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FULL PAPER

Storage stability of yoghurts enriched with coriander (*Coriandrum sativum* l.) seeds extract

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Abstract

This study was aimed to estimate the effects of the extract of coriander seed during storage on the chemical and sensory properties of yoghurt. Coriander seed extract was incorporated into yoghurt at different concentrations, 18 mg/mL (T1C1), 36 mg/mL (T2C2) and 54 mg/mL (T3C3) respectively, while control was performed using a sample without extract (T0C0). Samples were stored at 4°C for 42 days and every seven days were evaluated. For all samples containing extract, the values of lactose, fat, pH, protein, tyrosine, acid degree value, acid value, free fatty acid and sensory properties gave higher scores than those of yoghurt without extract. A major deterioration beyond 28 days of storage due to high acidity and an unpleasant taste was discovered by chemical and sensory evaluations of the yoghurt without plant extract. On the other hand, concentrations of 18, 36 and 54 mg/mL had shown to have a remarkable 42-day preservation activity in yoghurt. Compared to formulas T1C1 and T2C2, which contained 18 mg/mL and 36 mg/mL respectively, formula T3C3, fortified with coriander seed extract at 54 mg/mL, had the highest value in maintaining the chemical properties of yoghurt after 42 days. The findings indicated that coriander extract can be applied as a natural food preservative to milk products in order to increase stability during storage.

1. Introduction

Fermented dairy products are considered to be rich in nutrients and in probiotics, which have a promising potential for cancer prevention and management (Zhang *et al.*, 2019). Yoghurt is a fermented dairy product with significant nutritional benefits, it is a world-famous functional food product that provides a sufficient number of viable probiotic bacteria, these are important in assessing yoghurt's health-enhancing properties (Meybodi *et al.*, 2020). It not only protects against osteoporosis but also enhances intestinal microbiota and supports digestion (Esther Lydia *et al.*, 2020). Spices have been used traditionally as colouring agents, flavouring agents, preservatives and food additives (Sahib *et al.,* 2013). Coriander (*Coriandrum sativum* L.), which belongs to the Apiaceae family, is a seed of annual small plants harvested before flowering, it is usually referred to as cilantro or Chinese parsley, and is a worldwide valuable crop of vegetables. Coriander has high levels of nutrients and is high in Carotene and Vitamin C (Prachayasittikul *et al.,* 2018). Coriander is an edible vegetable, and its seeds can be used as spices, it also contains many ingredients with high medicinal value (Eriksson *et al.,* 2012). Coriander seeds contain potent antimicrobial agents against foodborne pathogens (Silva *et al.,* 2019). The qualitative bioactive analysis of the constituents of the ethanolic extracts of coriander showed the presence of specific phytochemicals such as steroids, flavonoids, saponin, tannin, alkaloids, coumarin and anthocyanin (Mallik *et al.,* 2020). Many studies have identified its biological properties and pharmacological actions in some human pathologies (Reyes *et al.,* 2010), such as hypocholesterolemic and antioxidant effects (Gonçalves *et al.,* 2013). Coriander seeds contain thymoquinone, phenolic acids and diosgenin (Agrawal *et al.,* 2016), including chlorogenic acid, caffeic acid and kaempferol (Hameed *et al.,* 2019).

Yoghurt cannot be stored beyond 21 days at refrigeration temperature, due to bacterial spoilage, this can endanger people's health (Odeyemi 2016). Cooling temperature and storage time have significant effects on the quality of natural yoghurts (Lesme *et al.,* 2020). Improper storage conditions lead to a decrement in the nutritional value and give rise to the deterioration of the sensory characteristics of yoghurts (Zhen *et al.,* 2020). Storage temperature may cause a change in the number

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and mutual proportions of lactic acid bacteria to the typical composition for the yoghurt, thus to its acidification and pH (Purwandari *et al.,* 2007). The recommended storage temperature of yoghurt ranges from 1°C to 8°C, but its stability may be extended by storing at 4°C or less during the whole shelf life (Karlsson *et al.,* 2019). The easiest and most efficient way of prolonging food shelf-life is to use natural or artificial preservatives. However, evidence indicates that most artificial preservatives damage the human body in various degrees (Bajpai and Baek, 2016). In addition, certain chemical preservatives have a certain effect on the sensory quality and natural flavour of food (Hugo and Hugo, 2015). Due to consumer worries about synthetic antioxidant compounds, current research has focused mainly on plant preservatives. Indeed, plant extracts derived from various plant types have been reported to be safer (Hugo and Hugo, 2015). However, few studies have examined the possibilities of using coriander within the food industry as a food preservative. Therefore, this study investigates the use of coriander seed extract as a preservative in yoghurt, in order to extend its shelf life and reduce spoilage. This study is aimed to use water extract of coriander seeds as a natural preservative instead of chemical preservatives, and to evaluate its stability during storage.

2. Materials and methods

2.1 Materials

Coriander seeds were collected on October 13, and fresh cow's milk was purchased from a local market in Erbil, Iraq. All chemicals used for modification were of analytical grade and yoghurt starter culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, which were purchased from (De Brooks, French).

2.2 Preparation of coriander seed extract

Preparation of coriander seed extract was performed according to the methodology proposed by (Joung *et al.,* 2016). The seeds were washed with distilled water and then soaked for 9 hrs in a water bath (Heidolph MFG.CORP) at 100°C, with occasional shaking. The solution was then filtered with Whatman filter paper. The clear resultant solution was concentrated by evaporating under vacuum to dryness, using a rotary evaporator (PER FIT, Indian origin) in temperatures not reaching 40°C. The water plant extracts were made at three concentrations: 18, 36 and 54 mg/mL.

