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Assessment of Quality Attributes and Storage Stability of Probiotic Yoghurt Enriched with Celery (*Apium graveolens* L.) and Dill (*Anethum graveolens* L.)

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ABSTRACT

Plant-based probiotic products have received much attention for functional foods with health benefits and improved functionality. Celery (*Apium graveolens* L.) and dill (*Anethum graveolens L.*) are important medicinal plants that can be used in the food industry. The present work aims to produce set yoghurt with functional properties by using probiotic bacteria supplemented with celery extract or dill extract (0, 1, 2, and 3%, *w/w*) and study the quality attributes and storage stability of this type of yoghurt. The resultant yoghurt treatments were examined for their physicochemical, microbiological, rheological, textural, and organoleptic characteristics. Phenoles and antioxidant activity were also detected. Results showed that total solids, protein, fat, and ash were higher in treatment compared with control. Additions of celery or dill extracts with different concentrations significantly increased the titratable acidity, acetaldehyde and diacetyl and also increased the amount of viscosity, and water holding capacity (WHC). Celery and dill contain higher amount of minerals than control such as calcium, magnesium, iron, copper, and zinc. As the level of this extracts increased, hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness significantly improved. Due to the stimulatory effect of celery and dill extracts, the viability of *Bifidobacterium bifidum*, *Streptococcus thermophilus* and lactic acid bacteria increase. The addition of herbal extracts enhance the body and texture. Treatment with 2% of celery extract gained the best flavor score (96.29 point), followed by treatment with 2% of dill extract (95.52 point), and these reflected in the overall acceptable score. Generally, it is recommended to use up to 2% celery extract or dill extract with a probiotic strain such as *Bifidobacterium bifidum* in yoghurt making to enhance its organoleptic and functional properties with good nutritional values.

1. Introduction

Yoghurt is fermented milk produced by *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus strains*. It is widely consumed as a functional food due to its good flavor, nutritional properties (rich in protein, calcium, potassium and vitamin B) and good vehicle for delivering probiotics to consumers. In recent years, probiotic bacteria have been introduced into numerous foods, such as dairy products, especially fermented milk or yoghurt (Marhamatizadeh et al., 2012).There is a worldwide interest in fermented milk products with probiotics as they enhance the beneficial effects on human health (therapeutic and health benefits) such as prevention of gastrointestinal disorders, colon cancer, diarrheal disease, improvement in lactose utilization and immune enhancement. In addition, probiotics should not adversely affect the taste or aroma of the product or acidification during the shelf life of the product (Heller, 2001). *Bifidobacterium* and *Lactobacillus* species are the most common types of probiotics. Recently, the plant-based probiotic products have gained much attention, chiefly to create functional foods with

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healthy benefits and improve their functionality. Celery (*Apium graveolens* L.) is an important medicinal plant throughout the world; it is an herb from parsley family. Celery contains fat (oleic acid, palmitic acid, linolenic acid, stearic acid, linoleic acid, and petroselenic acid) and it has a high caloric value. It is also known as a rich source of vitamin C, folic acid, fibers, β-carotene and various other minerals such as calcium, potassium, magnesium and sodium. It has been reported that celery has much antioxidant, antibacterial, anticancer, and antihypertensive. It has been used for medicinal purposes against cancer, high blood pressure, and cholesterol. The main constituents in the oil of celery were limonene (75 to 80 %), carvone and 3n-butylphthalide, Phthalides, β-selinene (10%), giaveobisides, and fatty oil (Sowbhagya & Srinivas, 2013; Khalil et al., 2015). Dill (*Anethum graveolens L.*) is a medicinal plant from the family Apiaceae (Umbelliferae). Dill herb has been used as flavoring agents in the food industry. Dill is strong antimicrobial, antihyperlipidemic, hypotensive, diuretic, antispasmodic, antiemetic, laxative and anticancer activity. The main bioactive constituents of dill are: proteins, carbohydrates, essential oil, fatty oil, mineral elements (potassium, calcium, magnesium, phosphorous, sodium), vitamin A and niacin. The main essential oil in dill is carvone (20–60%), limonene, a-pinene, a-terpinene, a-phelandrene, apiole, dill apiole, 1,8-cineole, dihydrocarvone, and p-cymene (Amin & Sleem, 2007; Kaur & Arora, 2010; Stanojević et al., 2016).This study was carried out to determine the suitability of celery extract (*Apium graveolens L.*) and dill extract (*Anethum graveolens L.*) for the production of bio-yoghurt by using *Bifidobacterium bifidum* as probiotic bacteria.

2. Materials and Methods

Materials

Fresh raw buffalo's milk was obtained from the Dairy Science Department, Faculty of Agriculture, Cairo University, Giza, Egypt. Fresh celery (*Apium graveolens* L.) and fresh dill (*Anethum graveolens* L.) were purchased from the local market. Folin-Ciocalteu's phenol reagent were purchased from Fluka (Madrid, Spain), and 2,2-diphenyl-1-picrylhydrazyl (DPPH) was obtained from Sigma-Aldrich (Germany).

Starter cultures

Freeze-dried yoghurt starter culture (FD-DVS YC-X11-Yo-Flex) containing *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus* (1:1) was obtained from Chr. Hansen's Laboratories, Copenhagen, Denmark; *Bifidobacterium bifidum* was obtained from Laboratorium Wiesby, Niebull, Germany.

Preparation of herbal extracts

The fresh leaves of herbs were washed thoroughly with tap water to remove soil particles, and then chopped. Then suspended in hot distilled water at the ratio 1:10. The mixture was incubated overnight in a water bath (60°C). Then was filtered using Whatman No. 1 filter paper to get the extract (Maduka et al., 2014). The supernatant (water herbal extract) was used in the experiments.

Production of a set of yoghurt

Fresh buffaloes milk was standardized to ~5.5% fat, heated at 90°C for 10 min, immediately cooled down to 42°C, then divided into seven equal portions as follows: C = (control); T_1 = 1% celery extract; T_2 = 2% celery extract; T_3 = 3% celery extract; T_4 = 1% dill extract; T_5 = 2% dill extract; and T_6 = 3% dill extract (see Table 1). All treatments were inoculated with *Bifidobacterium bifidum* and incubated for one hour at 42°C to enhance the probiotic activity. They were then inoculated with 0.02% of freeze-dried yoghurt starter culture and continuously incubated at 42°C. The fermentation was achieved when the pH reached about ~4.6 and was then directly refrigerated at ~5°C. All treatments were analyzed for physico-chemical, rheological, textural, microbiological, and organoleptic properties when fresh and after 7, 14, and 21 days of storage at 5 ±1°C, respectively.

