Improving Quality Properties of Frozen Yogurt by Fortification with Lemongrass (*Cymbopogon citratus*) as Prebiotic

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Abstract: The present study was carried out to evaluate lemongrass's antimicrobial activities and probiotic cultures' viability in frozen yogurt. The yogurt was prepared with two different commercial starters of probiotics [*Lactobacillus acidophilus* (LA-5), *Bifidobacterium lactis* (BB-12)], incorporation with *Streptococcus thermophiles* and two various concentrations of lemongrass powder or extract (0.5% and 1%). The data showed that lemongrass extract inhibited all microorganisms' growth at a concentration of 36 µl/mL for fungi species (*Aspergillus niger*, *Aspergillus flavus* and *Penicillium* spp.) and 48 µl/mL for bacteria species (*Pseudomonas fluorescens*, *aeruginosa, fragi* and *Aeromonas hydrophila, caviae, sobria*). Lemongrass powder or extract produced an alternative, stable color and stable quality of yogurt during frozen storage. Sensory evaluation of frozen yogurt with lemongrass powder 0.5% had acceptable quality characteristics with higher antioxidant effect (Thiobarbituric acid values 1.02 mg malonaldehyde /kg) after 30 days of frozen storage. The viability loss during frozen storage of commercial probiotic cultures *Lactobacillus acidophilus* (LA-5) and *Bifidobacterium lactis* (BB-12) decreased between 0.7, 1.15 and 0.76, 1.36 log CFU/g, respectively in all treatments. The population of these microorganisms remained above 10^5 CFU/g.

***Keywords*:** Lemongrass; probiotic bacteria; frozen yogurt; fungi; antimicrobial activity; *Cymbopogon citrates*

INTRODUCTION

Nowadays, there is an exponential growth in herbal functional foods as consumers everywhere desire diets healthier. Lemongrass (*Cymbopogon citratus*) is a grass that belongs to Cymbopogon genus and Graminaceae family (Adeneye and Agbaje, 2007). Lemongrass has phytochemicals such as flavonoids, tannins, alkaloids and essential oils. The prefix lemon attributes to its lemon-like typical odor due to the presence of citral, and citral is a combination of two steroisomeric monoterpene aldehydes (Majewska *et al.,* 2019). The aqueous lemongrass extract is commonly used as an aromatic drink and the whole plant is well incorporated into many various traditional foods for its lemon flavor (Figueirinha *et al.,* 2008).

The lemongrass usage was repeatedly found in ancient and recent folk remedies for treating coughs, elephantiasis, consumption, pneumonia, ophthalmia, malaria and vascular disorders. Many researchers have investigated that lemongrass holds antioxidants, antidepressant, astringent, antiseptic, bactericidal, fungicidal, sedative and nervine properties, hypoglycemic and hypolipidemic effects. Further, several studies had proved the lemongrass antibacterial activity against a diverse range of microorganisms comprising both gram-positive and gram-negative bacteria, fungus and yeasts. Lemongrass leaves extract exhibited a tremendous antimicrobial effect against various antibiotics resistant microorganisms (Li *et al.*, 2018; De Silva *et al.*, 2017).

Frozen yogurt has characteristics of both yogurt and ice cream and could be used as a probiotics carrier. Culture viability is often facing high stress during frozen yogurt production (Magarinos *et al.*, 2007). The main challenge of probiotic frozen yogurt processing is to ensure the maintenance of the surviving viability during the freezing process and frozen storage below 0°C (Favaro-Trindade *et al.,* 2006), especially the lethal effects of ice crystals on probiotics. The benefits of probiotics are well known that they help improve the consumer's general health and prevent many types of diseases and enhance the immune system when consumed sufficiently. These beneficial effects on the consumer can only be achieved by consuming 100 grams daily, containing 10^5-10^6 CFU/mL or gram (Jayamanne and Adams*,* 2006). Furthermore, probiotics can develop and improve different types of flavors and the nutritional quality of the product.

Hence the present study was carried out to investigate the potential application of lemongrass powder or extract as a food preservative for its antibacterial activity against some selected spoiling and pathogenic microorganisms and as a source of protection (prebiotic) for probiotic bacteria as well. The herbal ice cream was formulated with probiotics and lemongrass powder or extract based on the acceptable optimal levels and was evaluated according to sensory attributes as response variables.