2.3 Yoghurt preparation

Following the method described by (Mahrous and Abd-El-Salam, 2014), yoghurt was prepared by pasteurization of fresh cow's milk at 90°C for 10 mins and subsequently cooled to the fermentation temperature of 4°C. It was then inoculated with 2.0% yoghurt starter culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, which were manufactured by De Brooks, a French company. After incubation at 43°C for 30 mins, the starter was then cooled to stop the fermentation, and mixed with coriander seed extract. In this study, we mixed the water extract of coriander seed with the yoghurt after fermentation by starter culture (*Lactobacillus bulgaricus* and *Streptococcus thermophilus*) to stopped its action because the coriander seed extract contained high levels of active compounds with strong activity against bacteria Gram-positive and Gram-negative (Hashemi *et al.,* 2014). The samples were kept at 4°C (Moghaddas Kia *et al.,* 2018) and taken for analysis after 1, 7, 14, 21, 28, 35 and 42 days of storage (Figure 1).

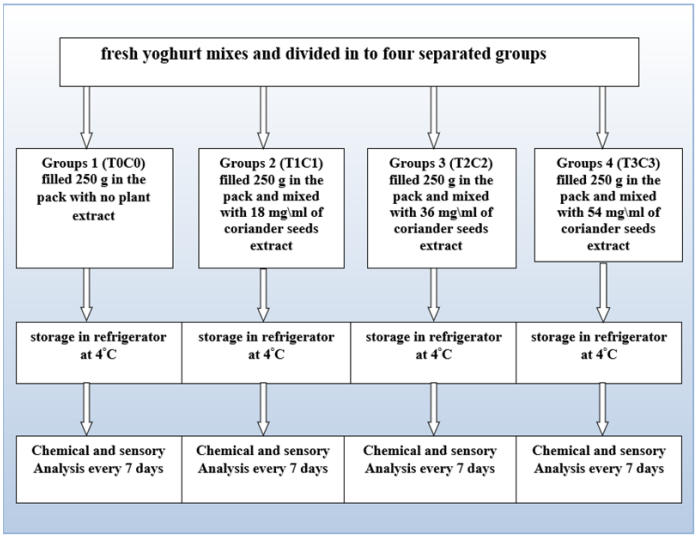

Figure 1. Schematic diagram of the production of yoghurt with the addition of coriander seed extract.

2.4 Chemical analysis

2.4.1 Determination of lactose

The lactose content of the yoghurt was estimated according to the phenol-sulfuric acid method, as modified by (Do *et al.,* 2009; Majsky, 1959). The yoghurt sample (1 g) was accurately weighed and transferred quantitatively to a flask of 1000 mL volume, then distilled water was added up to the mark, it was shaken vigorously, and let stand for 10 mins before filtering. Then, filtration by Whatman No. 42 filter paper gave a water-clear filtrate. A 2 mL of filtrate was placed in a clean, dry test tube, then six drops of 80% phenol solution were added, followed by 5 mL of pure sulphuric acid. The colour of yellow-brown was immediately produced at its highest strength and tended to be stable for 60 mins, then absorption of the solution was measured by a spectrophotometer (JASCO), at 490 nm wavelength.

A standard lactose solution was prepared by dissolving 0.05 g of pure lactose in 1000 mL of distilled water, 2 mL of standard lactose solution was placed in a clean, dry test tube, then six drops of 80% phenol solution were added, followed by 5 mL of pure sulphuric acid. The remainder of the procedure was the same as that used for the yoghurt sample.

$$\text{Lactose \%} = \frac{\text{mg. lactose in 2 mL of extract}}{20}$$

$$\text{mg. lactose in 2mL of extract} = \frac{\text{Sample absorbance} \times \text{mg. lactose in standard solution}}{\text{Standard solution absorbency}}$$

2.4.2 Determination of pH

The pH changes in the yoghurt samples were assessed periodically using a pH meter (PYE UNICAM, German origin) (Ghasempour *et al.,* 2012).

2.4.3 Determination of protein

The protein content of yoghurt was assessed utilizing the modified method of Castillo *et al.* (1962). by formaldehyde titrations (using oxalate): 10 g of yoghurt samples were mixed with 0.4 g of potassium oxalate, apply 1 mL of phenolphthalein to the blend. The mixture was then titrated with 0.1 N NaOH until pink colouration was observed. Next, 2 mL of 40% formaldehyde was added, and the titration with NaOH continued to the same tint as before. Then, the acidity of the formaldehyde was subtracted from the yoghurt titration; this was accomplished by similarly titrating 2 mL formaldehyde in 10 mL distilled water with 0.1 N sodium hydroxide solution.

Formal Number = Volume of NaOH consumed after adding formalin - volume of NaOH consumed in blank

Protein % = Formal number × 1.77

2.4.4 Determination of tyrosine

Tyrosine was evaluated following the method of Hull (1947). Whereby, 5 g of yoghurt was placed in a clean test-tube with addition of 1 mL distilled water. Next, 10 mL of 0.72 N trichloroacetic acid was applied and the test tube agitated for mixing. Then the tube was stopped, vigorously shaken, and left to stand for 10 mins prior to filtering the contents through filter paper. Using a 50-mL Erlenmeyer flask, 5 mL of the filtrate were applied, and 10 mL of the sodium carbonate reagent was thoroughly added and mixed, then 3 mL of Folin reagent was added. The sample was shaken continuously while adding the Folin reagent. The mixture was left for about 5 mins to allow the blue colour to reach a maximum before any readings were taken. The blue colour was measured with a Coleman spectrophotometer (JASCO), at 650 nm wavelength. A tyrosine standard solution was prepared by dissolving 100 mg of tyrosine in water; the solution was then diluted to 500 mL, then 6 mL of tyrosine standard solution was added to a test tube, followed by 10 mL of trichloroacetic acid. The remainder of the procedure was the same as that used for the yoghurt sample, except that filtering was not necessary.

