0.22^{efC}	12.14±1.45^{cB}	77.75±0.53^{fA}	-2.53±0.39^{dC}	12.27±0.54$^{c}_{dB}$	11.81±0.63$^{c}_{B}$	75.13±0.65$^{c}_{dB}$	0.94±0.08^{abA}	18.78±0.29$^{b}_{A}$	14.57±0.67$^{ab}_{A}$
F1	89.72±0.08^{aA}	0.29±0.08^{aB}	8.58±0.08$^{cd}_{C}$	3.49±0.84^{eA}	87.48±1.15$^{b}_{AB}$	0.37±0.09^{aB}	11.96±1.14$^{c}_{dB}$	2.24±0.56^{hA}	81.02±5.65$^{b}_{B}$	1.28±0.11^{aA}	13.73±0.42$^{c}_{dA}$	7.72±4.54^{dA}
F2	76.20±0.03$^{g}_{A}$	-1.24±0.07^{eA}	8.92±0.04$^{bc}_{A}$	14.65±1.84^{bB}	73.98±0.60$^{g}_{B}$	-1.41±0.04^{cA}	10.94±0.60$^{d}_{eA}$	15.25±0.73$^{b}_{B}$	68.96±1.50$^{e}_{C}$	-1.41±0.17^{fA}	11.77±2.34$^{d}_{eA}$	18.22±1.46$^{a}_{A}$
F3	72.13±0.56$^{h}_{A}$	-1.66±0.16^{fB}	4.05±0.29^{gC}	18.55±1.77^{aA}	71.08±0.66$^{h}_{AB}$	-2.120.30^{dB}	9.59±0.91^{eB}	18.23±1.73$^{a}_{A}$	69.75±1.20$^{e}_{B}$	0.86±0.21^{abA}	15.62±2.40$^{b}_{cA}$	18.12±1.36$^{a}_{A}$

Value reported as Mean ± SD of three replications. Means followed by same capital letter superscripts Within a row for same parameter and small letter superscripts within a column are not significantly different ($p<0.05$).

7.3.3. Phytochemical properties of yoghurt

Plants antioxidant effects are largely derived from phenolics, which include phenolic acids and flavonoids. In the present study, the total phenol content and DPPH free radical scavenging activity of yoghurt were deemed important factors in determining yoghurt's phytochemical properties. Yogurt without any additives (C1-C3) had a TPC that varied from 6.05 to 6.81 mg GAE/100 mL, while DPPH radical scavenging activity (% inhibition) varied from 37.45 to 38.57%. The phenol content and antioxidant activity varied significantly when gum, encapsulates, and haritaki extract were added. The variation in the content can be visualised in (**Table 7.3**). TPC ranged from 131.985 to 157.37 mg GAE/100 mL in samples prepared with encapsulates such as (E1-E6), while DPPH radical scavenging activity (% inhibition) differed from 65.51 to 73.51% on the 1st day. The findings show that adding encapsulates had a significant impact on the phytochemical properties. In the case of (F1–F3), the TPC and antioxidant values were in the range of 136.37–154.71 mg GAE/100 mL and 69.33–71.95% inhibition, respectively. Among the variations, E3 had the highest phenol and antioxidant content (157.55 mg GAE/100 mL and 73% inhibition).

There was a significant impact of storage on the phytochemical content, as it was noticed in (E1-E6) and (F1-F3). On the 12th day of storage, the phytochemical content was observed to decrease significantly. The TPC in the control sample was reduced to 6.81-6.38, while 18-21% of antioxidant activity was lost on the day of preparation and increased until the 24th day. In cases (E1–E6), the TPC values were found in the range of 129.24–156.55, while the DPPH activity was 63.63 – 69.84%, respectively. The decreasing trend was like the control sample. Similarly, the phytochemical activities of (F1- F3) were reduced. Phenolic compounds have been reported to impart a pleasant flavour to beverages and demonstrate antimicrobial activity [11]. Additionally, phenolic chemicals play a role in the sensory qualities of food, including colour and astringency [21].

The degradation of milk proteins phenolic side chain may be the cause of the TPC level in plain yoghurt [15; 44]. The amount of haritaki polyphenols (phenolics, anthocyanins, including flavonoids) in the final products is indicated by the obvious increase in TPC in fortified yoghurt over the controlled values yoghurt. Sigdel et al. [47] reported a similar outcome. Because phenolic was not detected in regular yoghurt, the mulberry fruit fortified yoghurt's phenolic content was greater than that of the control.

Scibisz et al. [43] also found 20% blueberry preserve in yoghurt contained 12 mg/100 g of anthocyanin. Many researchers have demonstrated plant phenolics anticancer effect, cardiovascular disease prevention, an anti-obesity impact, and better visual health [25; 39; 51; 53].

The phytochemical content of each specific fruit (phenols, flavonoids, anthocyanins, and ascorbic acid), including the results of microbial metabolic activities, were most likely responsible for the increased fruit yoghurt that contained greater antioxidant activity than control yoghurt. [50]. Plain yoghurt had less antioxidant activity than fortified yoghurt, and same observations were recorded by different authors Chouchouli et al. [10]; Shori and Baba [46]. Fruit yoghurt's high antioxidant activity is a preferred feature that might increase its therapeutic benefits and has been linked to a lower threat of certain diseases like cardiovascular disease including cancer [29].

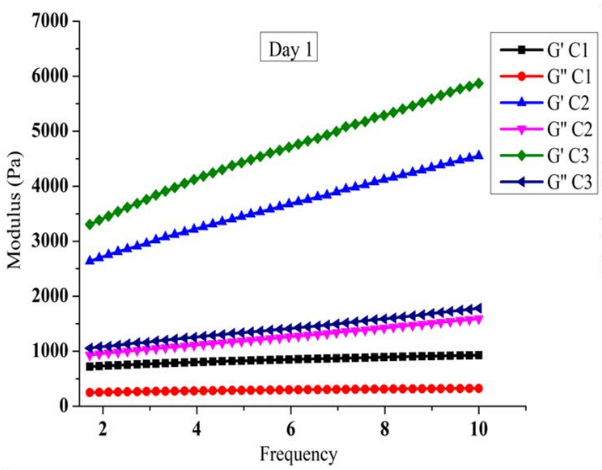
Table 7.3. Variation in phytochemical properties of yoghurt during storage

