Italian Journal of Food Science, 2024; 36 (4): 288–304

Fortification of yogurt with cloves extract: Quality characteristics, sensory attributes, and antioxidant evaluation

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Received: 6 July 2024; Accepted: 21 September 2024; Published: 19 October 2024

ORIGINAL PAPER

Abstract

The purpose of the current study was to evaluate the impact of different concentrations of clove extract (CE: 0%, 0.5%, 1.0%, and 2.0%) on the viscoelasticity, viscosity, syneresis, texture, sensory quality, and antioxidant properties of set yogurt up to 21 days in cold storage. The addition of CE enlarged the total suspended solids (TSS) and mineral contents while reducing whey separation. On the other hand, CE existence dropped the consistency index (k) and elastic modulus (G') of yogurt gels and further lessening was observed with prolonged storage period. Moreover, the textural firmness remained unaffected whereas gels that are more cohesive were attained with integration of CE. Similarly, total phenolics and free radical scavenging activity increased significantly ($p < 0.05$) by CE supplementation, and amplified lipid oxidation was observed with increased storage time. Addition of CE lowered the lightness (L*) index and manipulated the organoleptic properties whereas the sample with 1% CE showed improvement in texture and flavor; however, the overall acceptability reduced for samples with higher concentration of CE.

Keywords: antioxidant; cloves; extract; sensory; yogurt

Introduction

Yogurt, the most popular fermented dairy product, is consumed extensively due to its nutritional value and health advantages. Yogurt contains proteins, minerals, prebiotics, and probiotics bacteria, and a high concentration of calcium (Ca), riboflavin, pyridoxine (B_6), and cyanocobalamin (B_{12}) (Borgonovi *et al.*, 2022; Fazilah *et al.*, 2018; García-Burgos *et al.*, 2020; O'Sullivan *et al.*, 2016; Rodríguez-Sánchez *et al.*, 2021). Yogurt is flavored with fruits or flavoring compounds to enhance texture and flavor. In addition, the plant extracts incorporated in dairy products may enhance the physicochemical and functional properties, beneficial for consumers (Ozmen-Togay *et al.*, 2022). Natural flavors provide bioactive compounds with antioxidant activity, such as carotenoids, phenolic compounds, and tocopherols. Compared to fruited yogurt, spiced yogurt is less esteemed. Fruits and spices have a high concentration of bioactive compounds with excellent flavor, and this increases yogurt consumption by providing additional nutrients to meet body's needs and enhancing consumer acceptability (Surh, 2002).

In addition, consumers prefer flavored foods with health benefits derived from natural sources. There is a growing interest in using plant-based natural additives and addition of health-regulating substances in human diet (Thompson *et al.*, 2007; Varga, 2006). Preedy *et al.* (2013) suggest that fortifying yogurt with various nutritive additives could be the best method to increase nutrient intake by humans in their daily diet.

Clove (*Syzygium aromaticum*) is commonly used as a flavoring and seasoning agent in various traditional and commercial products prepared by the food industry. Additionally, clove is employed for diverse medicinal and therapeutic purposes to delay the onset of ageing, speeding the healing of wounds, and for cure of a wide range of illnesses, such as dermal cancer, thyroid dysfunction, digestive, and cardiovascular ailments (Cortés-Rojas *et al*., 2014; El-Maati *et al*., 2016). This is because cloves contain numerous bioactive phenolic compounds with potent antioxidant, antiviral, antimicrobial, and anticancer effects (Cortés-Rojas *et al*., 2014; Rubió *et al*., 2013).

Studies are conducted where single or blend of various flavoring essential oils was incorporated in yogurt to improve its sensory properties (Akan *et al*., 2022; Chon *et al*., 2020; Tavakoli *et al*., 2018), although only limited studies were conducted with cinnamon extract (CE) in dairy products, especially in set yogurt. Furthermore, none of the studies were focused the impact of CE on oxidation of saturated fat in yogurt. Therefore, the purpose of this study was to assess the effect of CE addition on the physicochemical properties, rheology, texture, and organoleptic properties of yogurt. In addition, the possible improvement in the anti-oxidative properties of set yogurt and inhibition of lipid oxidation were also calculated.

Materials and Methods

Materials

Clove pods and milk powder were bought from the local hypermarket of Riyadh, Saudi Arabia. Starter culture, that is, *Lactobacillus delbrueckii* subsp*. bulgaricus* and *Streptococcus thermophilus* were acquired from Chr. Hansen (Denmark) and saved at -80°C until further usage in producing yogurt. All other analytical reagents and chemicals were bought from Sigma-Aldrich (USA).

Methods

Preparation of clove extract

Clove extracts were prepared by using 80% methanol as a solvent. Briefly, 2-g clove pods powder was added to 200 mL of 80% ethanol and the extraction was done by employing an ultrasound bath (2800 CPX, USA) for 20 min at 42.5°C. The operating power and frequency were set to 110 W and 40 kHz, respectively. The CE extract was cooled to ambient temperature and filtered through a filter paper (Whatman No. 1), followed by freeze-drying and finally kept at –80°C for further experimentation.

Preparation of yogurt

Yogurt was prepared according to Zhang *et al*. (2019) with minor modifications. Briefly, powdered milk (12 g/100 mL) was mixed with distilled water, and the developed mix was homogenized using a homogenizer (T25, IKA; Ultra-Turrax, Germany) for 5 min and pasteurized for 30 min at 85°C. The pasteurized mix was cooled to 42°C and inoculated with 2.5% (v/v) of activated starter culture (*Lactobacillus delbrueckii* subsp. *Bulgaricus* and *Streptococcus thermophilus*). The inoculated mix (almost 14 g) was dispensed in polyethylene cup (100 mL) and kept at 42°C for almost 4 h for clot formation (~pH 4.6) and further stored at chilled temperatures (4°C) for 7, 15, and 21 days. Similarly, three samples of yogurt containing 0.5%, 1%, and 2% CE were prepared along with a control.

Chemical composition, pH, and color measurements

Pursuing the Association of Analytical Chemists (AOAC, 2005) standard methods, the moisture content was determined by the gravimetric method, fat was calculated by the Gerber method, protein was estimated by the micro-Kjeldahl method, total suspended solids (TSS) were calculated by the oven drying method, and ash was estimated by the charring method. The pH of samples was measured by a calibrated bench top pH meter (Corning Scientific Products, USA), while titratable acidity was estimated by the alkali titration method.

For color, the sample was poured into a transparent flat glass plate using a colormeter (CR-300 Minolta, Japan) and the color was reported by 'Commission Internationale de l'Éclairage' (International Commission on Illumination or CIE) parameters such as (L*) lightness, (a*) greenness, and (b*) redness at ambient conditions.

Minerals analysis

Minerals content in sample was measured by using an inductively coupled plasma–atomic emission spectrometer (ICP-AES; iCAP 6000; Thermo Scientific, USA). Briefly, sample (0.5 g) was digested in Ethos advanced microwave apparatus (Milestone, USA) for 31 min using 7 mL of HNO_3 (65%) and 1 mL H_2O_2 (30%) and diluted with deionized water to make up to 100 mL (Shori, 2022). All samples were analyzed in triplicate.

Whey separation

Yogurt sample (10 g) was poured into a plastic cup and placed tilted at 45° angle to collect drained whey on side of the cup. The sample cups were weighed every 10 s after separating the liquid using a syringe. The percentage of syneresis was evaluated by the weight loss of yogurt over the original initial weight and multiplying by 100 (Bakry *et al*., 2019).

Apparent viscosity and dynamic rheology

Using a rotating viscometer (Brookfield, RV-DVII), the apparent viscosity of yogurt was determined at ambient temperature according to Saleh *et al.* (2020b). Shear rate versus shear stress curves of all samples were plotted. The plots were fitted with power law model to estimate parameters as follows:

$$\sigma = k\,\gamma^{\,n}, \tag{1}$$

where σ denotes shear stress (pascal [Pa].s), *k* denotes consistency index (Pa.s), *γ* represents shear rate (s^{-1}), and *n* is the flow behavior index of the sample. To obtain flow index (*n*) from the slope estimation of the plotted data, the log data of shear stress versus shear rate was plotted. The dynamic rheology of the sample was measured at room temperature (25°C) according to Saleh *et al.* (2020b) using a Discovery Hybrid Rheometer (DHR-1; TA Instruments, USA).