$$\text{Tyrosine mg/mL} = \frac{\text{Sample absorbance} \times \text{concentration of tyrosine in the standard solution}}{\text{Standard solution absorbency}}$$

2.4.5 Determination of fat

The fat content was measured using the Gerber method (Kleyn *et al*., 2001). A perfectly clean butyrometer was filled with 10 mL of H_2SO_4, 11 g of yoghurt, and 1 mL of C_5H1_2O amyl alcohol. After sealing the butyrometer by adjusting the sealing stopper carefully, the contents were mixed by shaking the butyrometer several times. Then the butyrometer was centrifuged and then tempered at 65°C for 5 mins in a wsater bath (Heidolph MFG.CORP). Then read off the fat column.

2.4.6 Determination of lipolysis

Lipolysis was calculated as acid degree value, acid value, and free fatty acid, according to the reported procedure given by (Köse and Ocak, 2011). First, 25 g of yoghurt sample was added using a lipolysis butyrometer and 20 mL of BDI reagent was applied; butyrometer was then placed in a boiling water bath for 20 mins to remove the fat. Then the blend was centrifuged at 400 RPM for 1 min, and enough aqueous methanol was added to separate the fat at the upper layer of the butyrometer, then it was centrifuged for another 1 min. The fraction of liquid fat was transferred into a 100 mL flask and weighed, 5 mL fat solvent (1:4 n-propanol and petroleum ether) was added to the flask. This was then titrated (Chin *et al.,* 2021).

A quantity of the oil being examined was weighed accurately and placed in a 250-mL conical flask, then 50 mL of ethanol-ether solution was added, with shaking. The solution was titrated with sodium hydroxide titrant until pink colouration was observed, which persisted for 30 secs. The volume of sodium hydroxide titrant was measured, and the acid value was calculated according to the following equation:

$$\text{Acid value} = \frac{V_{NaOH} \times 5.61}{W}$$

Where V_{NaOH} = Volume of sodium hydroxide titrant used (mL) and W = Weight of fat (g)

$$\text{Free fatty acid} = \frac{V_{NaOH} \times 2.82}{W}$$

Where V_{NaOH} = Volume of sodium hydroxide titrant used (mL) and W = Weight of fat (g)

The acid degree value (ADV) refers to the amount of free fatty acids present in a fat sample, measured

according to the procedure (Nouira *et al.,* 2011), which is a quantitative index of hydrolytic lipolysis in dairy products. ADV was determined by the Standard Methods. Around 10 g of the sample was homogenized and put for fat extraction in a lipolysis butyrometer, 1 mL of the final extracted fat was titrated against the normal 0.02 N KOH solution for alcohol. ADV calculation was done using the formulation below:

$$\text{ADV} = \frac{\text{mL KOH for sample} - \text{mL KoH for blank} \times \text{N} \times 100}{\text{Weight of fat g}}$$

Where N = normality of KOH solution in methanol.

2.5 Sensory evaluation

The yoghurt samples were subjected to sensory analysis following the method described by

Mahrous and Abd-El-Salam (2014) with some modifications. Consisting of 10 members, panellists were academics in the department of food science, aged 32–49 years (6 females, 4 males). Panellists took part in a sensory assessment of yoghurt based on appearance, texture, flavour and acidity, using a point scale (Appearance = 10, Texture = 30, Acidity = 45, Flavour = 15). Panellists were requested to evaluate the sensory properties of the four different types of yoghurt: T0C0 = yoghurt with no plant extract, T1C1 = yoghurt containing 18 mg/mL of coriander seed extract, T2C2 = yoghurt containing 36 mg/mL of coriander seed extract, and T3C3 = yoghurt containing 54 mg/mL of coriander seed extract. All participants received a consent document and letter of information prior to participating in the analysis. Consented panellists were then given a pencil, water to clean their mouths, and four samples of yoghurt.

2.6 Statistical analysis

The experimental results were analysed statistically, using the SAS program. In addition, multiple range testing of Duncan's correlation coefficient was used to compare results between the various parameters. Statistical analysis is described as mean ± standard deviation and is found to be statistically significant at $p < 0.05$.

3. Results and discussion

3.1 Lactose content

Lactose, the sugar naturally present in milk, provides energy to the yoghurt starter culture (Mena and Aryana, 2020). Statistical analysis has shown that the effects of coriander extract on lactose were significant ($p < 0.05$) (Table 1). During the first 14 days, the lactose of all yoghurt samples appeared to decline. On day 1, the lactose content was in the control T0C0 (4.663%), T1C1 (4.673%), T2C2 (4.673%), and T3C3 (4.673%), while on day 28 the lactose content was: T0C0 (1.437%), T1C1 (3.837%), T2C2 (4.007%), T3C3 (4.411%). However, on day 42 the lactose content was: T1C1 (3.527%), T2C2 (4.063%), T3C3 (4.385%). Generally, lactose content had decreased after four weeks of storage, particularly in sample T0C0. Yoghurts with plant extracts showed slightly decreased lactose and pH compared with yoghurt without plant extracts, mainly due to lower hydrolysis of lactose in Yoghurts with plant extracts compared with yoghurt without plant extracts. The treatment T3C3 recorded the highest content of lactose (4.385) on day 42, mainly due to lower hydrolysis of lactose in treatment T3C3 compared with formulas T1C1 (3.527) and T2C2 (4.063). This is because the coriander seed extract in T2C3 (54 mg/mL concentration) contained high levels of active compounds with strong activity against bacteria. Differences in lactose concentration were observed because of the difference in metabolic pathways linked to lactic fermentation by lactic acid bacteria, and lactic acid production resulting from the fermentation of sugar and the conversion of lactose to lactic acid (Aly *et al.,* 2004). According to Mahrous and Salam (2016), significant differences in lactose concentrations were observed in frozen yoghurt mixtures when kept frozen for one month. Gilliland and Kim (1984) found that in the inoculated yoghurt mix at 65°C, lactose dropped from 6.26% to 4.23%. These findings are generally similar to those reported by Fournomiti *et al.* (2015).