Analytical Methods

Chemical analyses

Total solids, fat, protein, and ash contents of bio-yoghurt treatments were determined according to the methodology mentioned in (AOAC, 2012).

The titratable acidity was determined according to (Lees & Jago 1969 and 1970), respectively.
The total phenolics were determined with the Folin-Ciocalteu reagent method (Maurya & Singh, 2010). The total phenolic content was calculated from the standard calibration curve, and the results were expressed as mg of gallic acid equivalent per gram dry weight. Antioxidant activity was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging method as described by (Huang et al., 2005). Mineral contents were determined by using an atomic absorption spectrophotometer, NO. 3300 (PerkinElmer, US instrument Division Norwalk, CT, USA), as described by (Hankinson, 1975).

Rheological analysis

The apparent viscosity (centi poise) of bio-yoghurt treatments was measured using the Brookfield Engineering Labs DV III ultra rheometer, Inc., Stoughton, MA, USA, according to (Petersen et al., 2000). The viscometer was operated at 50 rpm, and the data were directly recorded from the instrument after one minute of spindle rotation to ensure a steady reading. The SC4-21 spindle was selected for the measurement. The water holding capacity (WHC) was measured by a centrifuge method according to the modified method of (Keogh & O'Kennedy, 1998).

Microbiological analyses

Samples of all yoghurt were prepared for microbiological analysis (total bacterial count and coliforms group), which was carried out following (APHA, 2005) using different selective media to enumerate different viable microorganism groups. *Bifidobacterium bifidum* was anaerobically incubated at 37°C for 48 h and counted on MRS-L medium according to Dave & Shah (1996) by using modified MRS agar supplemented with 0.05% L-cystein and 0.3% lithium chloride (Sigma Chemical Co., USA). Lactic acid bacterial count (LAB) for bio-yoghurt products was enumerated in MRS agar media, according to (Elliker et al., 1956). *Streptococcus thermophilus* was enumerated on M17 agar and aerobically incubated at 37°C for 24 h, according to de (Souza et al., 2008), while potato dextrose agar recommended by the (Oxoid 1962) was used for the enumeration of yeasts and molds.

Organoleptic evaluation

All yoghurt treatments undergo organoleptic analysis, according to (Tamime & Robinson 1999). The evaluation was done by experienced panelists and staff members of the dairy department at the Food Technology Research Institute.

Textural properties

The textural profile analysis test (TPA), such as hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness of bio-yoghurt treatments, was done using a Universal Testing Machine (TMS-Pro) as described by (Bourne 1978).

Statistical analysis

All experimental data were expressed as mean values. Statistical analysis was carried out using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test. The significance differences were defined at $P \leq 0.05$ using the SAS program (SAS, 2008).

3. Results and Discussion

Table 1. Chemical composition of milk, celery and dill extract

Parameters	Buffalo's Milk	Celery extract	Dill extract
Total solids (%)	15.48	23.18	21.45
Fat (%)	5.60	-	-
Protein (%)	3.75	4.31	4.22
Acidity (%)	0.16	0.26	0.24
pH values	6.68	6.32	6.45
Minerals (mg/g)			
Fe	-	6.72	22.17
Na	-	168.44	56.52
Zn	-	13.18	1.55
K	-	292.21	735.86
Ca	-	58.02	163.56
Cu	-	6.05	8.73
Mn	-	1.52	4.56

Chemical composition of yoghurt

Table 2. shows the effects of the storage time of bio-yoghurt fortified with different concentrations of celery or dill extracts on its chemical composition. Based on the results presented, the addition of celery or dill extracts with different concentrations increased the total solids slightly in fresh yoghurt treatments. This may be due to the higher percentage of total solids in these extracts. Therefore, the curd retained all the amounts added from these extracts (El-Sayed et al., 2017 and Kamaly et al., 2023).

On the other hand, the total solids content for all treatments gradually increased during the storage. These results agreed with (Nasser et al., 2017 and Balabanova et al., 2020). Supplementation of yoghurt with 1%, 2%, and 3% celery or dill extracts caused a significantly increase fat, protein, and ash content compared with the control, which might be due to the higher levels of these compounds in the celery and dill extracts than milk (Table 2.).

Moreover, the values of these contents were slightly increased by increasing the ratio of the extracts during the storage period. Similar trends were reported by (Thabet et al., 2014; Ali et al., 2021 and Tawfek & Ali 2022).

Titratable acidity (%) and pH value

The change in titratable acidity is an important factor since it affects the acceptability degree and the shelf life of yoghurt. Based on the results presented in Table 3., the addition of celery or dill extracts with different concentrations significantly increased the titratable acidity of the fresh yoghurt sample due to its acidic nature.

The acidity content (%) of fresh samples ranged from 0.86 to 0.91%. These data agree with (Tizghadam et al., 2021) who reported that, the dill extract increased the acidity of the treatments and this effect was increase in proportion with the dill extract content, and the sample containing 10% dill extract had significantly higher acidity compared with the other samples ($P \leq 0.05$).

The titratable acidity had an ascending trend over the storage time, which is due to the production of lactic acid by starter bacteria via the catabolism of lactose. Such a trend is expected, as it has been indicated in most related studies. At the end of the storage period (21 days), the titratable acidity (%) of yoghurt with celery or dill extracts was higher than that of plain yoghurt (Ramasubramanian et al., 2008 and Marhamatizade, 2015).

The pH values of bio-yoghurt during storage at 5 ±1°C are also presented in Table 3. Moreover, increasing the herbal extract concentrations decreased the pH values of fresh yoghurt significantly compared with the control. Afterwards, the pH values were continuously decreasing significantly for all treatments during the storage period; this was attributed to the continuation of metabolic activity in the starter culture. The current result agrees with (Amirdivani & Baba 2011; Zaky et al., 2013 and El -Shreef et al., 2015).

Mineral contents

Fermented dairy products are the most popular dairy products throughout the world due to their nutritional and functional properties. While having excellent nutritional properties, there is still a lack of some mineral components, such as iron, zinc and copper that play important roles in the human immune system (Jakopovi´c et al., 2022).

As can be seen in Table 4., the mineral (Fe, Na, Zn, K, Ca, Cu, Mg, Mn, and P) contents of herbal yoghurt treatments with celery or dill extracts were higher in these minerals than the control, and as the ratio of the herbal extracts' increased, the content of these minerals increased. Generally, it was observed that celery and dill have elevated levels of dietary minerals especially sodium and potassium (Dhawi et al., 2020).