Sample	1^{st} Day		12^{th} Day		24^{th} Day	
	TPC (mg GAE/100 mL) (FW)	DPPH (% inhibition)	TPC (mg GAE/100 mL) (FW)	DPPH (% inhibition)	TPC (mg GAE/100mL) (FW)	DPPH (% inhibition)
C1	6.05 ± 0.59^{gA}	37.45 ± 0.76^{eA}	5.60 ± 0.24^{fB}	30.70 ± 4.90^{cB}	5.01 ± 0.17^{eB}	19.72 ± 0.61^{fB}
C2	6.81 ± 1.01^{gA}	38.57 ± 1.26^{eA}	6.38 ± 1.06^{fB}	33.48 ± 3.36^{cB}	5.09 ± 0.23^{eB}	24.20 ± 1.06^{eB}
C3	6.32 ± 0.48^{gA}	37.64 ± 1.37^{eA}	5.85 ± 0.27^{fB}	33.41 ± 4.55^{cB}	4.88 ± 0.05^{eB}	23.82 ± 1.06^{eB}
E1	157.37 ± 1.55^{aA}	73.29 ± 0.22^{aA}	155.07 ± 4.49^{aB}	69.84 ± 2.27^{aB}	150.12 ± 1.22^{aB}	63.05 ± 1.62^{abB}
E2	142.33 ± 1.41^{cA}	69.41 ± 2.98^{bcA}	139.44 ± 2.95^{cB}	66.78 ± 4.64^{abB}	134.40 ± 2.27^{bB}	61.45 ± 1.06^{bcB}
E3	157.55 ± 4.01^{aA}	73.51 ± 0.26^{aA}	156.55 ± 1.24^{aA}	69.18 ± 1.06^{aB}	152.08 ± 5.72^{aA}	64.20 ± 1.62^{aB}
E4	141.32 ± 1.65^{cdA}	69.17 ± 2.75^{bcA}	138.01 ± 4.86^{cA}	66.65 ± 1.62^{abAB}	132.17 ± 5.94^{bcA}	62.38 ± 2.21^{abB}
E5	138.86 ± 1.19^{deA}	67.27 ± 2.82^{cdA}	135.98 ± 3.72^{cdA}	66.03 ± 1.82^{abA}	131.87 ± 4.81^{bcA}	60.55 ± 1.06^{bcB}
E6	131.98 ± 1.65^{fA}	65.51 ± 0.64^{dA}	129.24 ± 2.73^{eA}	63.63 ± 2.21^{bA}	123.76 ± 2.25^{dB}	55.46 ± 1.06^{dB}
F1	154.71 ± 1.65^{aA}	71.95 ± 1.60^{abA}	152.83 ± 1.29^{aA}	68.90 ± 0.24^{abB}	147.36 ± 2.21^{aB}	62.57 ± 1.62^{abC}
F2	148.63 ± 2.16^{bA}	71.57 ± 1.23^{abA}	147.12 ± 1.83^{bA}	66.85 ± 1.06^{abB}	138.14 ± 5.73^{bB}	60.67 ± 1.08^{bcC}
F3	136.37 ± 1.39^{eA}	69.33 ± 4.03^{bcA}	133.13 ± 1.06^{deA}	65.28 ± 1.62^{abA}	127.38 ± 3.75^{cdB}	59.24 ± 2.21^{cB}

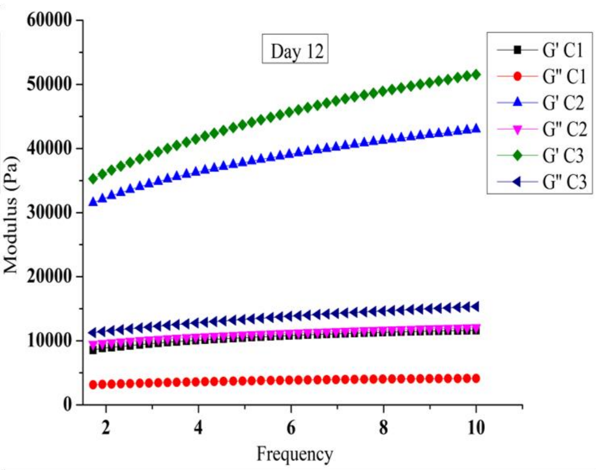
Value reported as Mean ± SD of three replications. Means followed by same capital letter superscripts Within a row for same parameter and small letter superscripts within a column are not significantly different ($p<0.05$).

7.3.4. Rheological properties

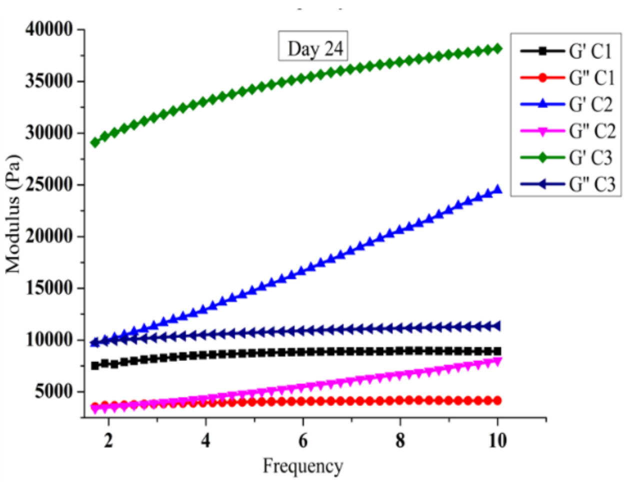
The relationship curve between storage-modulus G′ and loss-modulus G″ obtained at 25 °C is represented in **Fig. 7.2-7.4**. Day 1st G′ and G″ values of C1 were lower than C2 and C3 on that day. The highest values of G' and G″ were found in C3 samples. C2 samples had higher G' and G″ values than controlled samples. G′ > G″ across the entire range of frequencies investigated in all yoghurt samples, indicating the characteristic elastic behaviour of yoghurts showcasing weak gel characteristics. The gel like characteristic of the yoghurt samples was previously confirmed by Gentes et al. [22] who observed greater G′ than G″ of the yoghurt samples. Lee and Chang [30] also noted a concentration dependent rise in the values of G′ and G″ in guar gum containing samples of the yoghurt.



(a)



(b)



(c)

Fig. 7.2. Storage modulus (G′) and loss modulus (G″) of yoghurt samples (C1, C2, C3) during storage period (a) 1st day; (b) 12th day; (c) 24th day