3.2 pH value

Statistical analysis has shown that the effects of coriander extract on pH were significant ($p < 0.05$) (Table 1). The pH of the samples decreased significantly during storage time in control T0C0 (4.267 to 2.300) from day 1 to day 28. The decrease in pH values from day 1 to day 28 in T1C1 was 4.400 to 4.193; for T2C2, 4.433 to 4.216; and T3C3, 4.433 to 4.246. After 42 days of cold storage, pH decreased (to 4.240, 4.086, 3.833) in the samples T3C3, T2C2, T1C1 respectively at 4°C, indicating that the yoghurt quality significantly decreased after day 28 of storage in formula T0C0, compared with the three formulas T1C1, T2C2 and T3C3. The treatment (T3C3) recorded the highest pH value (4.240) on day 42, compared with formulas T1C1 (3.833) and T2C2 (4.086); mainly because the coriander seed extract in T3C3 (54 mg/mL) contained high levels of the active compound with strong activity against bacteria. The study (Hashemi *et al.,* 2014) reported a similar result: the titrable acidity of yoghurt samples increased at 6°C during storage. This increase may be attributed to lactic acid production and other organic acids (acetaldehyde, acetic acid, lactic acid and formic acid) by lactic acid bacteria (Joung *et al.,* 2016). The pH

Table 1. Effect of coriander extract on lactose, pH, protein and tyrosine during the storage period

Samples	Lactose (%)	pH	Protein (%)	Tyrosine (mg/mL)
(Day 1)				
T0C0	4.664±0.011^{a}	4.267±0.057^{c-e}	4.150±0.010^{a}	0.246±0.005^{no}
T1C1	^{a}0.005±4.673	4.400±0.100^{ab}	4.150±0.017^{a}	0.233±0.005^{o}
T2C2	^{a}0.015±4.673	4.433±0.230^{a}	4.150±0.010^{a}	0.233±0.005^{o}
T3C3	4.673±0.005^{a}	4.433±0.057^{a}	4.137±0.011^{ab}	0.233±0.005^{o}
(Day 7)				
T0C0	0.026±3.300^{o}	4.257±0.005^{def}	4.126±0.011^{ab}	0.273±0.005^{m}
T1C1	0.015±4.427^{b}	4.257±0.011^{def}	4.118±0.002^{abc}	0.253±0.005^{n}
T2C2	0.005±4.326^{c}	4.366±0.011^{abc}	4.130±0.010^{ab}	0.240±0.000^{no}
T3C3	0.011±4.427^{b}	4.383±0.005^{ab}	4.077±0.011^{de}	0.253±0.005^{n}
(Day 14)				
T0C0	2.637±0.005^{p}	4.023±0.015^{g}	4.110±0.010^{bcd}	0.393±0.015^{f}
T1C1	3.963±0.005^{i}	4.233±0.085^{ef}	4.086±0.005^{cde}	2.270±0.000^{m}
T2C2	40.005±086.^{d}	4.316±0.011^{b-e}	4.133±0.057^{ab}	0.250±0.000^{n}
T3C3	4.425±0.010^{h}	4.347±0.005^{a-d}	3.983±0.005^{g}	0.270±0.000^{m}
(Day 21)				
T0C0	1.457±0.005^{r}	3.547±0.015^{I}	4.026±0.011^{f}	0.750±0.010^{a}
T1C1	3.863±0.015^{j}	4.366±0.152^{abc}	4.076±0.011^{de}	0.296±0.011^{L}
T2C2	4.077±0.005^{de}	4.236±0.011^{ef}	4.083±0.005^{de}	0.273±0.005^{m}
T3C3	4.423±0.001^{hi}	4.313±0.005^{b-e}	3.923±0.005^{h}	0.313±0.005^{k}
(Day 28)				
T0C0	1.437±0.015^{s}	2.300±0.100^{k}	3.900±0.000^{hi}	0.606±0.015^{b}
T1C1	3.837±0.005^{k}	4.193±0.005^{f}	4.026±0.011^{f}	0.330±0.010^{j}
T2C2	4.007±0.005^{de}	4.216±0.005^{ef}	4.057±0.011^{ef}	0.290±0.000^{L}
T3C3	4.411±0.005^{k}	4.246±0.005^{def}	3.870±0.010^{i}	0.330±0.005^{j}
(Day 35)				
T0C0	-	-	-	-
T1C1	3.740±0.010^{m}	4.192±0.005^{f}	3.516±0.011^{j}	0.350±0.010^{hi}
T2C2	4.060±0.010^{f}	4.266±0.115^{c-f}	3.027±0.011^{L}	0.353±0.005^{k}
T3C3	4.410±0.010^{L}	4.244±0.011^{g}	3.527±0.005^{j}	0.353±0.005^{h}
(Day 42)				
T0C0	-	-	-	-
T1C1	3.527±0.005^{n}	3.833±0.115^{h}	2.446±0.005^{p}	0.380±0.010^{g}
T2C2	4.063±0.005^{ef}	4.086±0.005^{g}	2.920±0.010^{m}	0.365±0.010^{ij}
T3C3	4.385±0.005^{m}	4.240±0.010^{g}	3.146±0.005^{k}	0.353±0.005^{g}