MATERIALS AND METHODS

Microbial strains and media

Aspergillus niger (*Asp. niger*), *Aspergillus flavus* (*Asp. flavus*) and *Penicillium* spp. were obtained from mycotoxin laboratory, National Research Center, Doki, Cairo, Egypt. *Pseudomonas* spp. (*Ps. fluorescens*, *aeruginosa*, *fragi*) and *Aeromonas* spp. (*Aero. hydrophila, caviae, sobria*) were obtained from the Department of Food Hygiene, Animal Health Research Institute, Cairo, Egypt.

Freeze-dried starters of *Lactobacillus acidophilus* (LA-

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5) (*Lb. acidophilus*), *Bifidobacterium lactis* (BB-12) (*B. lactis*) and *Streptococcus thermophilus* (FD-DVS ABT-2– Probio-Tec) (*Str. thermophilus*) were obtained from Chr. Hansen's Lab, Copenhagen, Denmark. The cultures were stored at -18°C until used before their expiry date. MRS NNLP agar and MRS agar were obtained from Merck (Darmstadt, Germany). Lemongrass leaves (*Cymbopogon citratus*) were purchased from a local market in Ismailia, Egypt. Leaves were washed with tap water and dried using a connective dryer (WT-blinder, Type F115, Germany) at 40°C for 3 days. Dried leaves were finely ground using a blender (Warning Commercial, HGB2WTS3, Torrington, Connecticut, USA).

Preparation of lemongrass powder and extract:

300 mL of boiling water were added to 50 g of lemongrass powder in a conical flask (500 mL) and stirred by a magnetic bar on a hot plate for 10 mins at 90°C. The extract was then filtered and concentrated using rotary evaporator to semi-solid form. The concentrate was stored at 4°C until being analyzed.

Minimum inhibitory concentration (MIC)

Preparation of extract

0.1 g of extract was dissolved in 100 mL distilled water (w/v) to make 100 mg/100 mL (1000 µg/mL). 5 mL of the above solution were diluted with 50 mL distilled water (v/v) from which desired concentration such as 6, 12, 18, 24, 30, 36, 42 and 48 µg/mL.

Dilution susceptibility test

The dilution susceptibility test method was used to determine the minimum inhibitory concentration of leaves extract according to methods described by Brothers and Wyatt (2000) as follows: one mL of 24hr activated cultures were serially diluted and one mL from each dilution (in duplicates) was transferred into petri dishes. Different concentrations of the extract from 0 to 48 µg/mL were thoroughly mixed with 10 mL sterilized medium (sabouraud dextrose agar for fungi and nutrient agar for bacteria), then poured into the aforementioned petri dishes. The dishes were incubated at 30°C and 37°C for fungi and bacteria, respectively, for 48hr. Viable colonies were counted, and inhibition percent was calculated and referred to as the viable count at 0.0% of the extract.

Antimicrobial Assay of leaves extract:

The crook borer diffusion method was used to measure the antimicrobial activity according to the method described by **(**Piddock, 1990) by removing a slug from solidified agar media (sabouraud dextrose agar for fungi) with a sterile crook borer (1 cm diameter) after inoculation with bacteria or fungi. Leaves extract was added at a concentration of 26 µl in duplicates. Inoculated plates were incubated at 37°C for bacteria and 28°C for fungi, and then inhibition zones (mm) of the microbial growth were measured.

Preparation of Frozen Yogurt

Frozen yogurt has been prepared, as described by Marshall and Arbuckle (1996)**.** Control of frozen yogurt and four mix formulations were used in this study with different lemongrass levels to represent the effect of lemongrass on frozen yogurt quality and the viability of probiotics. The control of frozen yogurt (T1) was standardized (4% fat, 11% SNF, 15% sugar and 0.25% CMC), while other four-lemongrass frozen yogurt treatments were prepared with adding 0.5%, 1% and 0.5%, 1% lemongrass powder and extract, respectively.

Each frozen yogurt treatment was prepared in three replicates and analyzed for chemical, bacteriological and organoleptic characteristics at zero time and after 7, 15 and 30 days of frozen storage at -18±1°C.

The frozen yogurt was prepared as following; skimmed milk powder was reconstituted in warm water to 11% total solids for yogurt production. The prepared yogurt pasteurized at 85°C for 10 min, cooled to 45°C, and then inoculated with 2% of freeze-dried DVS starter (*Lb. acidophilus* (LA-5), *B. lactis* (BB-12) and *Str. thermophilus*) (10^7-10^8 CFU/mL). The inoculated yogurt incubated at 45°C for 4 hrs (to final pH 4.8).