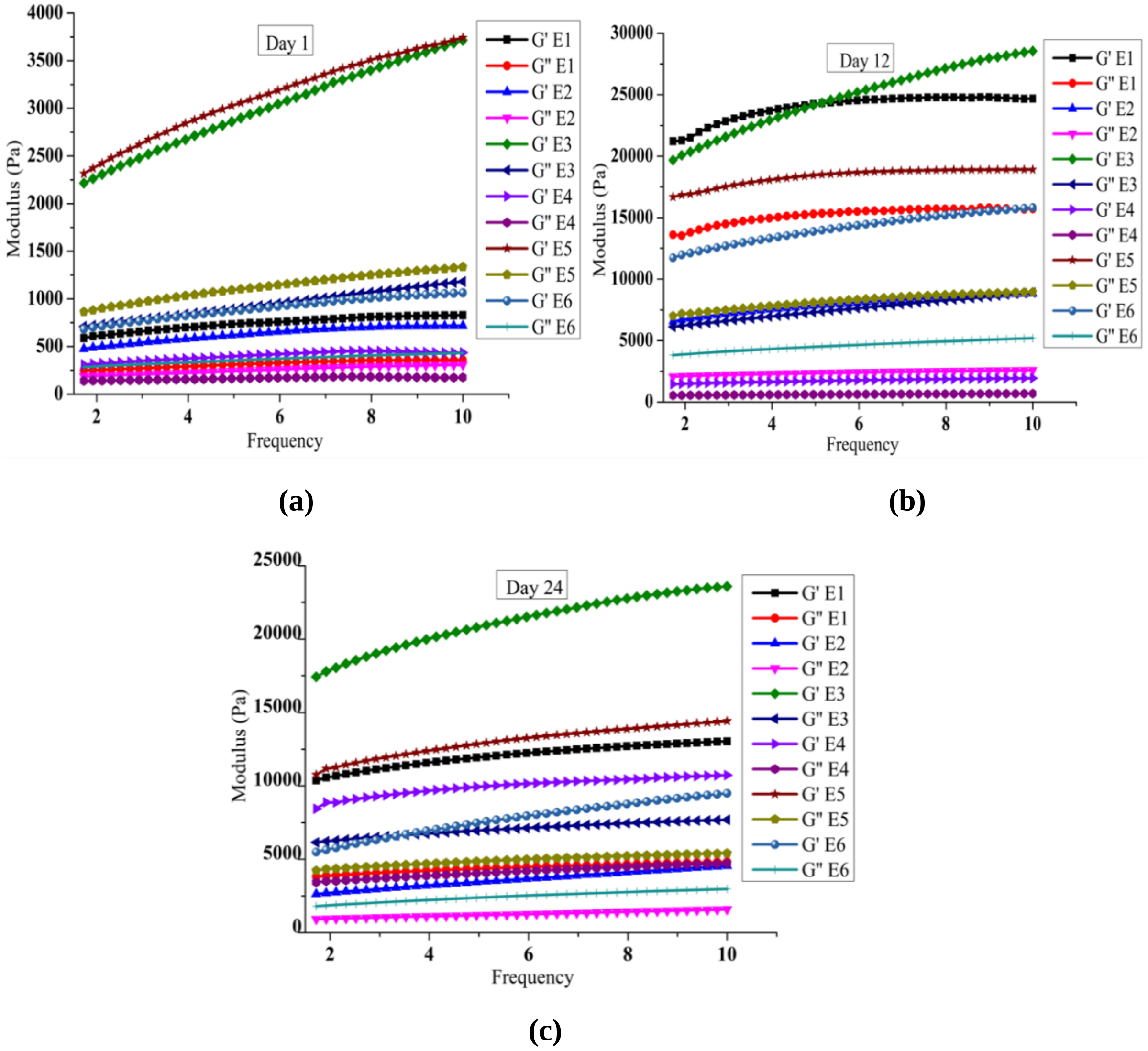
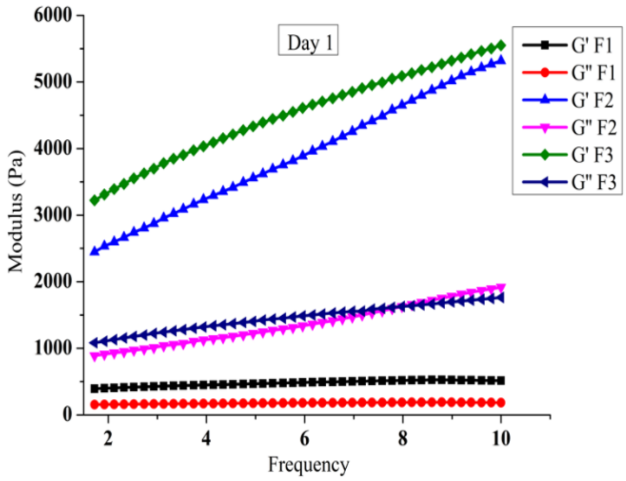
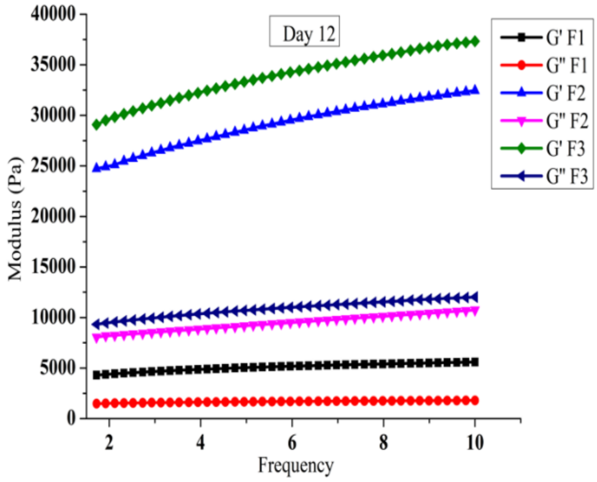


Fig. 7.3. Storage modulus (G′) and loss modulus (G″) of yoghurt samples (E1, E2, E3, E4, E5 and E6) during storage period (a) 1st day; (b) 12th day; (c) 24th day

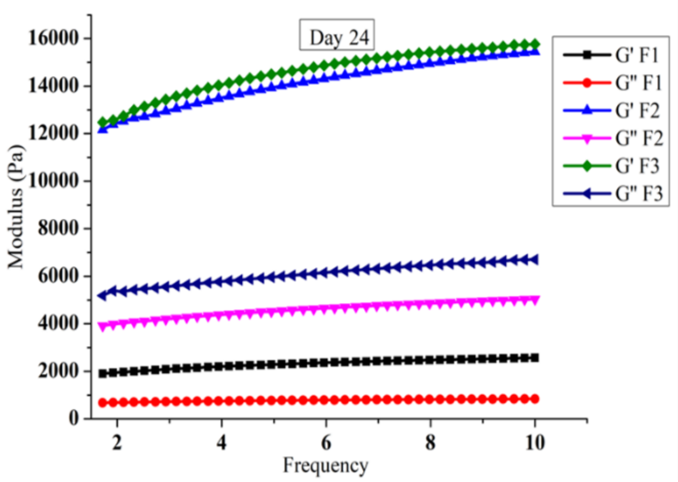
After 12 days of storage, the G′ and G″ values of the C1 samples were lower than those of the C2 and C3 samples. The highest G′ and G″ values were found in C3 samples. C2 samples had higher G' and G″ values than controlled samples. The interaction of hydrocolloids with the casein matrix of yoghurt produces a stronger three-dimensional network, which is thought to be the cause of the trend observed with the addition of guar gum [8]. According to Shaker et al. [45], G′ significantly increased when yoghurt fat contents increased. However, compared to the inclusion of haritaki extract, the absorption of encapsulated haritaki extract increased G′ and G″ more. Everett and McLeod [17] also noted that increasing guar gum concentration to depletion flocculation increased the compactness of casein micellar aggregates (greater dynamic moduli).



(a)



(b)



(c)

Fig. 7.4. Storage modulus (G′) and loss modulus (G″) of yoghurt samples (F1, F2 and F3) during storage period (a) 1st day; (b) 12th day; (c) 24th day

In contrast to C2 and C3 samples, C3 samples had higher G′ and G″ values on day 24th due to the longer storage time. Compared to controlled samples, G′ of C2 yoghurt samples was higher. However, the G″ values of the C2 samples decreased with storage time (**Fig.7.2**). After 12th days of storage, all of the samples' G′ and G″ values increased, and after 24th days, they all started to decline. The outcomes matched those of Xu et al. [54] for yoghurts made with okra polysaccharides. Yogurt fortified with pineapple peel powder showed an increase in G′ and G″ values during storage, according to Sah et al. [42].