Texture profile analysis (TPA)

Yogurt texture was estimated by employing a texture analyzer (TX-XT2, Stable Micro Systems, NY, USA) according to the method reported by Saleh *et al.* (2020b). The sample was subjected to a double compression cycle by using a plastic probe (45° Perspex Cone, 432–081) with a crosshead velocity of 70 mm/min, where the probe was inserted up to 20-mm depth from the surface. The texture data were interpreted in terms of hardness, springiness, cohesiveness, and adhesiveness.

Total phenolic content (TPC) estimation

A 100 g of sample was centrifuged for 5 min at 5,000×*g* at chilled temperature (4°C); the supernatant was collected and re-centrifuged for the preparation of yogurt extracts (Mohamed Ahmed *et al.*, 2020). The Folin–Ciocalteu's (FC) reagent method was used for estimating TPC of yogurt extract as reported by Cho *et al.* (2017), Briefly, extract (0.1 mL) was added to 1-M 0.1-mL FC and kept for 5 min at ambient temperature. After adding 0.3 mL of Na_2CO_3 and subsequent 30-min incubation, 1 mL distilled water was supplemented, and spectrophotometric absorbance of the sample was conducted at 725 nm using a spectrophotometer (Lambda EZ 150; PerkinElmer, USA). The results were specified as milligram (mg) of gallic acid (GA) equivalent/100 gram (g) of yogurt sample.

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity

The antioxidant activity of yogurt extract was evaluated by measuring DPPH free radical scavenging activity as modified by Jung *et al.* (2016), briefly, 0.2 mL from extract sample was blended with 1 mL of methanolic solution of DPPH (100 μM), and the mixture was subjected to 15-min incubation in the dark at ambient temperature, followed by measuring the absorbance of sample at 517 nm using a spectrophotometer (Lambda EZ 150; PerkinElmer). The radical scavenging activity was calculated as percentage inhibition using the following equation:

$$\text{DPPH radical scavenging (\%)} = \frac{\text{Absorbance of control} - \text{Absorbance of the sample}}{\text{Absorbance of control}} \times 100$$

Thiobarbituric acid reactive substances (TBARS) measurement

The TBARS assay was used to assess the lipid oxidation of yogurt stored for 21 days at 4°C as described previously (Bakry *et al*., 2019). In this assay, a mixture of 0.5-mL ethanolic butylated hydroxytoluene (0.8%) and 0.5 mL of thiobarbituric acid (1%) in 10% trichloroacetic acid (TCA) was prepared, and then 1 g sample was added for thorough mixing. The resultant mixture was kept for 1 h at 70°C, and subsequently centrifuged for 25 min at 5,000×*g* to collect supernatant. Thus, the absorbance of the resulting supernatant was estimated using a spectrophotometer (Lambda EZ 150; PerkinElmer) at a wavelength of 532 nm. Different concentrations of the authentic standard of 1,1,3,3-tetraethoxypropane (TEP), which is a precursor of malondialdehyde (MDA), were used to prepare standard curve, and the results were presented as mg MDA/kg of yogurt.

Sensory evaluation

Panelists aged 20–35 years assessed the yogurt's sensory quality. Yogurt samples, randomly coded with three numbers, were prepared and served to panelists in a random order. The panelists were requested to assess color, taste, flavor, textures, and the overall acceptance of yogurt samples using a 9-point hedonic scale, where 1 is ranked as 'dislike extremely' and 9 demonstrated 'like extremely'.

Statistical analysis

Three replicates of samples were prepared and each sample was measured thrice. All data of yogurt samples and measurements were analyzed by one-way analysis of variance by employing SAS® 9.4 (SAS Institute Inc., NC, USA). For comparison of mean values, Duncan's Multiple Range Test (DMRT) was applied by keeping the significance level of $p < 0.05$.

Result and Discussion

Yogurt chemical composition

Increase of CE concentration did not affect the moisture components of yogurt, although nonsignificant rise in total protein and a massive rise in ash were observed in samples with 2% CE (Table 1). A higher TSS in sample with 2% CE could be correlated to higher levels of ash and proteins. Generally, the apparent increase in solids assumed a parallel reduction in the moisture of foods. A similar rise in TSS was also observed by Salama *et al.* (2022) when nano-emulsions of various essential oils were incorporated in stirred yogurt. On the other hand, when fermented milk was added with phenolic-rich herbal extracts, no change was observed in TSS in the treated samples (Ramos *et al.*, 2017). Estimation of ash showed the presence of fractions of phosphorous (P) and calcium (Ca), followed by potassium (K) and magnesium (Mg) and traces of zinc (Zn). As casein proteins are complexed with calcium phosphates in the colloidal form of milk, calcium and phosphorus are massively higher in milk than other minerals. Addition of CE resulted in a significant ($p < 0.05$) rise in all the minerals enlisted above. A 2% addition of CE resulted in 28.2 mg increase in K, 21.4 mg increase in P, 17.1 mg increase in Ca, and 4.10 mg increase in Mg. Yangilar and Yildiz (2017) observed a significant increase in the mineral contents of bio-yogurt mixed with ginger oil. Nonetheless, no change was reported in ash content when phenolic-rich herbal extracts were added to yogurt (Ramos *et al.*, 2017).

Regarding acidity and pH of yogurt, no disparity was observed with the supplementation of 2% of CE (Table 2). The acidity of samples remained at 0.73–0.95 whereas higher values were realized by increasing storage time to 21 days. In a study, addition of phenolic-rich herbal extract in fermented milk resulted in a significant rise of treatable acidity (Ramos *et al.*, 2017). In an environment of increased acidity, an obvious decline in pH was exhibited in samples with increased storage period from 0 to 21 days. The samples' pH remained between 4.06 and 4.70 whereas the most acidic samples had 2% CE and were stored for a maximum of 21 days (Table 2). Yangilar and Yildiz (2017) supplemented yogurt with ginger essential oil (0.2%) and/or mixture of ginger (0.2%) and chamomile essential oil (0.2%), and discovered decrease in pH after 28 days of storage. The metabolic activities of yogurt culture produced more organic acids (e.g., lactic acid, acetic acid, acetaldehyde, formic acid, etc.) and resulted in the lowering of pH, with simultaneous intensification of acidity under storage conditions. The residual viability and activity of lactic acid bacteria provides post-acidification of yogurt during cold storage (Kaminarides *et al.*, 2007; Saint-Eve *et al.*, 2008). Contrarily, the addition of various concentration of clove oil in yogurt did not change its pH (Chon *et al.*, 2020).

Color estimation

The CIE color estimation was performed for all samples. Among all samples, the highest lightness (L*) was

Table 1. Chemical composition and minerals analysis of yogurt with different levels of clove extract.

Samples	Chemical composition				
	Moisture	Protein	Fat	TS**	Ash
0% CE*	86.73±1.25^{a}	3.72±0.09^{a,b}	3.54±0.01^{a}	13.27±0.58^{a,b}	0.75±0.01^{b}
0.5% CE	86.71±1.14^{a}	3.71±0.47^{a,b}	3.55±0.01^{a}	13.29±0.29^{b}	0.78±0.01^{a,b}
1% CE	86.70±1.00^{a}	3.71±0.01^{b}	3.56±0.01^{a}	13.30±0.36^{b}	0.80±0.01^{a}
2% CE	86.41±1.07^{a}	3.74±0.01^{a}	3.54±0.01^{a}	13.59±0.78^{a}	0.81±0.01^{a}
Samples	**Minerals (mg/100 g)**				
	P	**Ca**	**Mg**	**K**	**Zn**
0% CE*	128.23±1.20^{d}	153.34±2.01^{d}	19.05±0.39^{c}	61.84±0.65^{c}	0.039±0.01^{c}
0.5% CE	139.76±2.00^{c}	157.12±1.05^{c}	21.43±0.08^{b}	72.65±0.36^{b}	0.052±0.01^{b}
1% CE	144.54±1.07^{b}	162.33±0.09^{b}	22.95±0.94^{b}	83.71±0.07^{a}	0.065±0.01^{a}
2% CE	149.65±1.00^{a}	170.51±1.54^{a}	25.15±0.78^{a}	90.11±0.01^{a}	0.069±0.01^{a}

*CE: clove extract; **TS: total solid values followed by different superscripted letters within each column are significantly different ($p \le 0.05$).