Viability of probiotics

The viability of probiotics was determined before freezing [zero time] (neglected results), post-freezing, 7, 15 and after 30 days of storage period by serial dilutions in sterilized peptone water by pour plate method. *Lb. acidophilus* (LA-5) was enumerated by using MRS agar while *B. lactis* (BB-12) was determined by MRS NNLP agar. All these plates were incubated at 37°C anaerobically for 72 hrs.

Chemical analysis

The chemical composition of samples for ash, crude fiber, fat, moisture and protein contents were determined according to the method of AOAC (2012)**.** Carbohydrates were determined by difference (Table, 1).

Table (1): Chemical composition (%dry matter) of lemongrass leaves (Mean ±SD)

Proximal analysis	Moisture content	Crude protein	Total ash	fat	fiber	Carbohydrate
Wet weight	66.09 ±0.121	3.50 ±0.008	2.80 ±0.314	3.37 ±0.32	8.34 ±0.516	15.90 ±0.021
Dry weight	—	10.32 ±0.143	8.26 ±0.002	9.94 ±0.171	24.59 ±0.221	46.88 ±0.085

- Total phenolic compounds (TPC) of lemongrass leaves 46.08%
- Antioxidant activity (DPPH) of lemongrass leaves (81.70%)

Thiobarbituric acid value (TBA)

Lipid oxidation was measured by the 2-thiobarbituric acid distillation method of Pearson (1981)**;** 10 g yogurt sample was macerated with 50 mL water for 2 mins and washed into a distillation flask with 47.5 mL water. After that, 2.5 mL of 4 M HCl were added to bring the pH to 1.5, followed by any antifoaming preparation and a few glass beads. The flask was heated utilizing an electric mantle so that 50 mL distillate is collected in 10 mins from the time boiling commences. 5 mL of the distillate was pipetted into a glass-stoppered tube, and then 5 mL TBA reagent (0.2883 g/100 mL of 90% glacial acetic acid) were added, stoppered, shook and heated in boiling water for 35 mins. A blank was prepared similarly using 5 mL water with 5 mL reagent. The tubes was cooled in water for 10 mins and the absorbance (D) versus blank was measured at 538 nm using a spectrophotometer (T80 UV/VIS, PG Instruments Ltd, UK).

TBA No. [as mg malondialdehyde (MDA)/kg sample]= 7.8 D

Sensory evaluation

Sensory properties of frozen yogurt control and all treatments were evaluated in the same day of processing (day, 1) and after 7, 15 and 30 days of storage at -18±1°C according to the method of Salama (2004). Flavor (45 points), body and color (10 points) and total score (100 points) were evaluated by 15 panelists of the experienced staff members of Food Technology and Dairy Departments, Faculty of Agriculture, Suez Canal University, Egypt.

Instrumental color measurement

Objective measurement of color (CIE *L**, *a** and *b**) was performed at the surface of yogurt samples using a color reader CR-10 (Konica Minolta sensing, Inc., Osaka, Japan). In this coordinate system, the *L** value is a measurement of lightness, ranging from 0 (black) to 100 (white), *a** value ranges from -100 (greenness) to +100 (redness) and *b** value ranges from -100 (blueness) to +100 (yellowness). The redness index (*a**/ *b**) was determined as described by Chen *et al.* (1997)**.**

Statistical analysis

All measurement was done in triplicate and data were reported as means ± standard deviation (SD). The analysis of variance and significant differences were tested by one-way ANOVA using SPSS software (version 16.0 for windows, SPSS Inc., Chicago). It was considered that $p \leq 0.05$ was statistically significant.

RESULTS AND DISCUSSIONS

Antimicrobial activities of lemongrass extract

Antimicrobial activities of lemongrass extract were evaluated in this study. The data showed that lemongrass extract inhibited the growth of all microorganisms at concentrations (36 µl) for fungi species and bacteria species. The data exhibited that bacteria species were more resistant to lemongrass extract than fungi species. In general, the reduction of viable bacteria cells gradually increased according to the increase of the extract concentration, which was added to the growth agar media.