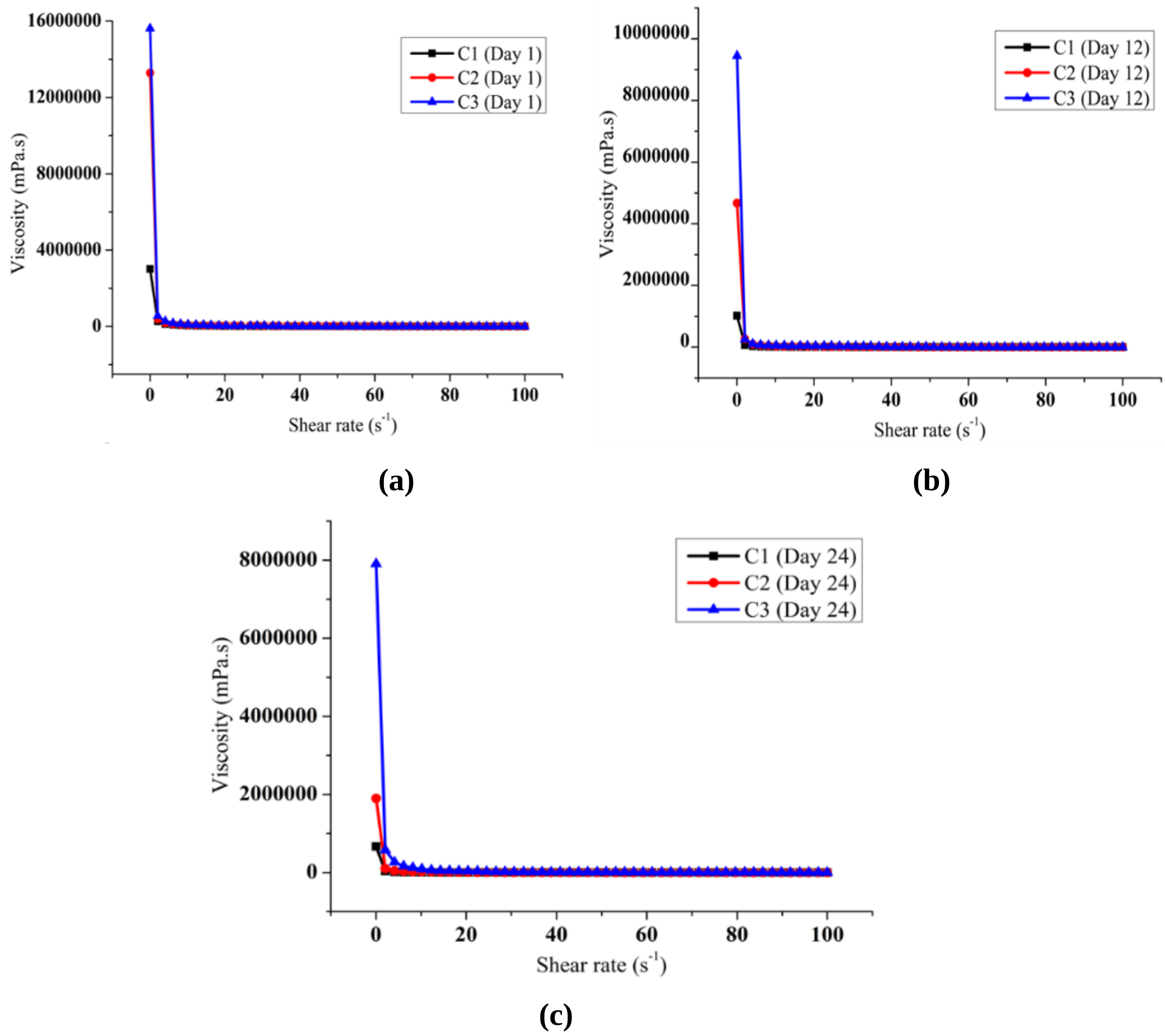
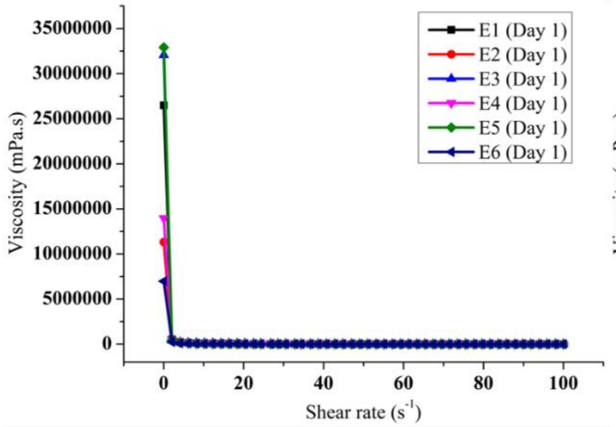


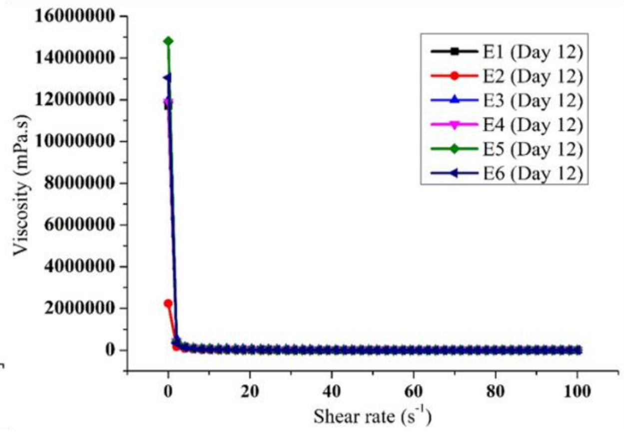
Fig. 7.5. Viscosity profile of yoghurt samples (C1, C2 and C3) during storage period (a) 1st day; (b) 12th day; (c) 24th day

The G′ and G″ values of the E3 and E5 samples on day 1st were the highest. Lower G′ and G″ values were seen in E2 and E1. Comparatively, the G' and G" values in the E4 sample were the lowest. Lee and Chang [30] also noted a concentration dependent rise in G′ and G″ values in guar gum-containing yoghurt samples. G′ and G″ readings of E3 samples peaked on day 12 of the storage period. Among all samples, the E4 sample had the lowest G′ and G″ values.

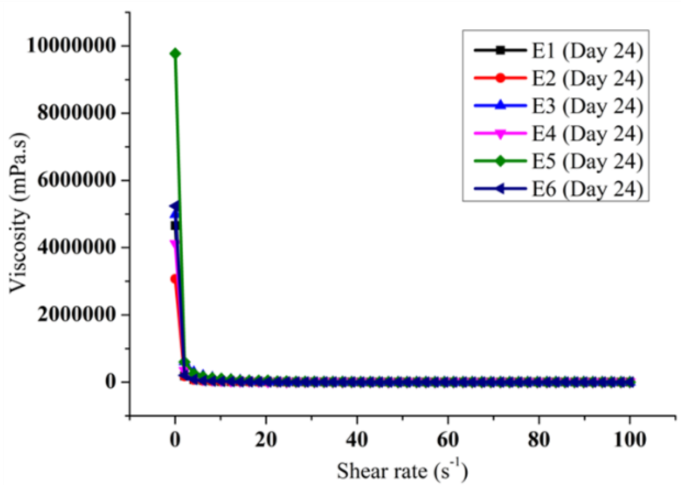
G′ and G″ readings of E3 samples peaked on day 24th of the storage period. G′ and G″ values for the E2 sample were the lowest of all the samples (**Fig.7.3**). The G′ and G″ values of the F3 samples were highest on day 1st. F2 samples had higher G' and G″ values than F1, which had lower G′ and G″ values. G′ and G″ values of F3 samples peaked on day 12th of the storage period. Compared to F2 and F3, the G′ and G″ values of the F1 samples were lower (**Fig.7.4**).