Table 2. Chemical composition of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C*

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
T.S (%)	Fresh	15.56^{b,b}	15.80^{ab,b}	15.95^{a,b}	16.06^{a,b}	15.79^{ab,b}	15.93^{a,b}	16.03^{a,b}
	7	15.89^{b,b}	16.07^{a,ab}	16.25^{a,ab}	16.26^{a,b}	15.95^{b,b}	16.12^{a,b}	16.34^{a,ab}
	14	16.31^{ab,a}	16.35^{ab,a}	16.38^{ab,a}	16.49^{ab,b}	16.16^{b,a}	16.41^{ab,a}	16.75^{a,a}
	21	16.38^{b,a}	16.40^{b,a}	16.53^{b,a}	16.81^{a,a}	16.39^{b,a}	16.46^{b,a}	16.82^{a,a}
Fat (%)	Fresh	5.65^{b,b}	5.95^{a,b}	6.02^{a,b}	6.11^{a,b}	5.91^{a,b}	6.00^{a,b}	6.08^{a,b}
	7	5.82^{b,b}	6.02^{a,b}	6.19^{a,b}	6.25^{a,b}	6.06^{a,b}	6.14^{a,b}	6.21^{a,b}
	14	6.25^{b,a}	6.49^{a,a}	6.48^{a,a}	6.51^{a,a}	6.48^{a,a}	6.43^{a,a}	6.59^{a,a}
	21	6.29^{b,a}	6.55^{a,a}	6.60^{a,a}	6.66^{a,a}	6.50^{a,a}	6.52^{a,a}	6.65^{a,a}
Protein (%)	Fresh	3.89^{b,b}	3.95^{ab,b}	4.04^{a,b}	4.12^{a,b}	3.98^{ab,b}	4.00^{ab,b}	4.10^{a,b}
	7	4.11^{b,a}	4.18^{ab,a}	4.27^{a,a}	4.32^{a,a}	4.17^{ab,a}	4.26^{a,ab}	4.28^{a,a}
	14	4.24^{b,a}	4.27^{b,a}	4.38^{a,a}	4.39^{a,a}	4.25^{b,a}	4.28^{b,ab}	4.38^{a,a}
	21	4.28^{b,a}	4.33^{b,a}	4.43^{a,a}	4.45^{a,a}	4.29^{b,a}	4.41^{a,a}	4.47^{a,a}
Ash (%)	Fresh	0.83^{a,a}	0.86^{a,a}	0.87^{a,a}	0.89^{a,a}	0.85^{a,a}	0.87^{a,a}	0.88^{a,a}
	7	0.87^{a,a}	0.88^{a,a}	0.90^{a,a}	0.93^{a,a}	0.87^{a,a}	0.91^{a,a}	0.91^{a,a}
	14	0.88^{a,a}	0.90^{a,a}	0.92^{a,a}	0.95^{a,a}	0.91^{a,a}	0.93^{a,a}	0.94^{a,a}
	21	0.92^{a,a}	0.95^{a,a}	0.97^{a,a}	0.99^{a,a}	0.94^{a,a}	0.96^{a,a}	0.97^{a,a}

The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ (*P≤0.05*).
C: (control). T_1:1% celery extract. T_2: 2% celery extract. T_3: 3% celery extract. .
T_4: 1% dill extract. T_5: 2% dill extract. T_6: 3% dill extract.

Table 3. Titratable acidity (%) and pH value of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C*

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
Titratable Acidity (%)	Fresh	0.69^{b,b}	0.72^{a,c}	0.75^{a,c}	0.76^{a,d}	0.71^{a,c}	0.72^{a,c}	0.73^{a,c}
	7	0.76^{b,b}	0.82^{a,b}	0.86^{a,b}	0.87^{a,c}	0.80^{a,c}	0.83^{a,c}	0.86^{a,b}
	14	0.87^{b,a}	0.95^{a,b}	0.98^{a,b}	0.99^{a,b}	0.91^{a,b}	0.95^{a,b}	0.97^{a,b}
	21	0.98^{b,a}	1.07^{a,a}	1.13^{a,a}	1.17^{a,a}	1.10^{a,a}	1.12^{a,a}	1.14^{a,a}
pH (values)	Fresh	4.67^{a,a}	4.64^{a,a}	4.61^{a,a}	4.57^{a,a}	4.65^{a,a}	4.59^{a,a}	4.58^{a,a}
	7	4.54^{a,a}	4.42^{a,b}	4.36^{a,b}	4.28^{b,b}	4.41^{a,b}	4.37^{a,b}	4.29^{b,b}
	14	4.46^{a,a}	4.39^{a,b}	4.28^{a,b}	4.17^{b,b}	4.35^{a,b}	4.26^{a,b}	4.18^{b,b}
	21	4.28^{a,b}	4.25^{a,b}	4.23^{a,b}	4.14^{a,b}	4.23^{a,c}	4.21^{a,b}	4.15^{a,b}

The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ (*P≤0.05*).
*See foot note Table 2.

Table 4. Mineral contents (mg/g) of bio-yoghurt fortified with celery or dill extract*

Treatments	Fe	Na	Zn	K	Ca	Cu	Mg	Mn	P
C	0.12	0.55	0.36	2.11	1.25	0.32	1.21	0.02	1.11
T_1	0.19	4.14	0.43	6.95	1.35	0.24	1.69	0.03	1.23
T_2	0.21	6.16	0.56	9.77	1.78	0.31	2.32	0.05	1.45
T_3	0.28	9.36	0.69	14.39	2.32	0.35	2.98	0.06	1.88
T_4	0.54	1.33	0.67	16.85	3.10	0.27	2.54	0.13	2.61
T_5	0.84	2.15	0.98	21.57	4.25	0.54	4.97	0.25	3.95
T_6	1.06	2.94	1.15	36.61	7.05	0.71	6.78	0.31	5.35

*See foot note Table 2.

Soluble indices

The flavor compounds of yoghurt are formed by the degradation of some milk components. The main effective compounds in yoghurt flavor are acetaldehyde and diacetyl, which are realized during the metabolism of microorganisms, especially lactic acid bacteria. Table 5. shows the changes in acetaldehyde and diacetyl contents of bio-yoghurt with celery or dill extracts when fresh and during storage at 5 ±1°C up to 21 days.

The acetaldehyde content of fresh yoghurt treatments ranged from 37.13 to 45.24 µg/g, while the diacetyl content was 12.52 to 16.59 µg/g. The highest values were for treatments supplemented with celery or dill extracts, and as the level of these extracts increased, the amount of acetaldehyde and diacetyl increased.