Values are presented as the means±standard deviation. Values with different superscript within each column are significantly different ($p \leq 0.05$). Formula (T0C0) yoghurt with no plant extract, formula (T1C1) yoghurt containing 18 mg/mL of coriander seeds extract, formula (T2C2) yoghurt containing 36 mg/mL of coriander seeds extract, formula (T3C3) yoghurt containing 54 mg/mL of coriander seeds extract, (-) sample is damaged.

slightly decreased in yoghurts with plant extracts, compared to those without plant extracts; this was because of the higher level of antimicrobial activity of coriander seed extract, because of the presence of such phenolic and antibacterial constituents (El-Abd *et al.,* 2018).

3.3 Tyrosine and protein

Tyrosine was measured to evaluate the hydrolysis ratio of the protein in yoghurt. This is because the sulphur-containing amino acids (methionine, Tryptophan and cysteine) are partially or completely destroyed by acid hydrolysis, while tyrosine is measured with much precision (Edelhoch, 1967). Therefore we used tyrosine to measure the ratio of protein hydrolysis in yoghurt (Sahan *et al.,* 2008).

The concentration of tyrosine was measured in all formulations, in order to determine whether or not additional coriander extract increased the protein hydrolysis (Table 1). On the first day, the tyrosine concentrations of formula T0C0, T1C1, T2C2 and T3C3

were observed to be 0.246, 0.233, 0.233 and 0.233 respectively. After 28 days, tyrosine had increased to 0.606, 0.330, 0.290 and 0.330 in the four formulas respectively. On day 42, tyrosine concentrations were 0.380, 0.365 and 0.353 in the formulas T1C1, T2C2 and T3C3 respectively at 4°C, while damage occurred in formula T0C0 after 28 days of cooling storage. The treatment T3C3 recorded a lower ratio of tyrosine (0.353) at 42 days compared with formulas T1C1 (0.380) and T2C2 (0.365). On the other hand, protein concentrations on the first day of formulas T0C0, T1C1, T2C2 and T3C3 were observed to be 4.150, 4.150, 4.150 and 4.137, respectively. After day 28, protein had decreased to 3.900, 4.026, 4.057 and 3.870 in the four formulas respectively. However, after 42 days, protein had decreased to 2.446, 2.920 and 3.146 in the formulas T1C1, T2C2 and T3C3 respectively at 4°C; while damage occurred in formula T0C0 after 28 days of cooling storage. The treatment T3C3 recorded the highest content of protein (3.146) at day 42, compared with formulas T1C1 (2.446) and T2C2 (2.920).

The differences in tyrosine and protein content were due to the addition of coriander seed extract to yoghurt; the best features of coriander seed extract were the high levels of 18, 36 and 54 mg/mL in the three formulas T1C1, T2C2 and T3C3. The proteolytic activities in yoghurt, including proteolytic enzymes from LAB proteolytic systems, can be functionally divided into cell-surface-associated proteinases that hydrolyse caseins to oligopeptides, and peptide transport systems that transport the oligopeptide and numerous intracellular peptidases (Chen and Steele, 1998; Savijoki *et al.,* 2006). As there was less activity in the samples with plant extracts, this indicates that the active compounds in coriander restricted the activity of microorganisms causing protein decomposition (Silva *et al.,* 2019). The action of the phenolic compounds present in the extract has been shown to inhibit or restrict the activity of microorganisms by inhibiting their enzymes through non -specialized interactions with proteins (Mashhadian and Rakhshandeh 2005).

3.4 Fat content

Statistical analysis showed that the effects of coriander extract on fat were significant ($p < 0.05$). The fat in all samples tended to decrease during the storage period (Table 2). The fat content slightly decreased in yoghurts with plant extracts, compared to those without extracts, While FFA of all yoghurt samples tended to increase during the storage period, FFA was higher in yoghurt without plant extract, and compared yoghurt with plant extract. Lipase enzyme hydrolyses fat in yoghurt to release a large amount of free fatty acid and affect yoghurt flavour (Nsogning Dongmo *et al.,* 2016). lipase increased the production of free fatty acids in control yoghurt compared with contain extract over the storage time(Huang *et al.,* 2020). Fat content on the first day for formulas T0C0, T1C1, T2C2 and T3C3 was 4.446, 4.493, 4.483 and 4.506, respectively. On day 7, fat had decreased to 3.536, 4.483, 4.477 and 4.486 in the four formulas respectively. From day 14 to day 28, the fat value declined in the control T0C0 (3.343 to 3.057), indicating that the yoghurt quality significantly decreased after 28 days of storage. The fat values decreased in T1C1 (4.473 to 4.037), T2C2 (4.453 to 4.420), and T3C3 (4.463 to 4.425) from day 14 to day 42. The treatment T3C3 recorded the highest fat content (4.425) at day 42, mainly due to less lipolysis of fat in this treatment, compared with formulas T1C1 (4.037) and T2C2 (4.420); this was mainly due to the coriander seed extract (54 mg/mL) which contained high levels of active compounds with strong antibacterial activity. The fat content was decreased by lipase enzymes, which lipolysis fat, thus liberating free fatty acids. Bacteriological lipases are produced by micro-organisms, many of which can produce lipases, either in raw milk or in pasteurized products after recontamination; many of them are able to produce very heat-resistant lipases (van den Berg, 1988). In raw milk, total lipase activity is sufficient to induce rapid hydrolysis of a large proportion of the fat (Deeth, 2006). Fat slightly decreased in yoghurts with plant extracts, compared to those without extracts; this is because of the antimicrobial activity of coriander extract, which can inhibit the growth of moulds, yeasts and bacteria (Dimić *et al.,* 2015). Krishnan *et al.* (2019) has shown that coriander extracts have antimicrobial activity, causing food spoilage; while Yildiz (2016) demonstrated that antioxidant activity is closely related to total phenolic content, such that a higher total phenolic content of the sample relates to higher antioxidant activity, indicating that phenolic compounds are dominant antioxidants.