(a)



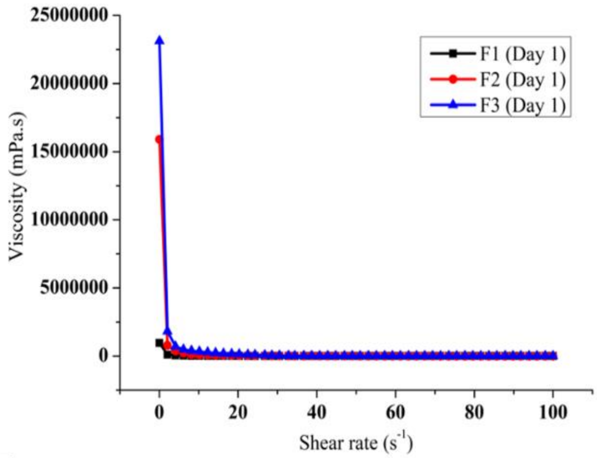
(b)

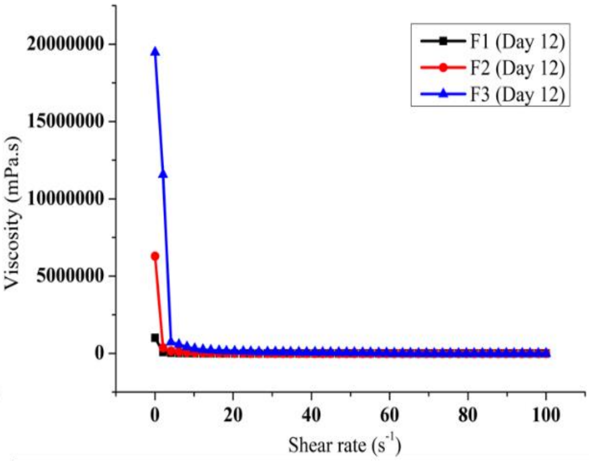


(c)

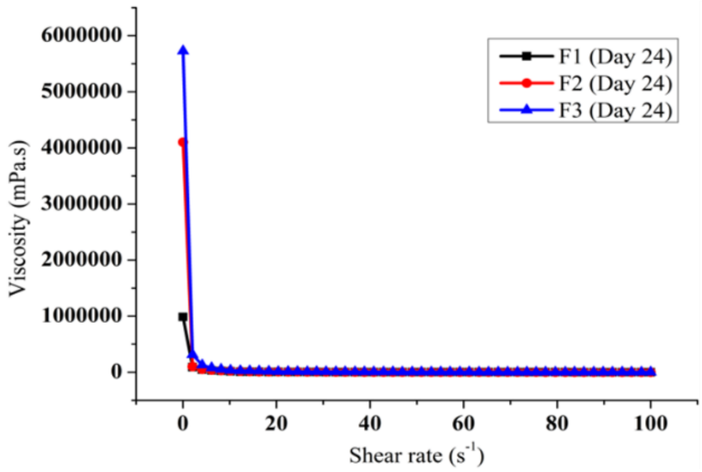
Fig. 7.6. Viscosity profile of yoghurt samples (E1, E2, E3, E4, E5 and E6) during storage period (a) 1st day; (b) 12th day; (c) 24th day

Food rheology is the study of how food products flow and deform. Since milk gels are viscoelastic, the viscous and elastic components of yoghurt can both be used to describe its rheological characteristics. Numerous non-Newtonian phenomena, including shear-thinning, yield stress, viscoelasticity, and time-dependency, are present in yoghurt [6; 49]. **Fig. 7.5-7.7** display the apparent viscosity versus shear rate plot for the various yoghurt samples (1st, 12th, and 24th days). According to Rezaei et al. [40], adding guar gum to yoghurt increased the viscosity in a concentration dependent manner. When extract was added, the viscosity of the yoghurt samples rose, however adding encapsulated haritaki extract as opposed to haritaki extract led to a higher increase the complex viscosity of the samples. According to Shaker et al. [45], the viscosity of yoghurt samples increased as the amount of fat increased.





(a) **(b)**



(c)

Fig. 7.7. Viscosity profile of yoghurt samples (F1, F2 and F3) during storage period **(**a) 1st day; (b) 12th day; (c) 24th day

As the number of days increased (1st to 24th), the viscosity decreased. In comparison to C3, C1 has a lower viscosity. 0.5% guar gum contains less than 1.5% guar gum. C2 has less viscosity than C3 does (**Fig. 7.5**). However, compared to E6, E5 has a lower viscosity. E3 and E5 were closer (**Fig. 7.6**). F1 has less viscosity than F3 does (**Fig. 7.7**). As milk's overall solid content increases, so does the viscosity of the yoghurt [5]. The resistance of a fluid to flow is its viscosity. The viscosity of yoghurt is influenced by a number of factors, including total solids, acidity, milk composition, homogenization, culture type, stabiliser, level of proteolysis, and milk preheating. Additionally, different starter microorganisms have different fermentative, aromatic, lipolytic, and proteolytic abilities, can ultimately impact the viscosity of the product [41].

7.3.5. Texture of yoghurt samples during storage period

The texture of yoghurt is a crucial sensory characteristic that determines its acceptance and quality. **Table 7.4** shows the textural characteristics of haritaki extract, encapsulate, and guar gum-incorporated yoghurts during storage.

In the present study, the adhesiveness and firmness of yoghurt were deemed important factors in determining yoghurt quality. Yogurt without any additives had a firmness of 0.69-0.72 N, while its adhesiveness varied from 6.28-7.68 g.s. The samples prepared using encapsulates such as (E1–E6) had firmness in the range of 0.38-0.70 N, whereas their adhesiveness was 5.86–8.96 g.s. The results show that the addition of encapsulates had a significant impact on the textural properties. However, the firmness of the samples (F1-F3) ranged from 0.36-0.54 N, which was lower than the control. In the case of adhesiveness, the values were in the range of 6.28–8.48 g.s, which is comparable to control. This implies that these samples had lower firmness but similar adhesiveness to the control samples.

The interaction of haritaki encapsulates and guar gum on the textural properties of yoghurt during storage was significant. The reason for such change could be attributed to the fact that, during the fermentation process, a number of chemical processes determine the yoghurt gel's strength. Disulfite bridging between the surface of the casein micelle and the denatured whey proteins causes yoghurt gel strength and viscosity [35]. Because the polysaccharides in the encapsulates and milk proteins are incompatible, the gel structure is disrupted, resulting in a decrease in firmness and other textural qualities [12]. Both Raju and Pal [38] and Sah et al. [42] found a comparable lowering in yoghurt stiffness with the addition of plant fibres. It was found that the hardness and consistency of the food reduced during storage, and that this decline was greater between days 13 and 26 than between days 0 and 13. The hardness and consistency measurements made during storage are consistent with the syneresis findings for days 0 and 13. When compared to yoghurt after 13 days of storage, the yoghurt after the first day of storage had greater syneresis, which caused the gel structure to shrink and made the yoghurt firmer [42]. The reduction in hardness and consistency between days 13 and 26 may be due to the yoghurt's increased acidity, which weakens the gel structure.