As a result of prolonging the cold storage of yoghurt treatments, the acetaldehyde content of all treatments significantly decreased, ranging from 23.02 to 37.89 µg/g. On the other hand, the diacetyl content of all yoghurt treatments took an opposite trend to acetaldehyde, as it significantly increased with the progress of the storage period.

This is related to the ability of some starter cultures to convert the acetaldehyde to ethanol and diacetyl with the progress of cold storage. Similar findings were observed by (Zaky et al., 2013; Bulut et al., 2021 and El-Alfy et al., 2021).

Rheological analysis

Viscosity is an important property of the food polydisperse system, which describes the equilibrium state between the processes of restoration and destruction of the structure. Fortification of yoghurt with celery or dill extracts at different concentrations markedly increased viscosity compared with the control and this increasing was proportional to the fortification ratio (Figure 1.). These results might be due to the increased water holding capacity of celery or dill extracts, which could be commonly attributed to the higher solid and fiber contents of these herbal extracts. The viscosity of all yoghurt treatments augmented as the storage period progressed up to 21 days. These results are in agreement with (El-Shreef et al., 2015; Melnyk et al., 2020 and Elbahnasi et al., 2021). Data revealed in Figure 2. indicated the water holding capacity (WHC%) of bio-yoghurt treatments. With the progress of cold storage, the values of all treatments slightly decreased as a result of the development of acidity and increasing the total solids through storage. In comparison with the control, the WHC of the yoghurt treatments containing celery or dill extracts gained higher values. Because they had higher total solids, crude fibers that acted as thickeners which had greater ability to bind water compared to the control. These results are in accordance with (Narayana & Gupta 2018 and Tizghadam et al., 2021).

Table 5. Acetaldehyde and diacetyl content of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C *

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
Acetaldehyde (µg/g)	Fresh	$37.13^{b,a}$	$39.69^{ab,a}$	$40.58^{ab,a}$	$45.24^{a,a}$	$37.95^{b,a}$	$38.55^{b,a}$	$43.21^{a,a}$
	7	$35.51^{b,b}$	$36.44^{b,b}$	$37.97^{ab,b}$	$41.09^{a,b}$	$35.40^{a,b}$	$36.94^{b,b}$	$38.05^{ab,b}$
	14	$29.09^{c,c}$	$30.07^{c,c}$	$36.44^{ab,c}$	$38.02^{a,c}$	$31.03^{c,c}$	$33.41^{b,c}$	$37.00^{a,c}$
	21	$23.02^{c,d}$	$29.98^{b,d}$	$34.06^{a,d}$	$37.89^{a,d}$	$28.95^{b,d}$	$31.04^{b,d}$	$35.85^{a,d}$
Diacetyl (µg/g)	Fresh	$12.52^{c,d}$	$14.55^{b,d}$	$15.17^{a.c}$	$16.59^{a,d}$	$13.50^{bc,b}$	$14.54^{b,b}$	$15.56^{a,c}$
	7	$13.69^{c,c}$	$15.72^{b,c}$	$15.75^{b,c}$	$17.78^{a,c}$	$15.69^{b,ab}$	$15.73^{b,ab}$	$15.75^{b,c}$
	14	$14.84^{c,b}$	$16.92^{b,b}$	$16.39^{b,b}$	$18.18^{a,b}$	$16.88^{b,a}$	$16.94^{b,a}$	$16.96^{b,b}$
	21	$15.80^{c,a}$	$17.44^{b,a}$	$18.48^{a,a}$	$19.50^{a,a}$	$17.10^{b,a}$	$17.45^{b,a}$	$18.06^{a,a}$

The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ (*P≤0.05*). *See foot note Table 2.

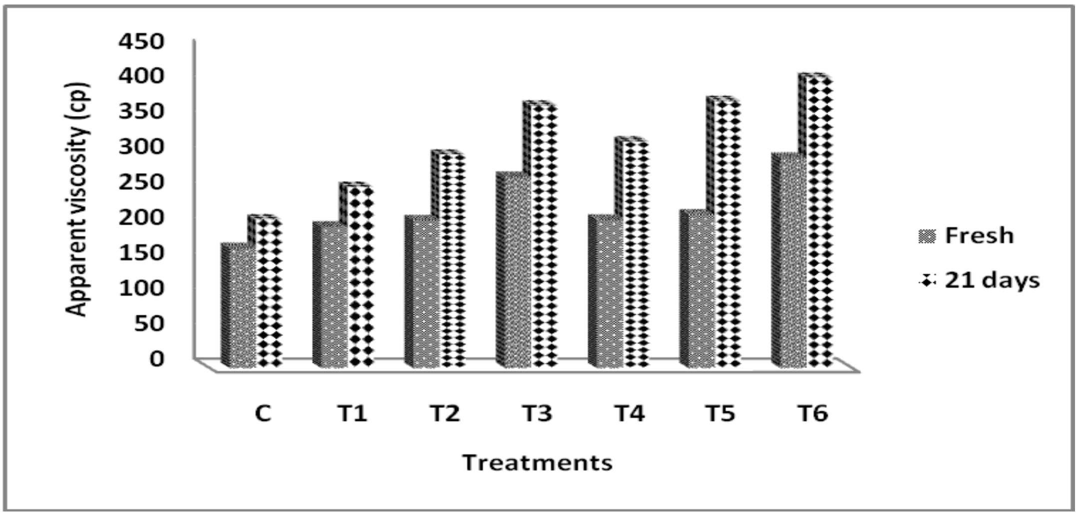

Figure 1. Apparent viscosity (cp) of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C

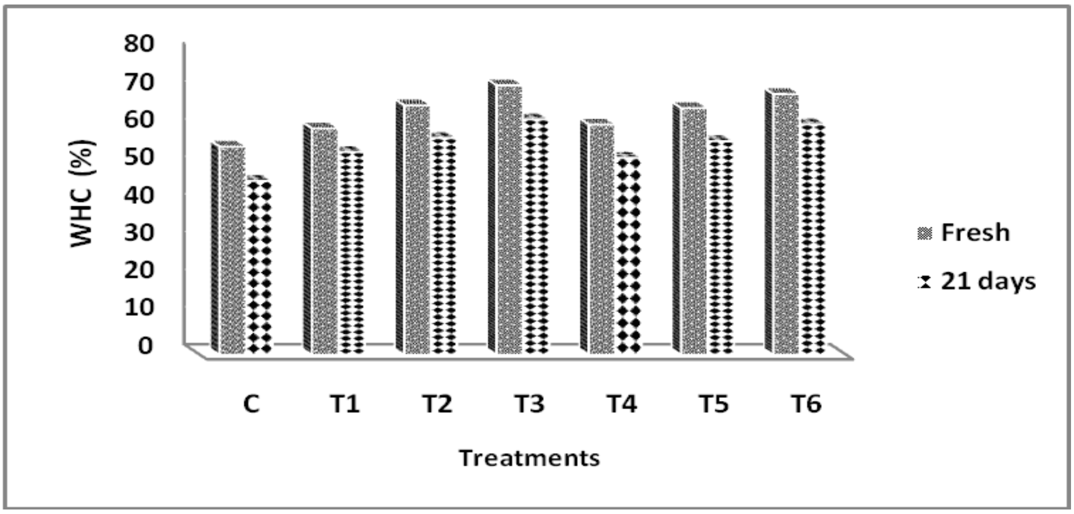

Figure 2. Water holding capacity (WHC %) of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C