3.5 Acid degree value, acid value, and free fatty acids

Acid degree value (ADV) refers to measuring the amount of free fatty acids contained in a fat sample as a quantitative hydrolytic lipolysis measure in dairy products. The acid degree values of the four yoghurt samples from day 1 to day 42 are summarized in Table 2. ADV on day 1 at 4°C for T0C0, T1C1, T2C2 and T3C3 were 0.620, 0.643, 0.630 and 0.633, respectively. After day 7, the acid degree value had increased to 1.740, 0.716, 0.723 and 0.726 in the four samples respectively. From day 14 to day 28, the ADV of the control T0C0 rose from 1.886 to 3.146, indicating that the yoghurt quality greatly decreased after 28 days of storage. The increased ADV in T1C1 (0.733 to 0.866), T2C2 (0.736

Table 2. Effect of coriander extract on fat, acid degree value, acid value and free fatty acid storage period

Samples	Fat (%)	Acid degree value	Acid value	Free fatty acid
(Day 1)				
T0C0	4.446±0.005^{abc}	0.620±0.010^{u}	0.013±0.005^{rs}	0.086±0.005^{q}
T1C1	4.493±0.005^{ab}	0.643±0.057^{s}	0.020±0.000^{qr}	0.020±0.000^{wy}
T2C2	4.483±0.005^{abc}	0.630±0.010^{tu}	0.020±0.010^{qr}	0.026±0.005^{vw}
T3C3	4.506±0.005^{a}	0.633±0.005st	0.023±0.005^{qr}	0.013±0.005^{xy}
(Day 7)				
T0C0	3.536±0.205^{j}	1.740±0.010^{f}	0.336±0.005^{g}	1.120±0.010^{d}
T1C1	4.483±0.005^{abc}	0.716±0.005^{r}	0.040±0.000^{p}	0.033±0.005^{uv}
T2C2	4.477±0.005^{abc}	0.723±0.005^{qr}	0.040±0.017^{p}	0.040±0.000^{tu}
T3C3	4.486±0.005^{abc}	0.726±0.005^{pqr}	0.030±0.000^{pq}	0.040±0.010^{tu}
(Day 14)				
T0C0	3.343±0.005^{k}	1.886±0.005^{c}	0.460±0.010^{d}	1.220±0.010^{c}
T1C1	4.473±0.011^{abc}	0.733±0.005^{pq}	0.070±0.010^{o}	0.053±0.005^{s}
T2C2	4.453±0.005^{abc}	0.736±0.005^{op}	0.060±0.000^{o}	0.067±0.066^{r}
T3C3	4.463±0.005^{abc}	0.746±0.005^{o}	0.063±0.005^{o}	0.046±0.005st
(Day 21)				
T0C0	3.243±0.005^{l}	2.116±0.005^{b}	1.616±0.005^{b}	1.323±0.005^{b}
T1C1	4.433±0.005^{bc}	0.7883±0.005^{mn}	0.086±0.005^{n}	0.093±0.015^{q}
T2C2	4.423±0.005^{c}	0.776±0.005^{n}	0.073±0.005^{o}	0.096±0.011^{q}
T3C3	4.436±0.005^{bc}	0.780±0.000^{mn}	0.090±0.000^{n}	0.073±0.005^{r}
(Day 28)				
T0C0	3.057±0.045^{m}	3.146±0.005^{a}	1.703±0.011^{a}	1.520±0.010^{a}
T1C1	4.093±0.005^{d}	0.833±0.005^{k}	0.130±0.010^{L}	0.126±0.005^{p}
T2C2	4.422±0.005^{fg}	0.776±0.005^{n}	0.133±0.005^{L}	0.133±0.005^{p}
T3C3	4.436±0.005^{f}	0.790±0.000^{m}	0.116±0.005^{n}	0.160±0.010^{no}
(Day 35)				
T0C0	-	-	-	-
T1C1	0.350±0.010^{hi}	3.516±0.011^{j}	4.192±0.005^{f}	3.740±0.010^{m}
T2C2	0.353±0.005^{k}	3.027±0.011^{L}	4.266±0.115^{c-f}	4.060±0.010^{f}
T3C3	0.353±0.005^{h}	3.527±0.005^{j}	4.244±0.011^{g}	4.410±0.010^{L}
(Day 42)				
T0C0	-	-	-	-
T1C1	4.037±0.011^{e}	0.866±0.005^{i}	0.223±0.015^{i}	0.213±0.005^{ij}
T2C2	4.420±0.010^{ghi}	0.856±0.005^{ij}	0.183±0.005^{j}	0.173±0.005^{Lm}
T3C3	4.425±0.005^{ghi}	0.850±0.010^{j}	0.155±0.010^{i}	0.167±0.011^{i}

Values are presented as the means±standard deviation. Values with different superscript within each column are significantly different ($p \leq 0.05$). Formula (T0C0) yoghurt with no plant extract, formula (T1C1) yoghurt containing 18 mg/mL of coriander seeds extract, formula (T2C2) yoghurt containing 36 mg/mL of coriander seeds extract, formula (T3C3) yoghurt containing 54 mg/mL of coriander seeds extract, (-) sample is damaged.