Table 7.4. Texture of yoghurt samples during storage period

Sample	1st Day		12th Day		24th Day	
	Firmness (N)	Adhesiveness (g.s)	Firmness (N)	Adhesiveness (g.s)	Firmness (N)	Adhesiveness (g.s)
C1	0.69±0.06^{aA}	6.27±0.11^{fA}	0.67±0.05^{aA}	5.64±0.05^{iB}	0.64±0.05^{aA}	5.51±0.05^{hB}
C2	0.71±0.03^{aA}	6.38±0.07^{fA}	0.69±0.05^{aA}	6.36±0.16^{fA}	0.66±0.07^{aA}	6.07±0.05^{fB}
C3	0.72±0.03^{aA}	8.68±0.06^{bA}	0.70±0.06^{aA}	8.57±0.08^{aA}	0.67±0.07^{aA}	8.52±0.11^{aA}
E1	0.70±0.05^{aA}	8.96±0.03^{aA}	0.67±0.05^{aA}	6.64±0.07^{eB}	0.65±0.07^{aA}	6.31±0.03^{eC}
E2	0.66±0.04^{abA}	8.37±0.10^{cdA}	0.63±0.04^{abA}	7.23±0.05^{dB}	0.61±0.06^{abA}	7.10±0.08^{cB}
E3	0.58±0.08^{bcA}	6.05±0.04^{gA}	0.55±0.04^{bcA}	5.94±0.07^{hAB}	0.51±0.08^{bcA}	5.82±0.16^{gB}
E4	0.38±0.06^{efA}	5.86±0.02^{hA}	0.35±0.05^{eA}	5.07±0.08^{jB}	0.33±0.05^{dA}	4.68±0.06^{iC}
E5	0.70±0.04^{aA}	8.65±0.06^{bA}	0.67±0.09^{aA}	8.32±0.08^{bB}	0.64±0.09^{aA}	7.87±0.07^{bC}
E6	0.48±0.06^{cdeA}	8.32±0.08^{dA}	0.45±0.07cd^{eA}	8.18±0.06^{bcA}	0.43±0.05^{cdA}	7.93±0.09^{bB}
F1	0.36±0.05^{fA}	6.27±0.10^{fA}	0.35±0.08^{eA}	6.08±0.04^{gB}	0.33±0.05^{dA}	5.75±0.11^{gC}
F2	0.45±0.06^{defA}	7.64±0.04^{eA}	0.44±0.04^{deA}	7.24±0.03^{dB}	0.42±0.03^{cdA}	6.86±0.09^{dC}
F3	0.54±0.06^{cdA}	8.48±0.05^{cA}	0.52±0.03^{bcdA}	8.15±0.09^{cB}	0.51±0.06^{bcA}	7.85±0.08^{bC}

Value reported as Mean ± SD of three replications. Means followed by same capital letter superscripts within a row for same parameter and small letter superscripts within a column are not significantly different ($p<0.05$).

7.3.6. Sensory analysis of yoghurt

The sensory qualities of a product are what determine whether or not customers would accept it, as indicated by the sensory analysis of yoghurt samples in **Table 7.5**. Comparing all samples, the control demonstrated the best overall acceptability. Encapsulated haritaki extract and haritaki extract combined with guar gum do not significantly alter the sensory qualities of the finished goods. The sensory scores of the yoghurt made with 0.5% (E2) guar gum can be seen to be similar to those of the control sample, but when the incorporation level was raised to 1.5%, the scores significantly decreased.

The colour, appearance, thickness, flavour, and general acceptability of the yoghurt sample were significantly decreased by the addition of 1.5% guar gum. The texture of the fortified samples, which were more or less creamy, was obviously inferior. The enhanced creaminess of dairy products may be due to higher fat content. Fortified samples were less sour than control. These elements working together to reduce sourness raise the possibilities of flavour interactions in food matrices [14]. However, pure haritaki extract instead of encapsulated haritaki extract had a more negative impact on the sensory characteristics of yoghurt. Gum was added to the samples, which increased their thickness, look, and mouth feel. The measured parameters were greatly enhanced by guar gum incorporation at 0.5%. Yogurt with encapsulated haritaki extract and guar gum at a 0.5% (E2) level of addition considerably improved the sensory characteristics.

Table 7.5. Sensorial properties of yoghurt samples

Parameters	C1	C2	C3	E1	E2	E3	E4	E5	E6	F1	F2	F3
Appearance	8.60±0.54^{a}	7.80±0.44^{abc}	7.20±0.83^{cd}	8.20±0.44^{ab}	8.40±0.89^{a}	7.20±0.83^{cd}	6.80±0.83^{d}	6.80±0.44^{d}	6.40±0.54^{d}	8.00±0.70^{abc}	7.40±0.89^{bcd}	6.60±0.54^{d}
Color	8.20±0.44^{a}	8.00±0.70^{a}	6.80±0.83^{b}	8.00±0.70^{a}	8.20±0.83^{a}	6.60±0.70^{b}	6.60±0.44^{b}	6.40±0.54^{b}	6.40±0.54^{b}	8.40±0.89^{a}	6.80±0.83^{b}	6.40±0.54^{b}
Flavor	8.20±0.44^{a}	7.80±0.83^{ab}	7.40±1.14^{abc}	7.60±0.89^{abc}	7.40±1.14^{abc}	7.40±1.14^{abc}	7.00±1.70^{bcd}	6.60±0.54^{cd}	6.20±0.44^{d}	7.40±0.54^{abc}	6.80±0.44^{bcd}	6.60±0.54^{cd}
Texture	8.60±0.54^{a}	7.60±0.54^{b}	7.40±0.54^{bc}	8.00±0.70^{ab}	7.80±0.44^{ab}	7.20±1.09^{bc}	6.60±0.54^{c}	6.40±0.54^{c}	6.40±0.54^{c}	8.00±0.70^{ab}	7.20±0.83^{bc}	6.60±0.89^{c}
Taste	8.20±0.44^{a}	7.60±0.89^{ab}	7.00±0.70^{bc}	7.60±0.54^{ab}	7.40±0.54^{ab}	7.00±0.70^{bc}	6.40±0.54^{c}	6.40±0.54^{c}	6.20±0.44^{c}	7.60±0.54^{ab}	6.40±0.89^{c}	6.40±0.54^{c}
Mouthfeel	8.20±0.44^{a}	7.40±0.54^{abcd}	6.60±0.89^{cde}	7.80±0.44^{ab}	7.60±0.54^{abc}	7.00±0.70^{bcde}	6.80±0.83^{bcde}	6.60±0.54^{cde}	6.20±0.44^{e}	7.00±1.22^{bcde}	6.80±0.83^{bcde}	6.40±0.54^{de}
Overall acceptability	8.40±0.54^{a}	7.40±0.54^{bcd}	7.20±0.83^{bcde}	7.80±0.44^{ab}	7.60±0.89^{abc}	7.40±0.54^{bcd}	7.00±0.70^{bcde}	6.80±0.44^{cde}	6.40±0.54^{e}	7.20±0.54^{bcd}	6.60±0.54^{de}	6.40±0.54^{e}

Value reported as Mean ± SD of three replications. Values followed by different superscript in a column are significantly different ($p \leq 0.05$).