Table 2. Acidity, pH, and whey separation of yogurt with different levels of CE at cold storage.

Samples storage days (D)	Acidity			
	0 D	7 D*	15 D	21 D
0% CE*	$0.74±0.02^{a,D}$	$0.83±0.02^{a,C}$	$0.87±0.01^{a,b,B}$	$0.91±0.01^{b,A}$
0.5% CE	$0.73±0.01^{a,D}$	$0.84±0.02^{a,C}$	$0.89±0.03^{a,B}$	$0.93±0.01^{a,b,A}$
1% CE	$0.73±0.01^{a,D}$	$0.84±0.01^{a,C}$	$0.89±0.02^{a,B}$	$0.95±0.01^{a,A}$
2% CE	$0.73±0.01^{a,D}$	$0.84±0.01^{a,C}$	$0.91±0.01^{a,B}$	$0.95±0.01^{a,A}$
Samples storage days (D)	**pH**			
	0 D	**7 D**	**15 D**	**21 D**
0% CE*	$4.70±0.08^{a,A}$	$4.51±0.09^{a,B}$	$4.34±0.08^{a,C}$	$4.22±0.01^{a,D}$
0.5% CE	$4.63±0.06^{b,A}$	$4.48±0.10^{a,b,B}$	$4.29±0.10^{a,b,C}$	$4.16±0.01^{b,D}$
1% CE	$4.64±0.30^{b,A}$	$4.46±0.21^{a,b,B}$	$4.21±0.01^{c,C}$	$4.12±0.01^{c,D}$
2% CE	$4.64±0.12^{b,A}$	$4.43±0.01^{b,B}$	$4.18±0.01^{c,C}$	$4.06±0.01^{d,C}$
Samples storage days (D)	**Whey separation**			
	0 D	**7 D***	**15 D**	**21 D**
0% CE*	$20.63±1.00^{a,D}$	$29.51±0.10^{a,C}$	$36.13±1.04^{a,B}$	$46.87±0.92^{a,b,A}$
0.5% CE	$19.27±0.70^{a,b,D}$	$29.53±0.64^{a,C}$	$36.49±0.90^{a,B}$	$47.02±0.72^{a,A}$
1% CE	$18.56±0.09^{b,D}$	$29.01±0.87^{a,b,C}$	$36.09±2.00^{a,B}$	$47.06±0.61^{a,A}$
2% CE	$17.98±0.45^{c,D}$	$28.63±0.09^{b,C}$	$35.76±0.96^{a,b,B}$	$45.02±0.87^{c,A}$

*CE: clove extract; **D: storage days.
Values are presented as mean ± standard deviation. $^{a–d}$Mean values followed by different lowercase superscripted letters in the same column are significantly different ($p < 0.05$).
$^{A–D}$Mean values followed by different uppercase superscripted letters in the same row for the same parameter are significantly different ($p < 0.05$).

presented by the control having no addition of CE. However, the addition of various concentrations of CE imparted a significant reduction in L* value whereas the sample with 2% CE presented maximum reduction in L*. Decline in L* of yogurt could be correlated to the pigmented phenolics found in CE, shifting to darker color, compared to color of the control. The storage period of 15 days did not alter further the lightness of samples; however, a decline in lightness was observed when samples were stored for 21 days whereas the darkest yogurt was the one having 2% CE (Table 3).

In samples, a* depicts redness (+a*) or greenness (-a*) of the product estimated using colormeter. In the current study, all samples showed -a* values, indicating their greenish tinge. The control was found to be having maximum greenish tinge whereas the addition of CE in the sample provided significant reduction in greenness, with the least greenish tinge observed for sample containing 2% CE. However, a drastic shift in a* was observed for all yogurt samples with 21 days storage, although the values remained in green coordinate (as -a*). This shows that the addition of CE diluted the greenness of yogurt, especially at higher concentrations, due to the presence of pigmented phenolics.

As anticipated, the existence of all levels of CE in yogurt significantly ($p < 0.05$) enhanced the yellowness (b*) of product. However, variation in CE concentration from 0.5% to 2% could not impart much change in yellowness. Increase in yellowness could also be justified with lower L* values of yogurt samples with higher concentrations of CE. Interestingly, the storage of yogurt samples enhanced their yellowness and the strongest change in coloration was observed for the samples stored for 21 days having 2% CE. Thus, it shows that the three-dimensional (3D) casein network is cured by the addition of CE and resulted in reduced whiteness of samples. Ogunyemi *et al.* (2021) reported lowering of L* and increase in b* in yogurt sample with addition of African black pepper and turmeric extract. Tavakoli *et al.* (2018) envisaged the addition of phenolics from olive leaf in yogurt and found reduced whiteness index. Besides, a larger reduction in lightness was also detected with amplified storage period.

Whey separation

Whey separation is an undesirable discharging of whey proteins from 3D casein network of set yogurt during storage; this is also called syneresis. Generally, syneresis

Table 3. Color characteristics of yogurt with different levels of CE.

Samples storage days (D)	L*			
	0 D	7 D*	15 D	21 D
0% CE*	89.32±0.11^{a,A}	88.55±0.23^{a,B}	88.46±0.12^{a,B}	87.47±0.12^{a,C}
0.5% CE	88.01±0.05^{b,A}	87.24±0.50^{b,B}	87.15±0.80^{a,b,B}	86.16±0.01^{b,C}
1% CE	85.76±0.03^{c,A}	84.99±0.97^{c,B}	84.90±0.19^{c,B}	83.91±0.43^{c,B}
2% CE	83.91±0.13^{d,A}	83.14±0.10^{d,A}	83.05±0.67^{d,A}	82.06±0.67^{d,B}
Samples Storage days (D)	**a***			
	0 D	**7 D****	**15 D**	**21 D**
0% CE*	–2.98±0.01^{c,C}	–2.96±0.01^{d,C}	–2.86±0.01^{d,B}	–2.81±0.01^{d,A}
0.5% CE	–2.57±0.01^{b,C}	–2.55±0.01^{c,C}	–2.45±0.01^{c,B}	–2.40±0.01^{c,A}
1% CE	–1.98±0.01^{a,b,C}	–1.96±0.01^{b,C}	–1.86±0.01^{b,B}	–1.81±0.01^{b,A}
2% CE	–1.78±0.01^{a,B}	–1.76±0.01^{a,B}	–1.66±0.01^{a,A}	–1.61±0.01^{a,A}
Samples Storage days (D)	**b***			
	0 D	**7 D****	**15 D**	**21 D**
0% CE*	14.98±0.01^{b,D}	17.63±0.09^{b,C}	19.62±0.32^{b,B}	20.28±0.09^{b,A}
0.5% CE	15.14±0.11^{a,b,D}	17.79±0.04^{b,C}	19.78±0.09^{b,B}	20.44±0.06^{b,A}
1% CE	15.35±0.01^{a,D}	18.00±0.01^{a,C}	19.99±0.07^{a,b,B}	20.65±0.01^{b,A}
2% CE	15.95±0.03^{a,D}	18.60±0.01^{a,C}	20.59±0.01^{a,B}	21.25±0.01^{a,A}

*L: lightness, a: redness, b: yellowness; *CE: clove extract; **D: storage days.
Values are presented as mean ± standard deviation. $^{a–d}$Mean values followed by different lowercase superscripted letters in the same column are significantly different ($p < 0.05$).
$^{A–D}$Mean values followed by different uppercase superscripted letters in the same row for the same parameter are significantly different ($p < 0.05$).