to 0.856), and T3C3 (0.746 to 0.850) from day 14 to day 42 indicates significant ($p < 0.05$) elevations in the ADV of all yoghurt samples after 42 days of storage. The treatment T3C3 recorded a lower acid degree value of 0.850 on day 42, compared with formulas T1C1 (0.866) and T2C2 (0.856). Lipolysis values were higher in yoghurt without plant extracts than those including extracts. Elevation of acid degree values suggests degradation in the nutritional and sensory consistency of dairy products during storage (Siddique and Park, 2019). Increased ADV values are in line with earlier studies on goat's milk cheeses (Jin and Park, 1995; Park, 2001). These ADV findings suggest that storage time and temperature, and their interactions, have a major effect on the lipolysis of experimental goat's cheeses.

As regards the acid value (AV), defined as the weight of KOH in mg needed for neutralizing the organic acids present in 1 g of fat, this is a measure of the free fatty acids (FFA) present in the fat. Differences in acid value between samples were significant ($p < 0.05$). The (AV) of all yoghurt samples tended to

increase during the storage period (Table 2). The AV values at 1 day at 4°C for T0C0, T1C1, T2C2 and T3C3 were 0.013, 0.020, 0.020 and 0.023, respectively. On day 7, the acid value had increased to 0.336, 0.040, 0.040 and 0.030 in the four samples respectively. The acid value in the control T0C0 changed from 0.460 to 1.703 between 14 and 28 days. From day 14 to day 42, the increases in AV were: T1C1 (0.070 to 0.223), T2C2 (0.060 to 0.183), T3C3 (0.063 to 0.155). The treatment T3C3 recorded a lower acid value (0.155) at 42 days, compared with formulas T1C1 (0.223) and T2C2 (0.183).

Free fatty acid (FFA) differences between the samples were significant ($p < 0.05$). The FFA of all yoghurt samples tended to increase during the storage period (Table 2). The FFA on day 1 at 4°C for T0C0, T1C1, T2C2 and T3C3 were 0.086, 0.020, 0.026 and 0.013, respectively. After 7 days, FFA increased to 1.120, 0.033, 0.040 and 0.040 in the four samples respectively. From day 14 to day 28, FFA in the control T0C0 rose from 1.220 to 1.520. The FFA increased in the T1C1 (0.053 to 0.213), T2C2 (0.067 to 0.173), T3C3 (0.046 to 0.167) from day 14 to day 42. The treatment T3C3 recorded a lower value of free fatty acid (0.167) at day 42, compared with formulas T1C1 (0.213) and T2C2 (0.173). FFA was higher in yoghurt without plant extract, compared to the fortified yoghurt. The higher levels of FFA in formula T0C0 were because of the rapid metabolism of the starter bacteria, compared with formulas T1C1, T2C2 and T3C3. Reports have shown that three different sources of lipolysis can arise: induced lipolysis, spontaneous lipolysis, and microbial lipolysis. Many microorganisms that contaminate dairy products cause microbial lipolysis and produce a rancid taste (Park, 2001). The free fatty acid content increases due to the effectiveness of the initiating bacteria, it also rises in milk during processing and storage (Wherry *et al*., 2019). In particular, *L. bulgaricus* produces more free fatty acids than *S. thermophilus* (Donovan and Hutkins, 2018).

In general, the increased ADV, AV and FFA values were related to the increment of acidity in yoghurt samples, which suggests the degradation of dairy sensory qualities during storage (Siddique and Park, 2019).

Lipolysis values were higher in yoghurt without plant extract than in those that included it. The inhibitory ability of coriander seed extract against microbes that cause food spoil is due to its compounds of thymoquinone, diosgenin, and phenolic acids, including chlorogenic acid, caffeic acid and kaempferol (Hameed *et al.,* 2019), which have antimicrobial properties against foodborne pathogens, inhibiting bacterial growth (Silva *et al.,* 2019). Extracts and essential oils have become an important source of natural products, and act as food preservatives to protect from the effects of poisoning due to oxidation (Tepe, 2008). Jobling (2000) Explained that plant extracts are generally more receptive and less dangerous than industrial compounds, and can therefore be included in the list of food additives used in food processing.

3.6 Sensory evaluation

Plant extracts cause various changes in the product's chemistry, which affect the sensory scores of the product (Rodrigues *et al.,* 2020). Table 3 shows the mean sensory characteristics of the yoghurt samples based on the acceptability of each group; there was a difference in mean scores of appearance, texture, acidity and flavour among the four formulae: T0C0, T1C1, T2C2 and T3C3. The sensory assessment of the samples showed that coriander extract concentrations (18, 39 and 54 mg/mL) had significant ($p < 0.05$) effects on the appearance, texture, acidity and flavour of the yoghurt samples.

The formula T0C0 had the lowest scores for appearance, texture, acidity and flavour at the end of storage, while the higher scores were for yoghurt samples containing 18, 36 and 54 mg/mL of coriander extract at the end of storage. These results generally agree with reports (Azarikia and Abbasi, 2010) showing that local herbal extracts in tragacanthin-stabilized dough could increase its overall taste score. According to scores for appearance (T1C1 = 6.333, T2C2 = 6.666, T3C3 = 8.000), texture (T1C1 = 25.666, T2C2 = 25.333, T3C3 = 26.666), acidity (T1C1 = 34.333, T2C2 = 35.666, T3C3 = 33.330), and flavour (T1C1 = 8.333, T2C2 = 11.666, T3C3 = 11.333), after 42 days of storage, the sensory panel did not detect any serious defects in any formulas. To conclude, the addition of coriander seed extract did not overlap with the yoghurt's overall acceptability.