7.4. Conclusion

In this chapter, freeze-dried haritaki capsules, supercritically assisted haritaki extract, and guar gum powder were used to make functional yoghurt. Comparing the bioactive qualities of the freeze-dried haritaki encapsulated yoghurt to those of regular yoghurts, a substantial improvement was seen. These bioactive elements might provide a range of health advantages. Additionally, there was a lot of antioxidant activity, which is thought to prevent cardiovascular disease. The outcome showed that gum addition caused a pH reduction that was concentration-dependent. The yoghurt with 1.5% guar gum added had the most acidity. With a storage period of 24 days at 4 °C, the pH value decreased and the acidity increased in all of the samples. In general, it can be seen that every variation has displayed a sporadic syneresis pattern. The syneresis was higher in all of the samples at 1^{st} day, but it started to decline on day 12^{th} and then started to rise again on day 24^{th} of storage. The colour of the yoghurt made with haritaki encapsulates was greener. L*, a*, and b* values did not significantly change during storage for the control sample, but they did for the other samples. When encapsulate powders were used to create the samples, lightness (L*) decreased and yellowness increased while a* values changed from green to red during storage. As seen in (E1-E6) and, storage had a considerable impact on the phytochemical content (F1-F3). The phytochemical content was seen to dramatically drop on day twelve of storage. While 18–21% of antioxidant activity was lost on the day of preparation and increased until the 24th day, the TPC in the control sample was decreased to 6.81–6.38. In cases (E1-E6), the TPC values ranged from 129.24 to 156.55, whereas the DPPH activity varied from 63.63 to 69.84%. The trend toward decline resembled that of the control sample. The phytochemical activities of (F1-F3) were also diminished. Over the whole range of examined frequencies, G′ > G″ was seen in all yoghurt samples, indicating a typical elastic behaviour of yoghurts with weak gel characteristics. The firmness of plain yoghurt ranged from 0.69 to 0.72 N, while its adhesiveness was between 6.28 and 7.68 g.s. The stiffness of the samples made with encapsulates like (E1-E6) ranged from 0.38 to 0.70 N, while their adhesiveness was 5.86 to 8.96 g.s. The findings demonstrate that encapsulation significantly affected the textural characteristics. However, the samples' firmness (F1-F3) was less than the control, ranging from 0.36 to 0.54 N. Adhesiveness values fell within the range of 6.28 to 8.48 g.s, which is similar to control. This means that these samples exhibited comparable adhesiveness to the control samples but lesser firmness. Haritaki extract in capsule form and haritaki extract combined with guar gum had a big impact on the yoghurt's quality traits. For the purpose of fortifying yoghurt, encapsulated haritaki extract performed better than haritaki extract in terms of phenolic and antioxidant activities. The sensory quality of yoghurt enriched up to 0.5% guar gum was found to be similar to that of the control sample for some sensory qualities and even better for others. It can be inferred from the present chapter that the guar gum altered the yoghurt rheology in a concentration dependent manner. These findings suggest that the pharmaceutical and functional food businesses would be very interested in the manufacturing of fortified yoghurt.

7.5. References

1. Acharjee, A., Afrin, S. M., and Sit, N. Physicochemical, textural, and rheological properties of yoghurt enriched with orange pomace powder. *Journal of Food Processing and Preservation*, 45(2), 15193, 2021.
2. Amirdivani, S., and Baba, A. S. 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-Food Science and Technology*, 44(6), 1458-1464, 2011.
3. Andiç, S., Boran, G., and Tunçtürk, Y. Effects of carboxyl methylcellulose and edible cow gelatin on physicochemical, textural and sensory properties of yoghurt. *International Journal of Agriculture and Biology*, 15(2), 245-251, 2013.
4. Avula, B., Wang, Y. H., Wang, M., Shen, Y. H., and Khan, I. A. Simultaneous determination and characterization of tannins and triterpene saponins from the fruits of various species of *Terminalia* and *Phyllantus emblica* using a UHPLC-UV-MS method: application to triphala. *Planta Medica*, 29(02), 181-188, 2013.
5. Becker, T., and Puhan, Z. Effect of different processes to increase the milk solids non-fat content on the rheological properties of yoghurt. *Milchwissenschaft*, 44(10), 626-629, 1989.
6. Benezech, T., & Maingonnat, J. F. (1994). Characterization of the rheological properties of yoghurt-a review. *Journal of Food Engineering*, *21*(4), 447-472.
7. Brand-Williams, W., Marie-Elisabeth, C, and C. L. W. T. Berset. Use of a free radical method to evaluate antioxidant activity. *LWT-Food Science and Technology*, 28(1), 25-30, 1995.
8. Bruzzone, F., Ares, G., and Giménez, A. Temporal aspects of yoghurt texture perception. *International Dairy Journal*, 29(2), 124-134, 2013.
9. Chaikham, P. Stability of probiotics encapsulated with Thai herbal extracts in fruit juices and yoghurt during refrigerated storage. *Food Bioscience*, 12, 61-66, 2015.
10. Chouchouli, V., Kalogeropoulos, N., Konteles, S. J., Karvela, E., Makris, D. P., and Karathanos, V. T. Fortification of yoghurts with grape (Vitis vinifera) seed extracts. *LWT-Food Science and Technology*, 53(2), 522-529, 2013.
11. Cirigliano, P., Chiriacò, M. V., Nunez, A., Dal Monte, G., and Labagnara, T. Combined effect of irrigation and compost application on Montepulciano berry composition in a volcanic environment of Latium region (central Italy). *Ciencia e*

investigación agraria: revista latinoamericana de ciencias de la agricultura, 44(2), 195-206, 2017.

12. Corredig, M., Sharafbafi, N., and Kristo, E. Polysaccharide–protein interactions in dairy matrices, control and design of structures. *Food Hydrocolloids*, 25(8), 1833-1841, 2011.
13. Dabija, A., Codină, G. G., Gâtlan, A. M., and Rusu, L. Quality assessment of yogurt enriched with different types of fibers. *Cyta-Journal of food*, 16(1), 859-867, 2018.
14. Dal Bello, B., Torri, L., Piochi, M., and Zeppa, G. Healthy yogurt fortified with n-3 fatty acids from vegetable sources. *Journal of Dairy Science*, 98(12), 8375-8385, 2015.
15. Damin, M. R., Alcântara, M. R., Nunes, A. P., and Oliveira, M. N. D. Effects of milk supplementation with skim milk powder, whey protein concentrate and sodium caseinate on acidification kinetics, rheological properties and structure of nonfat stirred yogurt. *LWT-Food Science and Technology*, 42(10), 1744-1750, 2009.
16. Emine, M., and Ihsan, B. Effect of different stablizers on quality characteristics of the set-type yogurt. *African Journal of Biotechnology*, 16(46), 2142-2151, 2017.
17. Everett, D. W., and McLeod, R. E. Interactions of polysaccharide stabilisers with casein aggregates in stirred skim-milk yoghurt. *International Dairy Journal*, 15(11), 1175-1183, 2005.
18. Fernandez-Garcia, E., and McGregor, J. U. Fortification of sweetened plain yogurt with insoluble dietary fiber. *Zeitschrift für Lebensmitteluntersuchung und-Forschung* A, 204(6), 433-437, 1997.
19. Forni, C., Facchiano, F., Bartoli, M., Pieretti, S., Facchiano, A., D'Arcangelo, D. and Jadeja, R. N. Beneficial role of phytochemicals on oxidative stress and age-related diseases. *BioMed research international*, 2019.
20. García-Pérez, F. J., Lario, Y., Fernández-López, J., Sayas, E., Pérez-Alvarez, J. A., and Sendra, E. Effect of orange fiber addition on yogurt color during fermentation and cold storage. *Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur*, 30(6), 457-463, 2005.