Data revealed in Figure 2. indicated the water holding capacity (WHC%) of bio-yoghurt treatments. With the progress of cold storage, the values of all treatments slightly decreased as a result of the development of acidity and increasing the total solids through storage. In comparison with the control, the WHC of the yoghurt treatments containing celery or dill extracts gained higher values. Because they had higher total solids, crude fibers that acted as thickeners which had greater ability to bind water compared to the control. These results are in accordance with (Narayana & Gupta 2018 and Tizghadam et al., 2021). Supplementation of yoghurt with celery or dill extracts resulted in a noticeable increase in antioxidant activity and total phenolic compounds (Figures 3 and 4). As herbs make natural antioxidants, phenolic compounds have the ability to absorb free radicals and therefore, are expected to enhance the antioxidant properties of yoghurt when present. These results might be due to the highest content of phenolic acids, bioactive compounds released in supplemented yoghurt with antioxidant properties (Ismail et al., 2016 and El-Sayed et al., 2017). The antioxidant activity and total phenolic compounds of the yoghurt treatment decreased as the storage period advanced. This may be due to the transformation of these compounds, which are highly unstable and undergo numerous enzymatic and chemical reactions during storage. These results are confirmed by (Tseng & Zhao 2013; El-Shreef et al. 2015 and Tizghadam et al., 2021).

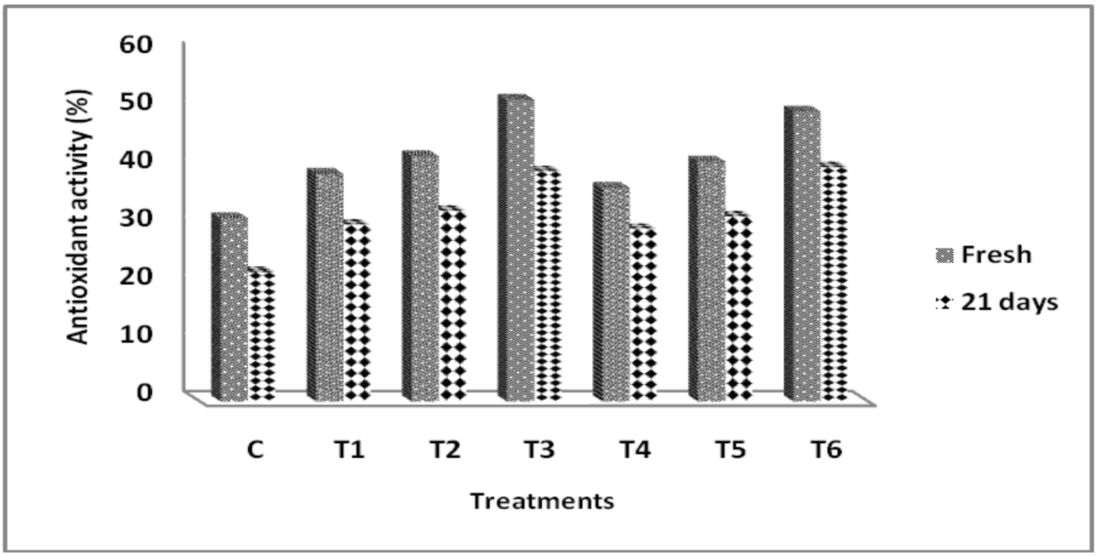

Figure 3. Antioxidant activity (%) of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C

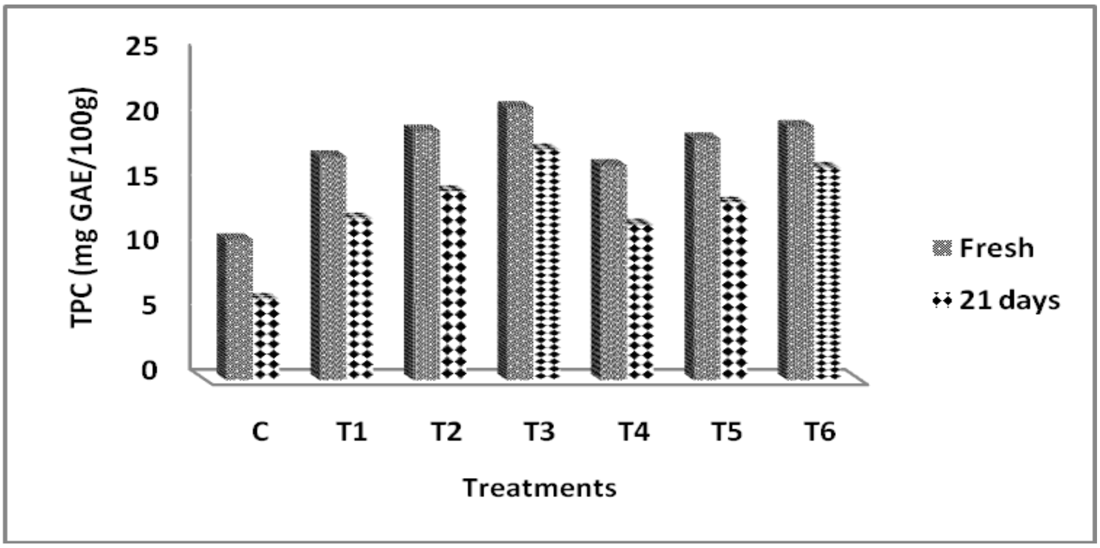

Figure 4. Total phenolic content TPC (mgGAE/100g) of bio-yoghurt fortified with celery or dill extract during storage at 5 ±1°C

Textural properties

Texture profile analysis is a widely used method for assessing the texture properties of food products. The texture profile analysis test performs two bites; every bite includes a loading and unloading cycle to describe the eating actions of humans. Table 6. reveals the texture properties (hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness) of bio-yoghurt enriched with celery or dill extracts when fresh and during storage at 5 ±1°C for up to 21 days. The obtained results showed significantly increased the texture properties in all treatments with herbal extracts compared to the control when fresh and throughout the storage period. Hardness values were significantly increased by increasing the ratios of herbs. This may be due to the addition of herbal extracts led to an increase in yoghurt total solids and protein contents, leading to firmness of the casein curd and improved the body structure.