is not preferred by consumers, as it indicates quality defect in yogurt. The impulsive parting of whey regardless of any exterior applied stress to yogurt gel is a gauge of its friable nature, which is interrelated with the reorganization of 3D casein network (Sigdel *et al*., 2018; Zhong *et al*., 2018). Whey separation in set yogurt is generally instigated by low pH, low milk solids, extended incubation period, disparity between whey–casein protein ratio, and physical shudders during transfer and storage. Thus, to alleviate whey separation, numerous additives, such as stabilizers, are used (Isleten and Karagül-Yüceer, 2006; Ramirez-Santiago *et al*., 2010; Saleh *et al*., 2020a, 2020b). Whey separation was decreased with the presence of CE, and momentous lessening was observed with the addition of 2% CE. However, with increase in storage time, a drastic surge in syneresis was observed for all samples, with the highest syneresis of 47.06 observed at 21 days of storage (Table 2). However, at any given period of storage (7, 15, or 21 days), the presence of CE improved yogurt quality by reducing syneresis, compared to the control. This reduction in syneresis shows that the texture of yogurt remained smoother and more coherent in the presence of CE. This ultimately depicts the ability of eugenol and cinnamaldehyde found in CE, which interacted with the casein network and supported to hold larger amount of whey proteins and water, thereby preventing syneresis. Salama *et al*. (2022) reported increased syneresis in yogurt added with plant essential oils with increased storage period to 15 days. A higher post-storage acidity of samples was due to the production of lactic acid by the residual activity of starter culture (lactic acid bacteria) which weakened the 3D network of casein and decreased-water holding capacity and enhanced syneresis. Yuliana *et al*. (2013) also suggested that the breakdown of thickening stabilizers in yogurt was due to the production of higher concentration of lactic acid, which also degraded the polymers and resulted in increased syneresis. In a study, increased syneresis was reported when rosemary extract was added to probiotic yogurt, especially at elevated levels (Massoud and Sharifan, 2020).

Rheological properties

The flowing properties of yogurt are key indicators of its behavior and stability under applied stresses (Gregersen *et al*., 2021). The rheological measurements of samples were arrived at by using a programmed shear ramping up at a given temperature, and consistency index (k) and flow behavior index (*n*) of samples were estimated using the power law model; data are presented in Table 4. The near-to-1 value of the coefficient of regression (R^2) indicated the suitability of model used for estimating the rheological behavior of samples.

In the case of *k*, an indicator of viscosity, a clear difference was observed between yogurt gels prepared with different concentrations of CE. The consistency of yogurt has a well-established correlation with its quality and organoleptic acceptability (Velez-Ruiz *et al*., 2013). The samples with added CE showed a massive reduction in consistency index, compared to the control. The consistency index dropped from 411 to 311 (a difference of 100) when 1% of CE was added to yogurt. Contrarily, a further rise in the concentration of CE (2%) in yogurt increased consistency index and provided almost similar value as that of the control.

Simultaneous decline (by 1% CE) and rise (by 2% CE) in consistency index could be due to entanglement and/or disentanglement of the casein (polymer) network, with the partial and/or complete chain configuration of micro-structure in the axis of applied shear, thus increasing/reducing the local drag (Behnia *et al*., 2013). This shows that at higher CE concentration (2%), the system behaved better and a positive change in viscosity was observed. It should be noted that the viscose behavior of yogurt gel is not necessarily an indicator of firmer gels (Saleh *et al*., 2020b). However, the lowering of consistency of samples by 0.5–1% addition of CE plasticized the 3D casein protein network of yogurt and provided a much lower consistency index, compared to the control. A greater decrease in the consistency index of samples was observed at 7, 15, and 21 days of storage, compared to zero day, indicating that CE had interacted unfavorably with the 3D casein network and reduced gel stability and viscosity during storage. It is noteworthy that the drop in consistency index was drastic during 15 days of storage, compared to zero day, although increase in storage time could not bring significant decline in consistency. It showed that maximum changes in rheology occurred during 15 days of storage, which could be due to curing of the protein network by the presence of metabolites and CE.

Addition of melatonin and vitamin B_{12} by Jurado-Guerra *et al*. (2023) in yogurt increased the consistency index of stirred yogurt, while a significant reduction was observed with increased storage time. The addition of *Rosmarinus officinalis* essential oil was reported to increase the consistency index of yogurt samples, although a reduction was observed with storage time (Massoud and Sharifan, 2020).

Table 4. Consistency index (*k*) and flow behavior index (*n*) of yogurt with different levels of CE at cold storage.

Samples storage days (D)	Consistency index (*k*)			
	0 D	7 D*	15 D	21 D
0% CE*	411.77±2.01	338.00±1.07	160.27±0.09	158.07±0.33
0.5% CE	379.63±1.20	365.23±1.00	143.10±0.27	136.53±0.45
1% CE	311.20±1.00	290.32±1.00	192.13±0.67	189.01±0.78
2% CE	411.77±1.00	338.00±0.90	160.27±0.53	158.07±0.60
Samples storage days (D)	**Flow behavior index (*n*)**			
	0 D	**7 D**	**15 D**	**21 D**
0% CE*	0.35±0.01	0.28±0.01	0.41±0.01	0.42±0.01
0.5% CE	0.35±0.01	0.28±0.01	0.46±0.01	0.45±0.01
1% CE	0.32±0.01	0.22±0.01	0.45±0.01	0.47±0.01
2% CE	0.35±0.01	0.28±0.01	0.41±0.01	0.42±0.01
Samples storage days (D)	**Coefficient of regression (R^2)**			
	0 D	**7 D**	**15 D**	**21 D**
0% CE*	98±1.51	99±0.35	89.2±0.56	98±0.67
0.5% CE	98.6±0.98	98.9±0.76	89.2±0.97	98.6±0.34
1% CE	98.1±0.76	99±0.26	90±0.67	98.1±0.28
2% CE	99.1±0.47	99.3±1.01	91.4±1.33	99.1±0.33

Results are expressed as mean ± SD; *CE: clove extract; **d: storage days.

All samples of yogurt gels, irrespective of the concentration of CE and storage time, showed time-dependent non-Newtonian thixotropy (a time-dependent shear thinning property) as the flow behavior index values remained well below 1. This indicated deviation from Newtonian flow behavior of samples, and generally, gels with higher total solids displayed such diverged performance. This singularity of shear thinning occurred when polymeric units aligned with the direction of applied shear and by the physical flagging of intermolecular interactions of caseins. For all fresh samples (0 day) with or without the addition of CE, no significant change was observed in flow behavior index (n). Yogurt samples stored for 7 days showed an obvious reduction in flow behavior index, which indicated the greater shear thinning behavior of samples; the least pseudoplastic nature (n = 0.22) and the thinnest gel were observed for yogurt added with 1% CE. However, samples stored for 15 and 21 days depicted almost similar behavior, where flow behavior index remained unchanged. At the same time, addition of all levels of CE did not modify flow behavior index at a given time of storage. Jurado-Guerra *et al.* (2023) observed decline in the flow behavior index of stirred yogurt when vitamin B12 and melatonin were added to gels. The reduced consistency of yogurt gels with enhanced flow behavior was reported and verified in literature (Basak and Rarnaswamy, 1994).

Dynamic rheological measurement

Dynamic rheology is measured to envisage the strength and cohesiveness of internal structure of yogurt gel, In the food industry, viscoelastic properties are important for detecting the start of gelation and assessing the extent and strength of internal structures, like those found in yogurt. Notably, measurements in the linear viscoelastic region allow for examining the sample's structure without causing damage. However, this is not the case during analysis with a texture analyzer or in the mouth, as irreversible deformation occurs. (Sendra *et al.*, 2010). Yogurt is fundamentally a viscoelastic gel system, where casein molecular interactions impart elastic properties and weaker intermolecular attractions and interactions impact viscose properties. A frequency sweep test (at angular frequency of 0.1–10 rad/s) was adopted to describe the time-dependent behavior of fresh and stored yogurt samples within nondestructive deformation range by maintaining a constant stress of 1 Pa.s. Elastic or storage modulus (G') profiles of yogurt samples are depicted in Figure 1.