The tabulated results indicated that *Ps. aeruginosa* and *fragi* were sensitive to lemongrass extract than *ps. fluorescens*, which were utterly inhibited in the presence of 42 µg/mL of extract, while *Ps. fluorescens* was still viable when the same concentration was added to the growth agar media. From the data, it can also be noticed that *Aero. hydrophila* was more resistant to lemongrass extract than *Aero. caviae* and *sobria*. On the other hand, the results revealed that MIC for *Asp. niger* and *Asp. falvus* of lemongrass extract was (36 µl/mL), while MIC for *Penicillium* spp. was (30 µl/mL) of lemongrass extract (Table 2). The inhibition effect of lemongrass may be due to its bactericidal components such as phenols, flavonoids and essential oil. According to Singh *et al.* (2011), phenolic compounds and tannins have been found to inhibit pathogenic microorganisms. Ewansiha *et al.* (2012) mentioned that lemongrass showed antimicrobial activity against *Staph. aureus*, *Salmonella typhi* and *E. coli*. All molds, yeasts, *Lactobacillus* and most of the *Bacillus* spp. were sensitive to lemongrass oil.

Antimicrobial tests using the diffusion method showed that lemongrass extract inhibited the growth of *Pseudomonas* and *Aeromonas* spp. The data revealed that *Aero. hydrophila* was more resistant to lemongrass extract than *sobria* and *caviae*, which had inhibition zone 27±0.3, 29±0.1 and 31±0.4 mm, respectively (Fig 1). On the contrary, *Ps. fragi* and *aeruginosa* were sensitive to lemongrass extract than *Ps. fluorescens* by inhibition zone 32±0.3, 31±0.1 and 28±0.6mm, respectively (Fig 2). on the other hand, *Asp. niger* and *flavus* showed inhibition zone 33±0.4 mm while *Penicillium* spp. were sensitive to lemongrass extract than *Asp.* spp. as well, *Penicillium* spp. had inhibition zone 35±0.1mm (Fig 3).

Viability of probiotics in frozen yogurt

Our results showed a slight decrease in the viable counts of *Lb. acidophilus* and *B. lactis* in all treatments during the frozen storage period (30 days). The initial viable cell counts of *Lb. acidophilus* and *B. lactis* for all treatments were between 7.97 ±0.02 - 7.60 ±0.07 and 6.91 ±0.01 - 6.25 ±0.04 log CFU/g, respectively (Table 3). From the data, it can be observed that counts of Lactobacilli decreased between 0.7 and 1.15 log CFU/g, depending on probiotic frozen yogurt treatments. Nonetheless, after 30 days of freezing storage, the population of these microorganisms remained above 10^5 CFU/g (5.49 ±0.10 log CFU/g). These results agreed with the minimum level suggested by Samona and Robinson (1994) for probiotic microorganisms in fermented milk products to produce therapeutic benefits. Bifidobacteria showed decreases between 0.76 and 1.36 log CFU/g in all treatments.

Table (2): Minimum inhibitory concentrations (MIC) of lemongrass extract on some *Aeromonas* spp., *Pseudomonas* spp. and fungi spp.

Microorganisms	Lemongrass concentration (µl)								
	0	6	12	18	24	30	36	42	48
	(Inhibition %)								
Aeromonas hydrophila	0.0	3.61	10.81	20.27	40.82	68.95	79.62	92.14	100.0
Aeromonas caviae	0.0	8.13	16.83	31.16	56.88	81.13	93.18	100.0	–
Aeromonas sobria	0.0	6.21	12.91	28.99	53.44	76.22	91.16	100.0	–
Pseudomonas fluorescens	0.0	5.21	18.10	22.33	44.81	66.11	81.25	90.0	100.0
Pseudomonas aeruginosa	0.0	8.12	24.08	28.86	51.62	84.18	95.73	100.0	–
Pseudomonas fragi	0.0	6.12	18.31	28.79	50.29	79.82	93.68	100.0	–
Aspergillus niger	0.0	5.29	20.83	50.17	78.81	83.1	100.0		
Aspergillus flavus	0.0	6.28	23.78	52.19	81.11	91.5	100.0		
***Penicillium* spp.**	0.0	7.39	28.01	60832	88.80	100.0	–		

Figure (1): Inhibition zones produced against *Aeromonas* spp. by using lemongrass extract

Figure (2): Inhibition zones produced against *Pseudomonas* spp. by using lemongrass extract.