4. Conclusion

This study found that the addition of coriander seed extract to yoghurt significantly affected its chemical properties, including lactose, protein, pH, tyrosine, fat, acid degree value, acid value, free fatty acids, and the sensorial properties of yoghurt. The findings showed that yoghurt samples containing 18, 36 and 54 mg/mL of coriander seed extract preserved the consistency of yoghurt samples by preventing lipid oxidation and protein hydrolysis, as well as other quality parameters. The chemical and sensory evaluation of yoghurt without plant extracts revealed that it cannot be stored beyond 21 days at refrigeration temperature, due to high acidity and other quality parameters. Therefore, coriander extract could be added to dairy products as a natural food preservative, to improve stability during storage. Further

Table 3. Effect of coriander extract on sensory characteristics (appearance, textures, acidy and flavour) during the storage period

Samples	Appearance (10)	Textures (30)	Acidy (45)	Flavour (15)
(Day 1)				
T0C0	8.000±1.732^{a-e}	28.333±1.154^{bc}	42.000±1.732^{b}	15.000±1.000^{a}
T1C1	9.000±1.732^{abc}	29.666±0.577^{b}	45.333±1.540^{a}	14.333±0.577^{ab}
T2C2	9.333±1.154^{ab}	29.333±1.154^{b}	45.000±1.732^{a}	13.666±0.577^{abc}
T3C3	9.666±0.577^{a}	31.000±1.732^{a}	45.333±1.527^{a}	14.670±1.540^{ab}
(Day 7)				
T0C0	7.000±1.732^{a-d}	28.333±0.577^{bc}	42.333±1.154^{b}	15.000±1.732^{a}
T1C1	8.333±1.547^{a-d}	28.333±0.577^{bc}	42.666±0.577^{b}	12.333±1.154^{cde}
T2C2	7.666±0.577^{b-f}	27.333±1.134^{cd}	42.000±1.000^{b}	13.666±0.577^{abc}
T3C3	9.333±1.154^{ab}	29.333±1.154^{b}	41.333±1.154^{bc}	14.666±1.154^{ab}
(Day 14)				
T0C0	6.666±0.577^{d-h}	26.00±0.000^{d-h}	39.666±0.577^{cd}	13.666±1.154^{abc}
T1C1	8.333±0.577^{a-d}	27.333±0.577^{cd}	42.666±1.154^{b}	12.333±0.577^{cde}
T2C2	7.666±1.154^{b-f}	27.000±1.000^{cde}	38.333±1.154^{de}	13.666±1.154^{abc}
T3C3	9.000±1.732^{abc}	28.333±1.154^{bc}	37.333±1.154^{e}	12.333±0.577^{cde}
(Day 21)				
T0C0	6.000±0.000^{f-i}	25.000±0.000^{ghi}	34.333±1.154^{g}	10.330±0.577^{gh}
T1C1	8.333±0.577^{a-d}	27.000±1.732^{cde}	42.000±1.732^{b}	10.666±0.577^{fgh}
T2C2	7.333±0.577^{c-f}	26.000±1.000^{d-h}	38.330±0.577^{de}	13.333±0.577^{bcd}
T3C3	8.333±1.154^{a-d}	27.334±0.577^{cd}	37.333±0.577^{e}	12.000±1.732^{def}
(Day 28)				
T0C0	4.000±0.000^{j}	24.666±0.577^{hi}	31.000±1.732^{h}	8.666±0.577^{ij}
T1C1	8.333±0.577^{a-d}	26.000±1.732^{d-h}	39.666±0.577^{cd}	10.666±0.577^{ih}
T2C2	7.000±1.732^{d-h}	26.333±1.154^{d-f}	37.000±1.732^{ef}	12.666±0.577^{cde}
T3C3	8.333±1.154^{a-d}	27.333±1.154^{cd}	36.666±0.577^{ef}	11.666±0.577^{efg}
(Day 35)				
T0C0	-	-	-	-
T1C1	6.666±2.309^{d-h}	27.333±0.577^{cd}	34.666±2.309^{g}	9.333±1.154^{hij}
T2C2	6.666±0.577^{d-h}	25.666±0.577^{e-h}	35.666±0.577^{a}	12.666±1.540^{cde}
T3C3	8.333±0.577^{a-d}	27.330±1.154^{cd}	33.666±0.577^{g}	11.333±0.577^{efg}
(Day 42)				
T0C0	-	-	-	-
T1C1	6.333±1.154^{e-i}	25.666±0.577^{e-h}	34.333±1.154^{fg}	8.333±1.154^{ij}
T2C2	6.666±0.577^{g-i}	25.333±1.154^{fgh}	35.666±0.577^{a}	11.666±1.154^{efg}
T3C3	8.000±1.000^{a-e}	26.666±0.577^{def}	33.330±1.154^{g}	11.333±1.154^{hij}

Values are presented as the means±standard deviation. Values with different superscript within each column are significantly different ($p \leq 0.05$). Formula (T0C0) yoghurt with no plant extract, formula (T1C1) yoghurt containing 18 mg/mL of coriander seeds extract, formula (T2C2) yoghurt containing 36 mg/mL of coriander seeds extract, formula (T3C3) yoghurt containing 54 mg/mL of coriander seeds extract, (-) sample is damaged.

studies should be conducted to measure the radical scavenging activity DPPH and peroxide value. However, this research needs further enlightenment in order to evaluate the suitability of these remarkable properties of this plant in practical applications and can therefore be included in the list of food additives used as natural food preservation.

Conflict of interest

The authors declare no conflict of interest.

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