The highest elastic modulus was observed on 0 day for the sample added with 0.5% CE, followed by the control and samples containing 1% and 2% CE. The highest elastic modulus of yogurt with 0.5% CE indicated the most elastic gel, whereas the least elastic gel was observed for the sample containing 2% CE. This clearly dictated that various levels of casein–casein interactions were initiated by the addition of CE depending on its concentration. However, after a storage period of 7 days, yogurt gels turned softer, with lowered curve height (magnitude), compared to the sample on 0 day. This could be attributed to the curing of gels in the presence of CE and continuous production of acidic metabolites by lactic acid bacteria.

This also augmented the flow behavior data of samples, where flow behavior index remained <1. However, physical gap between control yogurt and CE-containing samples was reduced drastically along with the overall lowering of elastic modulus for all samples, indicating reduced firmness of gels during cold storage. Additionally, the overall pattern for elastic modulus of yogurt samples remained similar to that of fresh samples (0 day). Increase in storage period to 15 days further lowered the elastic modulus of all samples, with an interesting superimposition of control and 0.5% CE samples. This suggested that the addition of lower concentration of CE did not make much difference in its elastic nature and behaved as a control, especially under higher deformations. Interestingly, storage for 21 days decreased the firmness of samples, where the least firm gel was the one with 2% CE, while the control presented more elastic gel. Overall, the sample with 0.5% CE ranked higher in elastic modulus, which was maintained during 7 days of storage, although it presented lower firmness, while control yogurt was the softest gel at 15 and 21 days of storage.

Jurado-Guerra *et al.* (2023) also observed that the stirred yogurt added with melatonin and vitamin B_{12} showed a higher elastic modulus value than the control. A similar higher elastic modulus value was observed for the yogurt sample with pomegranate extract in the formulation (Pan *et al.*, 2019). However, reduced elastic modulus with a higher frequency for all samples indicated a typical weak gel as reported in literature (Rudra *et al.*, 2017; Yekta and Ansari, 2019).

At 0 day, physical gap between the profiles of the control and CE-containing yogurt samples was higher, and this decreased after 7 days of storage and reduced firmness was observed. This showed the time-dependent softness of gels of yogurt samples. Saleh *et al.* (2020b) also reported time-dependent changes in the elastic modulus of yogurt added with various starches and hydrocolloids. In entirety, yogurt gels with 0.5% CE with the highest elastic modulus could be ascribed as stronger gels, while yogurt with 2% CE provided the softest gel structure. Thus, 0.5% CE-containing yogurt gel advocates the better stability of gel under the studied storage conditions.

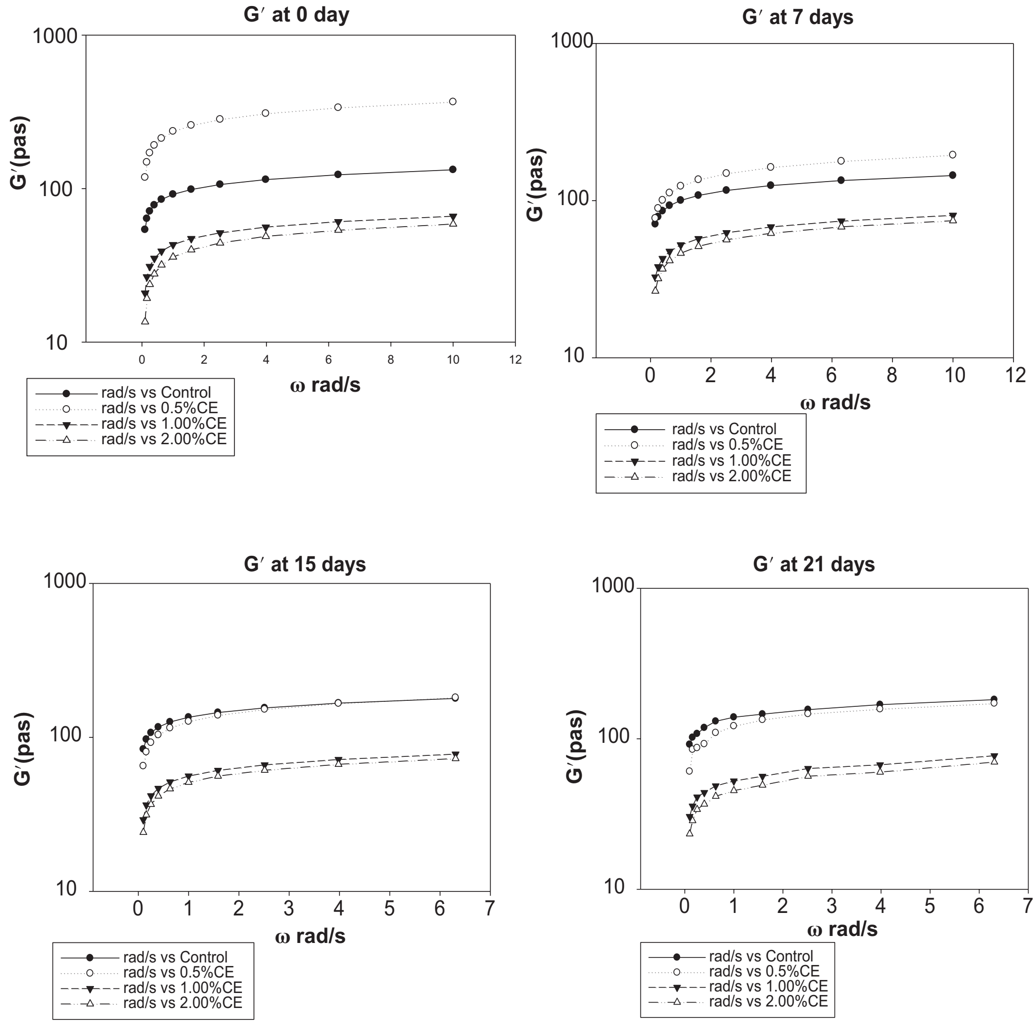

Figure 1. G′ of yogurt prepared with different concentrations of CE during cold storage for 0, 7, 15, and 21 days.

Hence, for stronger yogurt gels, addition of lower CE could be recommended.

Texture study

Texture of yogurt gel is closely associated with its internal structure, and this decreases the overall quality of the prepared final product. Classically, casein micelles amalgamate physically to build yogurt texture (Peng and Guo, 2015). The texture of yogurt was estimated by studying its hardness or firmness, springiness, cohesiveness, and adhesiveness at ambient temperature.

Hardness is defined as the force required to distort yogurt gel and is expressed in grams (g) (Mahmood *et al.*, 2015). The samples with and without all levels of CE did not show any variation in hardness at any given day of storage. However, the highest value of hardness (34.85 g) was observed for the yogurt added with 2% CE, although this was statistically similar to other CE yogurt samples (Table 5). A higher firmness of yogurt with 2% CE supports its consistency index data. At 7 days of storage, samples did not present any noticeable change in hardness, although a significant ($p < 0.05$) reduction in firmness was observed for samples stored for 15 and 21 days, with the least firmness of 32.81 g observed for the control. Thus, this indicated that yogurt without addition of CE was the least hard sample, compared to CE samples. Akan *et al.* (2022) found that the addition of basil, thyme, garlic, mint aqueous extracts enhanced the hardness of probiotic yogurt during the storage of 14 days.

Cohesiveness is defined as the total force of internal bondings that holds yogurt gel, and it identifies the degree of distortion during experiment. Cohesiveness of treated samples remained somewhat as that of the control with up to 1% addition of CE; however, gels added with 2% CE depicted a significantly better cohesiveness. The least stability of control yogurt (at the start of storage) followed the hardness data, where control yogurt remained softest among all. Conversely, the storage had

Table 5. Texture profile of yogurt with different levels of CE at cold storage.