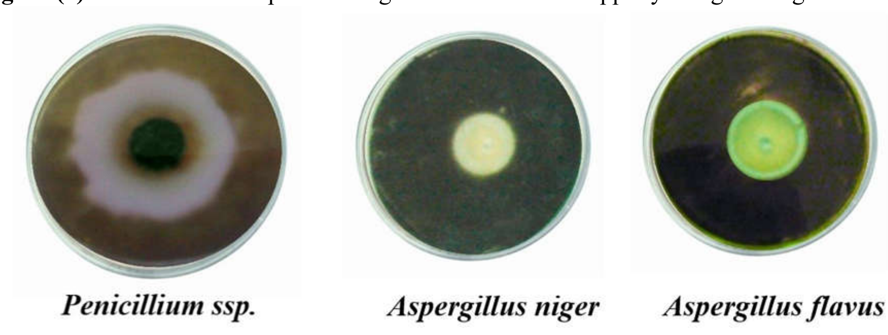

Figure (3): Inhibition zones produced against *Asp. niger*, *Asp. flavus* and *Penicillim* spp. by using lemongrass extract.

Table (3): The viability of probiotic bacteria in frozen yogurt fortified with lemongrass (mean ±S.D)

Days of storage at -18°C	Probiotic count (log CFU/g)									
	T0		T1		T2		T3		T4	
	Lb. acidophilus	*B. lactis*	*Lb. acidophilus*	*B. lactis*	*Lb. acidophilus*	*B. lactis*	*Lb. acidophilus*	*B. lactis*	*Lb. acidophilus*	*B. lactis*
0	7.83 ±0.01	6.56 ±0.12	7.97 ±0.02	6.91 ±0.01	7.95 ±0.04	6.90 ±0.01	7.63 ±0.03	6.38 ±0.06	7.60 ±0.07	6.25 ±0.04
7	7.72 ±0.09	6.56 ±0.03	7.83 ±0.04	6.69 ±0.04	7.80 ±0.07	6.66 ±0.03	7.43 ±0.10	6.35 ±0.08	7.41 ±0.18	6.20 ±0.05
15	7.33 ±0.07	5.96 ±0.02	7.43 ±0.04	6.49 ±0.03	7.42 ±0.10	6.47 ±0.02	7.31 ±0.04	5.83 ±0.03	7.02 ±0.05	5.82 ±0.04
30	6.86 ±0.03	5.50 ±0.09	6.96 ±0.03	5.55 ±0.07	6.90 ±0.03	5.65 ±0.05	6.48 ±0.04	5.51 ±0.07	6.55 ±0.13	5.49 ±0.10

T0: Control
T1: yogurt with 0.5% lemongrass powder
T2: yogurt with 1.0% lemongrass powder
T3: yogurt with 0.5% lemongrass extract
T4: yogurt with 1.0% lemongrass extract

The expected decreasing of viable count due to the adverse effects of freezing condition for the viability of bacteria. A loss of half to one log cycle in viable counts caused by the freezing process (Davidson *et al.,* 2000). Furthermore, this reduction of bacterial counts could be due to acid's ability to enhance the negative effect on bacterial growth.

Treatments 1 and 2 had the lowest decrease of Lactobacilli and Bifidobacteria counts, followed by the control sample. This reduction could be due to lemongrass addition as a powder form that provides conditions that may protect or enhance bacterial growth.

Natural additives were used to control fungal spoilage for clean-label products. In this study, lemongrass was used to control yeast and mold spoilage of frozen yogurt. The average value of molds and yeasts count of different treatments of yogurt was not more than 10^3 CFU/g compared to the control sample. (The data is not tabulated). It means that all yogurt treatments were outstanding in hygiene. According to Nyamath and Karthikeyan (2018), lemongrass had antimicrobial activity against gram-positive and gram-negative bacteria, yeasts and molds.

Antioxidant effect of lemongrass powder and extract in frozen yogurt

TBA test involves the reaction between MDA resulted from lipid oxidation and TBA reagent and formation of pink color. The oxidation of polyunsaturated fatty acids in yogurt leads to the formation of a TBA pink color with maximum absorption at 532 nm (Semeniuc *et al.,* 2016). Lemongrass had a significant effect ($P \leq 0.05$) on TBA values in yogurt samples compared with the control sample. During storage, TBA showed a significant increase from 0.9 mg MDA/Kg yogurt at zero time to 1.63 mg after 30 days of frozen storage at -18°C ±1 for the control sample and from 0.8 mg to 1.02, 1.00, 1.08 and 1.04 mg MDA/Kg yogurt after 30 days of frozen storage for T1, T2, T3 and T4, respectively (Table 4).