Also, the pH of yoghurt affects the texture of curd directly by influencing the solubility of the caseins; decreasing the pH of yoghurt causes the hardness to increase. Similar results are given by (Ares et al., 2006; El-Shreef et al., 2015; El-Sayed & Youssef 2019 and Bulut et al., 2021).

Cohesiveness values followed the same trend of hardness; with increasing herb levels, the cohesiveness trend ascended, showing higher values.

The results suggested that the internal structure of herbal yoghurt was bonded, and the bonds were stronger to break during the first compression than control without added herbs (Fox et al., 2000). Also, the data in Table 6. showed that the gumminess and chewiness values were higher in all herbal treatments compared to the control, which was expected as gumminess is the product of two parameters: hardness and cohesiveness. It was noticeable that the herbs level related proportionally to the gumminess and chewiness values. treatments with not only herbs but also during the storage period than in the control. The adhesiveness and springiness values decreased gradually by increasing the ratios of herbs (El-Taweel et al., 2017). These parameters also increased when protein and fat contents increased. This finding of gumminess is convenient with that obtained by (Tawfek et al., 2018).The adhesiveness and springiness values were inversely correlated to hardness values and were lower in all samples. Also, the data in Table 6. showed that the gumminess and chewiness values were higher in all herbal treatments than the control, which was expected as gumminess is the product of two parameters: hardness and cohesiveness. It was noticeable that the herb level related proportionally to the gumminess and chewiness values. treatments with not only herbs but also during the storage period than in the control. The adhesiveness and springiness values decreased gradually by increasing the ratios of herbs in yoghurt samples (El-Taweel et al., 2017). These parameters also increased when protein and fat contents increased. This finding of gumminess is convenient with that obtained by (Tawfek et al., 2018).The adhesiveness and springiness values were inversely correlated to hardness values and were lower in all samples.

Microbiological examination

The data obtained with respect to the total bacterial count (TBC) of bio-yoghurt enriched with different levels of celery or dill extracts is shown in Table 7. The fresh counts had a range from 7.26 to 7.77 log cfu/ml. The TBC significantly increased during the storage period and reaches its maximum count after 7 days of storage, which is from 7.83 to 7.97 log cfu/ml, and then decreases till the end of the storage period, which might be due to their sensitivity to the acidity increase of yoghurt samples. The same trend is shown for the counts of *Bifidobacterium bifidum* as the counts significant increase to gain the lowest number for control (6. 55 log cfu/ml) and the highest numbers for T_3 (6.95 log cfu/ml) after one week of storage. With regard to the results, it can be noticed that fresh treatments had a range from 5.65 to 5.92 log cfu/ml and 6.48 to 6.83 log cfu/ml for *Streptococcus thermophilus* and Lactic acid bacteria, respectively. The increase in bacterial counts may be due to the stimulating effect of herbal extracts, which contain many ingredients that stimulate bacterial growth. Meanwhile, the higher counts of Streptococcus and Lactobacillus may be due to herbal extracts containing carbohydrates and dietary fiber, which are considered prebiotics. These data were in agreement with (Zaky et al., 2013; Marhamatizade 2015; Mehdizadeh et al., 2019 and Ali et al., 2021). Comparing previous data (Table 7.), it can be found that enriched treatments with celery or dill extracts gained higher counts compared to control due to their richness in carbohydrates, which enhance the growth of starter cultures. These findings are in harmony with the results obtained by (Yadav & Shukla 2014; Mehdizadeh et al., 2019 and Al-Shawi 2020). Data in Table 7. indicated that yeasts and molds were not detected in all yoghurt treatments, either fresh or after storage at 5 ±1°C for up to 21 days. This may be related to the development of acidity and antibiotic production by starter cultures or probiotic bacteria. Also, coliforming groups were not detected in all yoghurt treatments up to the end of the storage period. These results may be due to the good hygienic conditions followed during the manufacture of yoghurt (Alhamdani et al., 2018 and Elbahnasi et al., 2021).

Organoleptic score

The quality of fermented dairy products is largely dependent on their organoleptic perception. The organoleptic acceptance of yoghurt fortified with celery or dill extracts is shown in Table 8. Data revealed that panelists scored all examined fresh yoghurt samples and all tested properties with very

very similar scores, and there was no great difference between the samples. During storage, there were considerable differences in the organoleptic properties of the experimental samples as compared with the control. It could be noticed that yoghurt containing celery or dill extracts were more acceptable than the control (Marhamatizadeh et al., 2012). The addition of herbal extracts enhance the body and texture properties of yoghurt. There were no significant differences in the appearance of the control and all treated samples. Treatments with 2% of either celery or dill extract gained the best flavor scores, and these reflected in the overall acceptable score. On the other hand, control scored the lowest acceptable score. Diacetyl and acetaldehyde give the typical flavor to fermented dairy products, and their amount during the cold storage period decreased. A lack of the typical yoghurt flavor was present, so all yoghurt treatments' organoleptic scores decreased unevenly along with storage periods. A lack of the typical yoghurt flavor was present, so all yoghurt treatments' organoleptic scores decreased unevenly along with storage period. These results are similar to those of (Zaky et al., 2013; El-Shreef et al., 2015; Al-Shawi 2020 and Tizghadam et al., 2021).