Samples storage days (D)	Hardness (g)			
	0 D	7 D*	15 D	21 D
0% CE*	34.32±0.74^{a,A}	34.35±0.87^{a,A}	33.26±0.12^{a,A,B}	32.81±0.45^{a,b,B}
0.5% CE	34.50±0.23^{a,A}	34.53±0.48^{a,A}	33.43±0.49^{a,B}	32.99±0.56^{a,b,C}
1% CE	34.67±0.62^{a,A}	34.71±0.64^{a,A}	33.61±0.12^{a,B}	33.17±0.34^{a,B}
2% CE	34.85±0.31^{a,A}	34.88±0.34^{a,A}	33.78±0.33^{a,B}	33.34±0.56^{a,B}
Samples storage days (D)	**Cohesiveness**			
	0 D	**7 D**	**15 D**	**21 D**
0% CE*	0.35±0. 01b^{D}	0.40±0. 01^{b,C}	0.43±0. 01^{b,A,B}	0.45±0. 01^{d,A}
0.5% CE	0.36±0. 01^{a,b,D}	0.41±0.01^{a,c,C}	0.44±0.01^{a,b,B}	0.46±0. 01^{c,A}
1% CE	0.37±0. 01^{a,D}	0.42±0. 01^{a,b,C}	0.45±0. 01^{a,b,B}	0.47±0. 01^{b,A}
2% CE	0.38±0. 01^{a,D}	0.43±0. 01^{a,C}	0.46±0. 01^{a,B}	0.48±0. 01^{a,A}
Samples storage days (D)	**Springiness (mm)**			
	0 D	**7 D****	**15 D**	**21 D**
0% CE*	9.19±0.02^{c,B,C}	9.20±0.01^{c,B}	9.22±0.01^{b,c,B}	9.25±0.01^{c,A}
0.5% CE	9.24±0.01^{b,A,B}	9.25±0.04^{c,A}	9.24±0.02^{b,B}	9.25±0.02^{c,A}
1% CE	9.29±0.03^{b,A,B}	9.30±0.02^{b,B}	9.29±0.01^{b,A,B}	9.32±0.01^{b,A}
2% CE	9.34±0.02^{a,B}	9.35±0.01^{a,B}	9.38±0.03^{a,A}	9.38±0.01^{a,A}
Samples storage days (D)	**Adhesiveness**			
	0 D	**7 D**	**15 D**	**21 D**
0% CE*	0.52±0.01^{b,A,B}	0.53±0.01^{b,A}	0.52±0.01^{b,A,B}	0.52±0.01^{b,A,B}
0.5% CE	0.52±0.01^{b,A,B}	0.53±0.01^{b,A}	0.53±0.01^{b,A}	0.52±0.01^{b,A,B}
1% CE	0.53±0.01^{b,B}	0.55±0.01^{a,A}	0.55±0.01^{a,A}	0.53±0.01^{b,B}
2% CE	0.56±0.01^{a,B}	0.56±0.01^{a,B}	0.56±0.01^{a,B}	0.58±0.01^{a,A}

Notes. *CE: clove extract; **d: storage days.
Values are presented as mean ± standard deviation.
$^{a–d}$Mean values followed by different lowercase superscripted letters in the same column are significantly different ($p < 0.05$).
$^{A–D}$Mean values followed by different uppercase superscripted letters in the same row for the same parameter are significantly different ($p < 0.05$).

a massive impact on the cohesiveness of yogurt gels, as drastic rise in cohesiveness was observed with increase in storage days. However, more coherent gel texture was observed for samples stored for 21 days, compared to yogurt stored for 7 or 15 days. Overall, higher concentration of added CE along with longer storage time provided more cohesiveness to yogurt samples. In line with the current results, Ramos *et al.* (2017) also described that supplementation with optimized phenolic-rich herbal extract enhanced the cohesiveness of fermented milk.

Springiness represents the energy essential to masticate and retention of the form after application of force. Springiness followed the pattern of cohesiveness, where control yogurt showed the least value, while the highest springiness was observed for sample with 2% CE at 0 day, and a similar pattern was observed for all samples under different days of storage. However, with increasing the storage time from 0 to 21 days, all samples showed higher springiness, although the pattern of springiness remained similar as that on 0 day, with maximum springiness (9.38) for the sample with 2% CE.

Adhesiveness is the attraction force between the food and any solid in contact with it, and largely helps to detect food stickiness. In general, gels with greater adhesion are supposed to be soft-textured (Saleh *et al.*, 2020a). However, this generality did not hold in the present situation, as control yogurt depicted the least coherent disposition and textural hardness. In the current study, the least adhesive nature of gel was observed for control yogurt at 0 day. However, the addition of 0.5% and 1% CE did not show any change in yogurt gels whereas a significant ($p < 0.05$) increase was observed with the addition of 2% CE. On the other hand, storage of yogurt could not bring significant change in adhesiveness, and statistically similar values were observed for all samples, except for the yogurt with 2% CE. Contrarily, the addition of phenolic-rich aqueous extract of *Pleurotus ostreatus* improved the springiness, adhesiveness, and cohesiveness of low-fat yogurt (Vital *et al*., 2015).

Total phenolic content

Chemically, the phenolic compounds encompass one or more hydroxy functional groups linked to an aromatic ring and are abundantly found in most of the plant extracts. These are among the most operative antioxidative ingredients that impart antioxidant activity to plant essential oils. Yogurt samples incorporated with CE extract showed significantly higher TPC than control yogurt. The enhanced level of phenolics in yogurt confirmed the existence of phenolic compounds in CE as shown in Table 6. However, storage time showed a negative impact on TPC, as lower phenolic contents were estimated for yogurt samples stored for 21 days. However, the highest TPC degradation of 41.3% was observed in the yogurt sample containing 2% CE. This drop in TPC could be associated with the possible degradation of phenolics as they are sensitive to light and higher temperatures. Ramos *et al*. (2017) also observed that the addition of optimized plant extract augmented TPC in fermented milk. Nevertheless, higher storage time reduced TPC in fermented milk samples, and probable deprivation was hypothesized for lowering of TPC as well. On the other hand, yogurt containing aqueous extracts of green, black, and white tea (*Camellia sinensis*) enhanced TPC of samples by three folds than the control, and, interestingly, storage time did not impact TPC (Muniandy *et al*., 2016).

DPPH radical scavenging

Free radical scavenging is the most common measurement of antioxidation potential of plant extracts. The hydrogen atom donation of yogurt supernatants was estimated by the purple color solution of DPPH. Following the pattern of total phenolics, the DPPH estimation of samples indicated increased inhibition values with addition of CE in samples. The DPPH values varied between 16.16% and 53.15%, where the highest inhibition

Table 6. Total phenolics, antioxidant activity, and TBARS of yogurt with different levels of CE.