This decrease in TBA values in treatments might be due to the presence of bioactive compounds in lemongrass, which have antioxidant effect; the data also revealed a significant difference in the TBA values of different treatments. It can be assumed that the addition of lemongrass (powder or extract) to yogurt caused a reduction of oxidation and aldehydes formation compared to control. There were also significant differences in additive material type (powder or extract) or in lemongrass addition concentrations. The high lemongrass ratio tended to have slightly lower TBA absorbance scores than the low ratio. According to Hartatie *et al.* (2019), lipid oxidation in broiler meat was reduced by using lemongrass as a natural antioxidant. Lemongrass is used as a medicinal tea with antimicrobial and antioxidant properties (Kieling *et al.,* 2019). Lemongrass contains essential oil and phenolic compounds known to have antioxidant activity (Anggraeni *et al.*, 2018).

Table (4): Effect of lemongrass on thiobarbituric acid value (mg MDA/kg) of frozen yogurt during storage at -18°C±1 (Mean ±SD)

Treatments	Storage time (days)				
	0	**5**	**15**	**20**	**30**
T_0	0.91[a] ±0.002	1.01[a] ±0.002	1.21[a] ±0.071	1.39[a] ±0.719	1.63[a] ±0.191
T_1	0.82[b] ±0.121	0.85[c] ±0.225	0.91[b] ±0.003	0.98[c] ±0.211	1.02[c] ±0.138
T_2	0.80[b] ±0.331	0.81[d] ±0.142	0.88[c] ±0.008	0.90[b] ±0.254	1.00[c] ±0.145
T_3	0.82[b] ±0.421	0.89[b] ±0.115	0.93[b] ±0.113	0.99[b] ±0.617	1.08[b] ±0.111
T_4	0.81[b] ±0.008	0.82[d] ±0.161	0.89[c] ±0.004	0.92[b] ±0.476	1.01[c] ±0.002

Means within the same column marked with different letters are significantly different are ($P < 0.05$).
T0: Control
T1: yogurt with 0.5% lemongrass powder
T2: yogurt with 1.0% lemongrass powder
T3: yogurt with 0.5% lemongrass extract
T4: yogurt with 1.0% lemongrass extract

Effect of lemongrass powder and extract on color parameters of frozen yogurt

Color is one of the most important sensory attributes as it helps us to reject or accept food. Lemongrass effect on frozen yogurt's color parameters was studied during storage at -18°C ±1 for 30 days. Table (5) showed that lightness *L** and yellowness *b** were increased by increasing storage time up to 30 days. On the contrary, *a** value decreasing from -2.15 at zero time to -2.54 after 30 days of frozen storage. Color change may be referred to the chemical changes during storage (Abd-El Fattah *et al.,* 2010). Also, Wallace and Giusti (2008) reported that powders and extracts of fruits and vegetables could be a functional component in food. In our study, the addition of lemongrass powder or extract to yogurt produced an attractive, stable color, stable quality product and eliminating the need for industrial colorant extraction.

Table (5): Effect of lemongrass on color parameters of frozen yogurt during storage at -18°C ±1 (Mean ± S.D).

Treatment	*L**	*b**	*a**	*L**	*b**	*a**
	At zero time			After 30 days of storage		
T0	91.82 ±0.11	10.78 ±0.014	-2.15 ±0.111	92.11 ±0.102	11.82 ±0.111	-2.54 ±0.113
T1	91.31 ±0.002	10.61 ±0.009	-2.14 ±0.321	92.69 ±0.007	11.73 ±0.006	-2.31 ±0.111
T2	90.98 ±0.008	10.63 ±0.021	-2.11 ±0.235	92.71 ±0.025	11.69 ±0.013	-2.29 ±0.231
T3	91.73 ±0.031	10.79 ±0.031	-2.13 ±0.142	92.70 ±0.002	11.74 ±0.152	-2.34 ±0.007
T4	91.25 ±0.001	10.62 ±0.052	-2.11 ±0.135	92.76 ±0.031	11.71 ±0.009	-2.25 ±0.121

T0: Control
T1: yogurt with 0.5% lemongrass powder
T2: yogurt with 1.0% lemongrass powder
T3: yogurt with 0.5% lemongrass extract
T4: yogurt with 1.0% lemongrass extract

Effect of lemongrass powder or extract on sensory characteristics of frozen yogurt

Sensory evaluation showed that frozen yogurt fortified with lemongrass powder 0.5% had a good body, texture, flavor and quality characteristics with higher antioxidant effect (TBA values 1.02 mg MAD/kg) compared with frozen yogurt fortified with lemongrass powder 1% and lemongrass extract 0.5-1%.