21. Garrote, G., Cruz, J. M., Moure, A., Domınguez, H., and Parajó, J. C. Antioxidant activity of byproducts from the hydrolytic processing of selected lignocellulosic materials. *Trends in Food Science & Technology*, 15(3-4), 191-200, 2004.
22. Gentès, M. C., Turgeon, S. L., and St-Gelais, D. Impact of starch and exopolysaccharide-producing lactic acid bacteria on the properties of set and stirred yoghurts. *International Dairy Journal*, 55, 79-86, 2016.
23. Gurkan, H., Boran, O. S., and Hayaloglu, A. A. Influence of purple basil extract (Ocimum basilicum L.) on chemical composition, rheology and antioxidant activity of set-type yoghurt. *Mljekarstvo/Dairy*, 69(1), 2019.
24. Hematyar, N., Samarin, A. M., Poorazarang, H., and Elhamirad, A. H. Effect of gums on yoghurt characteristics. *World Applied Sciences Journal,* 20(5), 661-665, 2012.
25. Jayaprakasam, B., Vareed, S. K., Olson, L. K., and Nair, M. G. Insulin secretion by bioactive anthocyanins and anthocyanidins present in fruits. *Journal of agricultural and food chemistry*, 53(1), 28-31, 2005.
26. Kang, S. H., Yu, M. S., Kim, J. M., Park, S. K., Lee, C. H., Lee, H. G., and Kim, S. K. Biochemical, microbiological, and sensory characteristics of stirred yogurt containing red or green pepper (*Capsicum annuum* cv. *Chungyang*) juice. *Korean journal for food science of animal resources*, 38(3), 451, 2018.
27. Kim, Dae-Ok, Seung Weon Jeong, and Chang Y. Lee. Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food Chemistry,* 81(3), 321-326, 2003.
28. Kiros, E., Seifu, E., Bultosa, G., and Solomon, W. K. Effect of carrot juice and stabilizer on the physicochemical and microbiological properties of yoghurt. *LWT-Food Science and Technology*, 69, 191-196, 2016.
29. Kris-Etherton, P. M., Harris, W. S., and Appel, L. J. Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *circulation*, 106(21), 2747-2757, 2002.
30. Lee, Y., and Chang, Y. H. Influence of guar gum addition on physicochemical, microbial, rheological and sensory properties of stirred yoghurt. *International Journal of Dairy Technology*, 69(3), 356-363, 2016.
31. Lucey, J. A. The relationship between rheological parameters and whey separation in milk gels. *Food Hydrocolloids*, 15(4-6), 603-608, 2001.
32. Mousavi, M., Heshmati, A., Garmakhany, A. D., Vahidinia, A., and Taheri, M. (2019). Optimization of the viability of Lactobacillus acidophilus and physico-

chemical, textural and sensorial characteristics of flaxseed-enriched stirred probiotic yogurt by using response surface methodology. *LWT*, 102, 80-88, 2019.

33. Mudgil, D., Barak, S., and Khatkar, B. S. Development of functional yoghurt via soluble fiber fortification utilizing enzymatically hydrolyzed guar gum. *Food Bioscience*, 14, 28-33, 2016.
34. Neirynck, N., Dewettinck, K., and Van der Meeren, P. (2007). Influence of pH and biopolymer ratio on sodium caseinate—guar gum interactions in aqueous solutions and in O/W emulsions. *Food Hydrocolloids*, 21(5-6), 862-869, 2007.
35. Ozcan, T. Determination of yogurt quality by using rheological and textural parameters. *Food Science & Nutrition*, 53, 118-122, 2013.
36. Perrechil, F. A., Braga, A. L. M., and Cunha, R. L. Interactions between sodium caseinate and LBG in acidified systems: Rheology and phase behavior. *Food Hydrocolloids*, 23(8), 2085-2093, 2009.
37. Purwandari, U., Shah, N. P., and Vasiljevic, T. Effects of exopolysaccharide-producing strains of Streptococcus thermophilus on technological and rheological properties of set-type yoghurt. *International Dairy Journal*, 17(11), 1344-1352, 2007.
38. Raju, P. N., and Pal, D. Effect of dietary fibers on physico-chemical, sensory and textural properties of Misti Dahi. *Journal of food science and technology*, 51(11), 3124-3133, 2014.
39. Rechner, A. R., and Kroner, C. Anthocyanins and colonic metabolites of dietary polyphenols inhibit platelet function. *Thrombosis research*, 116(4), 327-334, 2005.
40. Rezaei, R., Khomeiri, M., Kashaninejad, M., and Aalami, M. Effects of guar gum and arabic gum on the physicochemical, sensory and flow behaviour characteristics of frozen yoghurt. *International Journal of Dairy Technology*, 64(4), 563-568, 2011.
41. Robinson, R. K., Lucey, J. A., and Tamime, A. Y. Manufacture of yoghurt. *Fermented milks*, 53-75, 2006.
42. Sah, B. N. P., Vasiljevic, T., McKechnie, S., and Donkor, O. N. Physicochemical, textural and rheological properties of probiotic yogurt fortified with fibre-rich pineapple peel powder during refrigerated storage. *LWT-Food Science and technology*, 65, 978-986, 2016.
43. Ścibisz, I., Ziarno, M., Mitek, M., and Zaręba, D. Effect of probiotic cultures on the stability of anthocyanins in blueberry yoghurts. *LWT-Food Science and Technology*, 49(2), 208-212, 2012.

44. Shah, N. P. Probiotic bacteria: selective enumeration and survival in dairy foods. *Journal of dairy science*, 83(4), 894-907, 2000.
45. Shaker, R. R., Jumah, R. Y., and Abu-Jdayil, B. Rheological properties of plain yogurt during coagulation process: impact of fat content and preheat treatment of milk. *Journal of Food Engineering*, 44(3), 175-180, 2000.
46. Shori, A. B., and Baba, A. S. Comparative antioxidant activity, proteolysis and in vitro α-amylase and α-glucosidase inhibition of Allium sativum-yogurts made from cow and camel milk. *Journal of Saudi Chemical Society*, 18(5), 456-463, 2014.
47. Sigdel, A., Ojha, P., and Karki, T. B. Phytochemicals and syneresis of osmo-dried mulberry incorporated yoghurt. *Food Science & Nutrition*, 6(4), 1045-1052, 2018.
48. Sit, N., Misra, S., Baruah, D., Badwaik, L. S., and Deka, S. C. Physicochemical properties of taro and maize starch and their effect on texture, colour and sensory quality of tomato ketchup. *Starch-Stärke*, 66(3-4), 294-302, 2014.
49. Steffe, J. F. *Rheological methods in food process engineering*. Freeman press, 1996.
50. Thompson, J. L., Lopetcharat, K., and Drake, M. A. Preferences for commercial strawberry drinkable yogurts among African American, Caucasian, and Hispanic consumers in the United States. *Journal of dairy science*, 90(11), 4974-4987, 2007.
51. Tsuda, T., Horio, F., Uchida, K., Aoki, H., and Osawa, T. Dietary cyanidin 3-O-β-D-glucoside-rich purple corn color prevents obesity and ameliorates hyperglycemia in mice. *The Journal of nutrition*, 133(7), 2125-2130, 2003.
52. Varga, L. Effect of acacia (*Robinia pseudo-acacia L.*) honey on the characteristic microflora of yogurt during refrigerated storage. *International journal of food microbiology*, 108(2), 272-275, 2006.
53. Wang, T., Jonsdottir, R., and Ólafsdóttir, G. Total phenolic compounds, radical scavenging and metal chelation of extracts from Icelandic seaweeds. *Food chemistry*, 116(1), 240-248, 2009.
54. Xu, K., Guo, M., Du, J., and Zhang, Z. Okra polysaccharide: Effect on the texture and microstructure of set yoghurt as a new natural stabilizer. *International journal of biological macromolecules*, 133, 117-126, 2019.