Samples storage days (D)	TPC (mg GAE/100 g)			
	0 D	7 D*	15 D	21 D
0% CE*	25.55±0.01^{d,A}	22.20±0.01^{d,B}	17.02±0.10^{d,C}	15.80±0.01^{d,D}
0.5% CE	30.04±0.10^{c,A}	25.34±0.01^{c,B}	21.31±0.14^{c,C}	19.32±0.02^{c,D}
1% CE	32.23±0.03^{b,A}	26.09±0.01^{b,B}	22.30±0.11^{b,C}	20.65±0.04^{b,D}
2% CE	36.45±0.03^{a,A}	30.35±0.01^{a,B}	26.21±0.11^{a,C}	21.37±0.01^{a,D}
Samples storage days (D)	**DPPH (% inhibition)**			
	0 D	**7 D****	**15 D**	**21 D**
0% CE*	29.37±0.12^{d,A}	27.08±0.11^{d,B}	23.65±0.01^{d,C}	16.16±0.01^{c,D}
0.5% CE	36.46±0.98^{c,A}	34.98±0.12^{c,B}	29.69±0.01^{c,C}	23.47±0.34^{b,D}
1% CE	41.65±0.56^{b,A}	36.32±0.12^{b,B}	31.09±0.01^{b,C}	29.65±0.17^{a,D}
2% CE	53.15±0.22^{a,A}	48.67±0.24^{a,B}	39.96±0.01^{a,B}	23.81±0.34^{b,C}
Samples storage days (D)	**TBARS (mg MDA/kg)**			
	0 D	**7 D****	**15 D**	**21 D**
0% CE*	1.41±0.01^{c,C}	1.43±0.01^{c,B}	1.44±0.01^{d,B}	1.48±0.01^{d,A}
0.5% CE	1.49±0.01^{b,B}	1.52±0.01^{b,A,B}	1.53±0.01^{c,A,B}	1.55±0.01^{c,A}
1% CE	1.49±0.01^{b,C}	1.50±0.01^{b,C}	1.58±0.01^{b,B}	1.64±0.01^{b,A}
2% CE	1.54±0.01^{a,D}	1.58±0.01^{a,C}	1.73±0.01^{a,B}	1.77±0.01^{a,A}

TBARS: thiobarbituric acid reactive substances.
*CE: clove extract; **d: storage days.
Values are presented as mean ± standard deviation. $^{a–d}$Mean values followed by different lowercase superscripted letters in the same column are significantly different ($p < 0.05$).
$^{A–D}$Mean values followed by different uppercase superscripted letters in the same row for the same parameter are significantly different ($p < 0.05$).

was observed for the yogurt sample containing 2% CE (Table 6). On the contrary, the least DPPH inhibition was shown by control yogurt. However, in the presence of phenolics, decrease in DPPH inhibition was observed when the samples were stored for 21 days—a longer storage provided poor DPPH inhibition of samples. This drop in DPPH inhibition could be due to the lessening of the effective concentration of CE because of exposure to light, resulting in the breakdown and lysis of bioactive fractions in CE.

Tavakoli *et al.* (2018) added olive leaf phenolic extract to yogurt and found an enhanced DPPH activity in samples; however, reduced activity was observed after storage of yogurt for 14 and 21 days. Contrarily, Muniandy *et al.* (2016) reported constant DPPH activity in yogurt with extended storage period.

Inhibition of lipid oxidation (TBARs)

Thiobarbituric acid reactive substances are formed as the end product of lipid peroxidation of foods, where MDA is one of the end products generated by the breakdown of lipid peroxidation products. TBA test encompasses chemical reaction between TBA and MDA and production of a pink compound that displays absorbance maxima at 530 nm. For all yogurt samples, TBAR values varied between 1.41 mg MDA/kg and 1.77 mg MDA/kg (Table 6). Yogurt samples with CE showed higher TBAR values, although nonsignificant changes were observed. In the case of increased storage time, the apparent rise in TBAR values was significantly higher, showing enhanced oxidation of mono- and polyunsaturated fatty acids in yogurt. These values of TBARs are expected to be lower than the the control, as CE has shown good antioxidation ability and higher TPCs. However, in a study conducted by Semeniuc *et al.* (2016), it was demonstrated that the TBAR estimation was interfered by other minor volatiles, such as acetaldehyde, cinnamaldehyde, limonene, lactose, lactic acid, etc., found in yogurt, and these compounds presented high molar absorptivity at 530 nm (a wavelength used in photometric quantification of TBARs). Hence, this clarifies the presence of these compounds in yogurt during estimation of TBARs in samples stored for 21 days (Semeniuc *et al.*, 2016).

Sensory analysis

Sensory analysis is one of the authoritative tools that permits to set correlation between microstructural data and fondness of consumers for produced food products. Yogurt organoleptic as well as nutritional characteristics are strongly impacted by starter culture, initial composition, and processing conditions along with additives (Yekta and Ansari, 2019). The appearance of yogurt is a prime factor in determining the choice and intention of its purchase consumers. Panelists rated control yogurt as more appealing for color, compared to the samples added with all levels of CE, especially the increased level of CE resulting in much lower sensory acceptance for color. The addition of CE might have imparted color to yogurt and influenced luminosity, and hence was ranked lower by panelists. Additionally, a longer storage period also resulted in dropping of sensory score for color. The possible production of metabolite by the residual activity of starter culture might have changed the structure of yogurt gel and resulted in poor acceptance by panelists. Tavakoli *et al.* (2018) also showed a lower sensory score for yogurt samples added with phenolic-rich olive leaf extract.

Similarly, the taste of control yogurt was preferred, compared to CE containing yogurt samples. Nonetheless, a decreased sensory acceptance was observed with increased CE concentration, and the least preferred was the sample with 2% CE. In line with color, fresh yogurt samples were preferred than the ones stored for 15 and 21 days. The lower acceptance of treated samples could be related to the phenolic compounds of CE, which might have imparted a slightly pungent taste and hence changed the gustatory perception of panelists. Contrary to our results, Chon *et al.* (2020) found a better taste acceptance score for dairy products added with 1% cinnamon oil, compared with the control. However, higher concentrations of oil negatively impacted taste of the product and received a poor score.

Yogurt flavor is a result of complex mixture of volatiles produced during fermentation along with some added herbs and extracts. Additionally, packaging material and storage conditions (light, temperature, oxygen, etc.) could induce other secondary oxidation products that change flavor either positively or negatively, thus impacting the organoleptic properties of yogurt (Frederiksen *et al.*, 2003). Similar to taste, the most liked yogurt sample for flavor was the control without addition of CE, as shown in Table 7. The addition of CE resulted in the lowering of flavor acceptability by panelists. Interestingly, the sample with 1% CE obtained higher acceptability for flavor than the sample with 0.5% CE, indicating that panelists preferred CE-flavored yogurt. However, irrespective of CE concentration, the control was the most desired sample. Moreover, the storage of samples resulted in further reduction of sensory scores for all samples with and without CE, although samples containing 2% CE and stored for 21 days were the least preferred samples for flavor.

Among various parameters, yogurt texture is a vital characteristic along with sensory quality that governs consumer's acceptability. It is assessed either directly by

Table 7. Sensory evaluation of yogurt with different levels of CE.

Samples storage days (D)	Color			
	0 D	7 D**	15 D	21 D
0% CE*	8.91±0.45^{a,A}	8.81±0.89^{a,A}	8.11±0.66^{a,B}	8.11±0.55^{a,B}
0.5% CE	7.15±0.33^{b,A}	7.13±0.78^{b,A}	7.04±0.01^{b,A}	6.32±0.71^{b,B}
1% CE	7.33±0.56^{b,A}	7.05±0.21^{b,B}	7.02±0.67^{b,B}	6.13±0.16^{b,C}
2% CE	6.91±0.32^{c,A,B}	7.05±0.34^{b,A}	6.01±0.31^{c,C}	6.03±0.98^{b,c,C}

Samples storage days (D)	Taste			
	0 D	7 D**	15 D	21 D
0% CE*	8.02±0.76^{a,A}	7.89±0.17^{a,A}	7.79±0.65^{a,A,B}	7.02±0.11^{a,C}
0.5% CE	8.01±0.77^{a,A}	7.76±0.39^{a,A,B}	7.31±0.88^{a,b,A,B}	7.03±0.23^{a,C}
1% CE	7.61±0.66^{a,A}	7.45±0.1^{1a,b,A,B}	6.09±0.45^{c,C}	6.09±0.58^{b,C}
2% CE	6.32±0.43^{b,A}	6.19±0.78^{c,B}	6.01±0.25^{c,C}	6.04±0.98^{b,C}

Samples storage days (D)	Flavor			
	0 D	7 D**	15 D	21 D
0% CE*	8.72±0.33^{a,A}	8.62±0.65^{a,A,B}	7.90±0.11^{a,B}	6.91±0.01^{a,C}
0.5% CE	8.02±0.12^{b,A}	8.31±0.49^{b,A}	7.12±0.06^{b,B}	6.16±0.33^{b,C}
1% CE	8.61±0.56^{a,A}	7.98±0.23^{b,B}	6.40±0.98^{b,c,C}	6.40±0.88^{a,b,C}
2% CE	7.32±0.01^{c,A}	6.12±0.65^{c,B,C}	6.34±0.99^{b,c,B}	6.10±0.80^{b,C}