Although T1 had the highest sensory mean scores, all lemongrass frozen yogurt treatments showed higher flavor scores with accepted mild acid taste than the control sample (Table 6). Frozen yogurt was commercially evaluated to be the lowest-acid product. Moreover, lemongrass can also add a pleasant light, lemony flavor to foods (Abdelazez *et al.,* 2017).

Table (6): Effect of lemongrass on sensory characteristics of frozen yogurt during storage at -18°C±1 (Mean ±S.D).

Days / Treatments	Zero	7	15	30
Control	$72.0^{d} \pm 1.000$	$71.6^{d} \pm 0.570$	$70.0^{d} \pm 1.000$	$69.7^{d} \pm 1.520$
T_1	$95.6^{a} \pm 1.150$	$95.0^{a} \pm 0.001$	$93.0^{a} \pm 1.732$	$92.3^{a} \pm 1.520$
T_2	$95.0^{a} \pm 1.130$	$93.3^{a} \pm 1.520$	$92.0^{a} \pm 1.000$	$89.7^{a} \pm 0.570$
T_3	$89.3^{b} \pm 0.577$	$86.7^{b} \pm 0.570$	$85.3^{b} \pm 3.210$	$84.3^{b} \pm 0.570$
T_4	$82.7^{c} \pm 1.527$	$81.3^{c} \pm 0.570$	$80.0^{c} \pm 0.001$	$78.3^{c} \pm 1.150$

Means with the same column with different superscript (a, b, c…) are not significantly different ($p<0.05$)
T0: Control
T1: yogurt with 0.5% lemongrass powder
T2: yogurt with 1.0% lemongrass powder
T3: yogurt with 0.5% lemongrass extract
T4: yogurt with 1.0% lemongrass extract

CONCLUSION

Many studies have focused on probiotics and prebiotics and their health effects. Probiotics and lemongrass as dietary fiber (prebiotics) are well known for their beneficial health effects and source of functional foods. In conclusion, the addition of the powder or extract of lemongrass to frozen yogurt improved the viability of probiotic and quality characteristics of frozen yogurt.

Authors' contributions

Eldeeb, G.S.S. was involved in chemical and microbial analysis, manuscript writing, correcting and editing. Mosilhey, S.M. was involved in the preparing for the implementation, calculating and manuscript writing. Abouelnaga, M. was involved in processing, data tabulating and manuscript writing. All authors read and approved the final manuscript.

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تحسين خواص الجودة للزبادى المجمد بواسطة تدعيمه بحشيشة الليمون كداعم حيوي

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يهدف هذا البحث إلى دراسة تأثير إضافة حشيشة الليمون كمضاد للميكروبات وكمعزز ومدعم لنمو بكتريا البروبيوتيك في منتج الزبادي المجمد. تم تصنيع الزبادي بسلالات *Streptococcus thermophiles* وبإضافة [*Lactobacillus acidophilus* (LA-5), *Bifidobacterium lactis* (BB-12)] بتركيزات ٠.٥ و ١.٠٪ من مسحوق أو مستخلص حشيشة الليمون. أوضحت النتائج قدرة مستخلص حشيشة الليمون عند تركيز 36 µl/mL على تثبيط نشاط فطريات (*Aspergillus niger*, *Aspergillus flavus* and *Penicillium* spp.) وعند تركيز 48 µl/mL قامت بتثبيط بكتريا (*Pseudomonas fluorescens*, *aeruginosa fragi* and *Aeromonas hydrophila, caviae, sobria*). وكان هناك ثبات في لون وجودة الزبادي خلال فترة التخزين المجمد. وكان هناك قبول للتقييم الحسي لتركيز ٠.٥٪ من مسحوق حشيشة الليمون بالإضافة إلى التأثير المضاد للأكسدة خلال ٣٠ يوم من التخزين المجمد. وكان هناك تأثير بسيط على معدل فقد بكتريا البروبيوتك خلال فترة التخزين المجمد وتم الإبقاء على أعداد تصل إلى أعلى من (10^5 CFU/g) وذلك مقارنة بالعينة الكنترول..