Table 6. Textural properties of bio-yoghurt fortified with celery or dill extract during storage period at 5 ±1°C*

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
Hardness (N)	Fresh	$4.33^{b,c}$	$4.92^{b,c}$	$5.63^{ab,c}$	$6.84^{a,b}$	$4.52^{b,c}$	$5.26^{ab,c}$	$5.31^{ab,c}$
	7	$5.25^{b,b}$	$5.94^{ab,c}$	$6.37^{a,b}$	$6.95^{a,b}$	$5.27^{b,b}$	$5.51^{ab,b}$	$5.82^{ab,c}$
	14	$5.56^{c,b}$	$6.41^{b,b}$	$6.56^{b,b}$	$7.56^{a,a}$	$5.64^{c,b}$	$6.47^{b,a}$	$6.56^{b,b}$
	21	$6.11^{c,a}$	$7.13^{ab,a}$	$7.32^{ab,a}$	$7.92^{a,a}$	$6.70^{b,a}$	$6.95^{b,a}$	$7.20^{ab,a}$
Adhesiveness (mJ)	Fresh	$0.71^{d,a}$	$0.79^{c,a}$	$0.88^{b,a}$	$0.96^{a,a}$	$0.77^{c,a}$	$0.84^{b,a}$	$0.86^{b,a}$
	7	$0.66^{c,b}$	$0.73^{bc,a}$	$0.83^{b,a}$	$0.91^{a,a}$	$0.70^{bc,b}$	$0.75^{b,b}$	$0.79^{b,b}$
	14	$0.50^{c,c}$	$0.65^{b,b}$	$0.77^{a,b}$	$0.83^{a,b}$	$0.69^{b,b}$	$0.58^{c,c}$	$0.64^{b,c}$
	21	$0.41^{c,d}$	$0.58^{b,b}$	$0.64^{b,c}$	$0.76^{a,c}$	$0.42^{c,c}$	$0.45^{c,d}$	$0.51^{c,d}$
Cohesiveness (ratio)	Fresh	$0.36^{b,c}$	$0.37^{b,c}$	$0.39^{b,c}$	$0.44^{a,c}$	$0.38^{b,b}$	$0.39^{b,d}$	$0.40^{ab,d}$
	7	$0.41^{b,b}$	$0.42^{b,b}$	$0.44^{b,c}$	$0.48^{a,c}$	$0.43^{b,a}$	$0.45^{b,c}$	$0.49^{ab,c}$
	14	$0.44^{b,a}$	$0.49^{ab,a}$	$0.52^{ab,b}$	$0.57^{a,b}$	$0.46^{b,a}$	$0.50^{ab,b}$	$0.56^{a,b}$
	21	$0.45^{c,a}$	$0.52^{b,a}$	$0.61^{a,a}$	$0.63^{a,a}$	$0.48^{bc,a}$	$0.56^{ab,a}$	$0.67^{a,a}$
Springiness (mm)	Fresh	$5.28^{b,a}$	$5.32^{b,a}$	$6.40^{a,a}$	$6.44^{a,a}$	$5.41^{b,a}$	$5.98^{ab,a}$	$6.75^{a,a}$
	7	$4.41^{c,b}$	$4.81^{b,b}$	$5.16^{a,b}$	$5.34^{a,b}$	$4.71^{b,b}$	$4.88^{b,b}$	$5.05^{a,b}$
	14	$3.95^{b,c}$	$4.03^{ab,c}$	$4.29^{a,c}$	$4.67^{a,c}$	$4.00^{ab,c}$	$4.68^{a,c}$	$4.83^{a,c}$
	21	$3.29^{b,d}$	$3.45^{b,d}$	$3.61^{b,d}$	$4.24^{a,c}$	$3.56^{b,d}$	$4.02^{a,d}$	$4.14^{a,d}$
Gumminess (N)	Fresh	$1.56^{c,c}$	$1.82^{c,b}$	$2.20^{b,c}$	$3.01^{a,b}$	$1.72^{c,b}$	$2.05^{b,b}$	$2.12^{b,c}$
	7	$2.15^{bc,b}$	$2.49^{b,b}$	$2.80^{b,c}$	$3.34^{a,b}$	$2.27^{bc,ab}$	$2.48^{b,b}$	$2.85^{b,c}$
	14	$2.45^{c,b}$	$3.14^{b,a}$	$3.41^{b,b}$	$4.31^{a,a}$	$2.59^{c,ab}$	$3.24^{a,a}$	$3.67^{b,b}$
	21	$2.75^{c,a}$	$3.71^{b,a}$	$4.47^{a,a}$	$4.99^{a,a}$	$3.22^{b,a}$	$3.89^{b,a}$	$4.82^{a,a}$
Chewiness (mJ)	Fresh	$8.23^{c,b}$	$9.68^{c,c}$	$14.05^{b,b}$	$19.38^{a,a}$	$9.29^{c,c}$	$12.27^{b,b}$	$14.34^{b,c}$
	7	$9.49^{c,a}$	$12.00^{b,b}$	$14.46^{b,b}$	$17.81^{a,b}$	$10.67^{bc,b}$	$12.10^{b,b}$	$14.40^{b,c}$
	14	$9.66^{d,a}$	$12.66^{c,a}$	$14.63^{bc,b}$	$20.12^{a,a}$	$10.38^{c,b}$	$15.14^{bc,a}$	$17.74^{b,b}$
	21	$9.05^{d,a}$	$12.79^{c,a}$	$16.12^{b,a}$	$21.16^{a,a}$	$11.45^{c,a}$	$15.65^{b,a}$	$19.97^{a,a}$

The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ (*$P \leq 0.05$*). *See foot note Table 2.

Table 7. Microbiological aspects (log cfu/ml) of bio-yoghurt fortified with celery or dill extract during storage period at 5 ±1°C*