Samples storage days (D)	Texture			
	0 D	7 D**	15 D	21 D
0% CE*	7.50±0.12^{b,c,A}	7.09±0.36^{c,B}	5.09±0.66^{b,C}	5.09±0.87^{a,C}
0.5% CE	8.91±0.11^{a,A}	8.11±0.30^{b,B}	5.01±0.38^{b,C}	5.07±0.79^{a,C}
1% CE	8.87±0.56^{a,A}	8.61±0.01^{a,A,B}	5.06±0.62^{b,C}	5.03±0.03^{a,C}
2% CE	7.92±0.19^{b,A}	7.45±0.59^{b,A,B}	6.25±0.54^{a,C}	5.07±0.21^{a,D}

Samples storage days (D)	Overall acceptability			
	0 D	7 D**	15 D	21 D
0% CE*	8.76±0.02^{a,A}	8.31±0.55^{a,A,B}	6.0±0.37^{a,C}	6.09±0.22^{a,C}
0.5% CE	8.46±0.15^{b,A}	8.15±0.18^{a,b,B}	5.6±0.89^{a,b,C}	5.01±0.64^{b,C}
1% CE	7.31±0.23^{c,A}	7.26±0.09^{c,A}	6.1±0.69^{a,B}	5.01±0.30^{b,C}
2% CE	7.10±0.76^{c,A}	6.89±0.11^{d,A,B}	6.1±0.44^{a,C}	5.01±0.10^{b,D}

*CE: clove extract; **d: storage days.
Values are presented as mean ± standard deviation. $^{a–d}$Mean values followed by different lowercase superscripted letters in the same column are significantly different ($p < 0.05$). $^{A–D}$Mean values followed by different uppercase superscripted letters in the same row for the same parameter are significantly different ($p < 0.05$).

tasting the product or by using a spoon. Normally, a viscose yogurt is tough to swallow as it stays for a longer period on the tongue. The sample's flow ability is observed visually as well by taking the sample on spoon and slanting the same for some time. CE-containing samples were rated higher for texture by panelists. Interestingly, yogurt with 2% CE depicted better texture than the control without addition of CE. Preference of texture of yogurt samples with CE could be due to the firmer and cohesive body of yogurt, which was observed from instrumental textural data. All yogurt samples presented a similar pattern of textural preference after 21-day storage.

Regarding the overall acceptability, control yogurt was the most preferred one whereas the second preferred was the sample with 0.5% CE. On the other hand, the sample with 2% CE was the least accepted sample with a sensory score of 7.1 on 0 day, and it had the least overall acceptability even after 21-day storage. This indicated that the addition of CE might have improved the texture and firmness of yogurt, changes in yogurt color and taste were not accepted by panelists, resulting in lower overall sensory acceptance. Natural yogurt possessed mild sweetish taste blended with a little sourness of organic acids produced during fermentation. However, the addition of CE could change the sweet profile of yogurt and imparting a little sparkling pungent flavor of phenolic compounds present in CE, resulting in lower overall acceptability. In a study, the addition of cinnamon oil in dairy products resulted in lower acceptability (Chon *et al*., 2020). Although consumer preferences vary globally, the addition of CE and other phenolic-rich extracts in yogurt could augment its functional properties and sensory attributes (Figure 2).

Conclusion

The impact of CE supplementation on the physicochemical, sensory and antioxidant properties of set yogurt was estimated until 21 days in chilled storage. The supplementation of CE improved the minerals and total solids while reduced yogurt consistency and elastic modulus of yogurt samples. However, textural hardness did not change by CE yet more cohesive gels were obtained. On the other hand, increased antioxidant properties and total phenolics by CE supplementation. Nonetheless, addition of 1% CE improved the flavor and texture of yogurt yet overall acceptability of yogurt. Findings show that yogurt samples supplemented with lower concentrations of CE remained much preferred than control (plain yogurt). Thus, the developed functional yogurt could be a probable contributor in improving consumer health and wellbeing due to its higher antioxidant profile and mineral contents.

Data Availability Statement

The data used to support the findings of this study are included within the article.

Acknowledgements

This research was supported by Princess Nourah bint Abdulrahman University Researchers Supporting Project

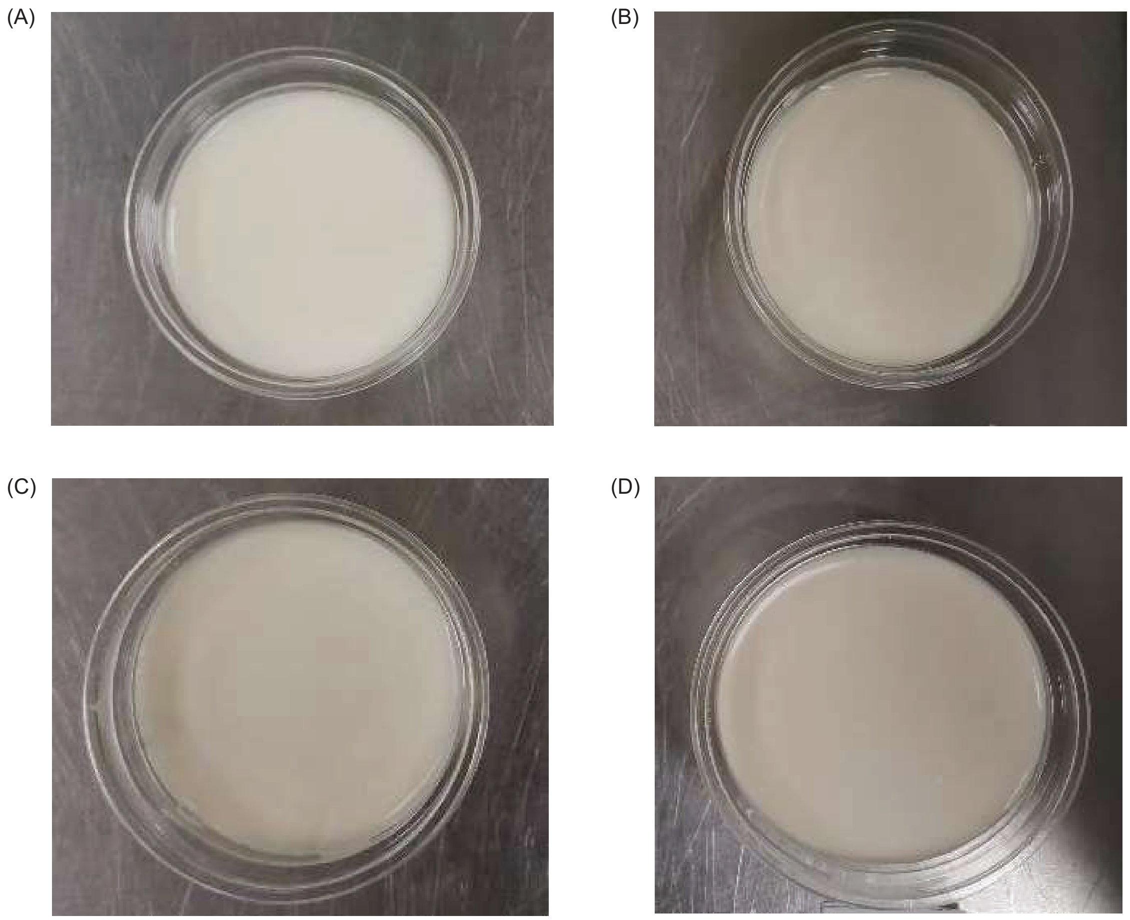

Figure 2. Photograph of yogurt. (A) Control (0%CE); (B) 0.5% CE*; (C) 1%CE; (D) 2%CE. * CE: clove extract.

number (PNURSP2024R251), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia.

Conflict of Interest

The author declared no conflict of interest.

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