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
Total bacterial counts(TBC)	Fresh	$7.26^{c,d}$	$7.66^{b,b}$	$7.70^{a,b}$	$7.77^{a,b}$	$7.65^{b,b}$	$7.69^{b,b}$	$7.73^{a,b}$
	7	$7.83^{a,a}$	$7.88^{a,a}$	$7.93^{a,a}$	$7.97^{a,a}$	$7.86^{a,a}$	$7.90^{a,a}$	$7.95^{a,a}$
	14	$7.76^{b,b}$	$7.82^{a,a}$	$7.84^{a,a}$	$7.86^{a,a}$	$7.80^{ab,a}$	$7.82^{a,a}$	$7.83^{a,a}$
	21	$7.56^{b,c}$	$7.59^{b,b}$	$7.65^{a,b}$	$7.68^{a,b}$	$7.58^{b,b}$	$7.60^{a,b}$	$7.61^{a,b}$
Bifidobacterium bifidum	Fresh	$6.03^{b,b}$	$6.22^{ab,b}$	$6.37^{a,b}$	$6.51^{a,c}$	$6.40^{a,b}$	$6.46^{a,c}$	$6.50^{a,c}$
	7	$6.55^{b,a}$	$6.65^{a,}$	$6.62^{a,a}$	$6.95^{a,a}$	$6.63^{a,a}$	$6.74^{a,a}$	$6.85^{a,a}$
	14	$6.40^{c,a}$	$6.42^{c,}$	$6.50^{b,a}$	$6.70^{a,b}$	$6.48^{b,b}$	$6.59^{b,b}$	$6.66^{a,b}$
	21	$6.05^{b,b}$	$6.17^{ab,}$	$6.41^{a,b}$	$6.46^{a,c}$	$6.28^{a,c}$	$6.35^{a,d}$	$6.48^{a,c}$
Streptococcus thermophilus	Fresh	$5.67^{c,a}$	$5.65^{c,b}$	$5.87^{b,a}$	$5.\ 90^{a,a}$	$5.78^{b,a}$	$5.92^{a,a}$	$5.81^{b,a}$
	7	$5.70^{c,a}$	$5.84^{b,a}$	$5.90^{a,a}$	$5.95^{a,a}$	$5.80^{b,a}$	$5.99^{a,a}$	$5.95^{a,a}$
	14	$5.68^{b,a}$	$5.81^{a,a}$	$5.72^{b,b}$	$5.65^{b,b}$	$5.82^{a,a}$	$5.62^{b,b}$	$5.61^{b,b}$
	21	$5.46^{b,b}$	$5.62^{a,b}$	$5.15^{c,c}$	$5.44^{b,c}$	$5.51^{ab,b}$	$5.33^{b,c}$	$5.41^{b,c}$
Lactic acid bacteria**	Fresh	$6.55^{a,b}$	$6.50^{a,b}$	$6.68^{a,b}$	$6.55^{a,b}$	$6.48^{a,a}$	$6.65^{a,b}$	$6.83^{a,a}$
	7	$6.69^{b,a}$	$6.63^{b,a}$	$6.95^{a,a}$	$6.99^{a,a}$	$6.55^{b,a}$	$6.92^{a,a}$	$6.95^{a,a}$
	14	$6.56^{a,b}$	$6.41^{ab,c}$	$6.49^{a,bc}$	$6.86^{a,a}$	$6.39^{b,b}$	$6.47^{a,c}$	$6.53^{a,b}$
	21	$6.42^{a,c}$	$6.30^{b,c}$	$6.35^{a,c}$	$6.40^{a,c}$	$6.28^{b,b}$	$6.33^{a,c}$	$6.38^{a,c}$
Yeasts & molds	Fresh	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	7	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	14	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	21	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliforms group	Fresh	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	7	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	14	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	21	Nil	Nil	Nil	Nil	Nil	Nil	Nil

**Lactic acid bacteria=*Lactobacillus delbrueckii ssp. bulgaricus* and *Lactobacillus acidophilus*
The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ ($P \leq 0.05$). *See foot note Table 2.

Table 8. Organoleptic score of bio-yoghurt fortified with celery or dill extract during storage at 5±1°C*

Properties	Storage Period (days)	Treatments						
		C	T_1	T_2	T_3	T_4	T_5	T_6
Appearance (10)	Fresh	$9.20^{b,a}$	$9.65^{a,a}$	$9.75^{a,a}$	$8.96^{c,a}$	$9.15^{b,a}$	$8.75^{c,a}$	$8.89^{c,a}$
	7	$8.91^{b,b}$	$8.78^{bc,b}$	$9.50^{a,a}$	$8.25^{c,a}$	$8.87^{bc,a}$	$9.00^{b,a}$	$8.78^{bc,a}$
	14	$7.76^{c,c}$	$8.25^{b,b}$	$9.00^{a,b}$	$8.12^{b,a}$	$7.74^{c,b}$	$8.50^{b,a}$	$7.75^{c,b}$
	21	$7.25^{cd,c}$	$8.15^{b,b}$	$8.67^{a,b}$	$7.75^{c,b}$	$8.25^{b,a}$	$7.95^{c,b}$	$7.64^{c,b}$
Body & texture (60)	Fresh	$58.50^{a,a}$	$58.13^{b,a}$	$58.67^{a,a}$	$57.98^{ba,}$	$58.33^{a,a}$	$57.87^{b,a}$	$57.67^{b,a}$
	7	$55.67^{b,b}$	$57.64^{b,a}$	$58.51^{a,a}$	$57.45^{b,a}$	$58.11^{a,a}$	$58.19^{a,a}$	$57.41^{b,a}$
	14	$54.33^{c,b}$	$56.55^{b,b}$	$58.14^{a,a}$	$56.61^{b,a}$	$57.64^{a,a}$	$58.12^{a,a}$	$55.90^{b,b}$
	21	$54.25^{b,b}$	$56.15^{a,b}$	$57.68^{a,a}$	$55.25^{b,b}$	$56.45^{a,b}$	$56.67^{a,a}$	$55.75^{b,b}$
Flavor (30)	Fresh	$27.25^{b,a}$	$28.55^{a,a}$	$28.87^{a,a}$	$29.00^{a,a}$	$27.75^{b,a}$	$28.90^{a,a}$	$28.45^{a,a}$
	7	$28.33^{a,a}$	$29.11^{a,a}$	$28.99^{a,a}$	$27.58^{b,a}$	$28.16^{a,a}$	$29.25^{a,a}$	$27.57^{b,a}$
	14	$27.00^{b,a}$	$28.85^{a,a}$	$29.05^{a,a}$	$28.45^{a,a}$	$27.28^{b,a}$	$28.50^{a,a}$	$26.66^{b,a}$
	21	$26.05^{b,b}$	$27.25^{a,b}$	$28.91^{a,a}$	$25.68^{b,b}$	$26.81^{ab,a}$	$28.89^{a,a}$	$25.57^{b,b}$
Total (100)	Fresh	$94.95^{b,a}$	$96.33^{a,a}$	$97.29^{a,a}$	$95.94^{b,a}$	$95.23^{b,a}$	$95.52^{b,a}$	$95.01^{b,a}$
	7	$92.91^{b,a}$	$95.53^{a,a}$	$97.00^{a,a}$	$93.28^{b,a}$	$95.14^{a,a}$	$96.44^{a,a}$	$93.76^{b,a}$
	14	$89.09^{b,b}$	$93.65^{a,b}$	$96.19^{a,a}$	$93.18^{a,a}$	$92.66^{a,b}$	$95.12^{a,a}$	$90.31^{b,b}$
	21	$87.55^{c,b}$	$91.55^{b,b}$	$95.26^{a,a}$	$88.68^{c,b}$	$91.51^{b,b}$	$93.51^{a,a}$	$88.96^{c,b}$

The letters before comma possess the factor of celery and dill level. While those after comma possesses the factor of the cold storage period. The means with the same letter at any position did not significantly differ ($P \leq 0.05$). *See foot note Table 2.

4. Conclusion

It can be concluded that celery extract or dill extract (up to 2% *w/w*) can be used in making set yoghurt with added Bifidobacterium bifidum as a probiotic bacteria with good nutritional values and to enhance its organoleptic and functional properties.

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