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Textural, Sensory and Physico-chemical changes in *Dahi* made using EPS and non-EPS producing Cultures during storage

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Abstract

This study was carried out to investigate the changes in physicochemical, textural and sensory properties of milk fermented using exopolysaccharide (EPS) and non-EPS producing strains of Lactic Acid bacteria (LAB). *Dahi* samples were prepared using the standard procedure and analyzed on days 0, 7, 14 and 21 during storage at 5 ± 2 °C. The study results showed that *dahi* prepared using EPS producing cultures as well as Non-EPS cultures differed significantly with respect to textural and sensory characteristics. Sensorily, *dahi* prepared using the EPS producing culture comprising of *Lactobacillus helveticus* MTCC 5463+ *Streptococcus thermophiles* MTCC 5460 scored the highest. *Dahi* samples prepared using EPS producing cultures exhibited a higher cohesiveness, springiness, chewiness, resilience and adhesiveness in comparison to *dahi* made using non-EPS producing cultures which showed higher values for fracturability, hardness and gumminess. During the shelf-life study significant changes in the sensory, physico-chemical and textural properties of *dahi* samples were observed and the pattern of these changes remained almost similar in *dahi* samples irrespective of whether the products were prepared using EPS starters or non-EPS starters. The total viable count of cultures were within the acceptable range up to 21 days of storage at refrigerated temperature (5±2°C) for both group of *dahi* samples.

Keywords: Lactic acid bacteria, Exopolysaccharides, Storage, Texture, *Dahi*

Dahi is considered as one of the most popular fermented milks of India. It occupies a pivotal position in Indian dietary practice, in the traditional scientific system of Indian medicine (Ayurveda), in Hindu rituals and in traditional cosmetic applications (Prajapati and Sreeja 2013). It has close resemblance to yoghurt. Since conversion of milk into *dahi* is an important intermediate step in the manufacture of indigenous fat-rich dairy products like butter and ghee, it can be said that over 40% of the total milk production in India is converted into *dahi*. Despite changing life style and food habits, *dahi* still remains one of the widely consumed indigenous fermented milks in India.

Along with the milk quality, the type and character of starter organisms used in the production of *dahi* defines the flavour, textural and overall quality of the final product. Exopolysaccharides (EPS) produced by LAB are widely used to improve the body and texture of yoghurt and other fermented milk products (Broadbent *et al*. 2003; Faber *et al*. 2001). EPS produced by the microorganisms have unique rheological properties because of their capability of forming very viscous solutions at low concentrations and their pseudoplastic nature (Becker *et al*. 1998). Textural characteristics of *dahi* have been defined by hardness, adhesiveness, cohesiveness, fracturability and springiness (Megenis *et al*. 2006). Cohesiveness indicates structural integrity and is often discussed in terms of the bond strength; adhesiveness indicates adherence of yogurt/*dahi*; whereas springiness reflects the structural integrity of yogurt/*dahi*. Greater cohesiveness and springiness may be related to stronger gel structures, indicating greater structural integrity. There is correlation between syneresis and hardness, as hardness increases the synersis decreased. The firmness and cohesiveness of yoghurts made with "ropy" strains decreased with the presence of increased amounts of EPS (Marshall and Rawson, 1999). Amatayakul *et al*. (2006) found that the firmness of fermented skim milk made using capsular EPS-producing or ropy EPS-producing cultures was lower than that of fermented skim milk made with non- EPS-producing starter cultures. The fermented skim milk gel formation process was accompanied by EPS secretion, and the EPS interfered with protein-protein interactions, which resulted in a soft curd (Ayala- Hernández *et al*. 2009).

The overall sensory impression perceived from a fermented milk product like *dahi* largely depends on its textural characteristics and physico-chemical properties. Evaluation by instrumental methods give a more relevant and accurate information about textural properties. Very few detailed studies are available related to the use of EPS producing cultures in the preparation of *dahi* as well as its influence on the sensory, physico-chemical and textural aspects of the product. Hence in the current study efforts are being taken to understand the influence of EPS and non-EPS producing cultures on the quality attributes of *dahi*.

MATERIALS AND METHODS

Cow milk for the production of *dahi* was obtained from Livestock Research Station, Anand Agriculture University, Anand, and Gujarat, India. The milk contained 3.5% fat and 8.5% solids-not-fat. Titratable acidity and pH of the milk were 0.126 ± 0.002 % LA and 6.65 ± 0.02, respectively. Sagar Skimmed Milk Powder used for standardization was purchased from the market. Starter cultures (Table 1.0) used in the study comprised of indigenous strains *viz*., *Lb. helveticus* MTCC 5463(V_3), *Lb. rhmnosus* (NS_6), *S. thermophiles* MTCC 5461(MD_8), *S. thermophiles* MTCC 5460 (MD_2) as well as *dahi* cultures obtained from a commercial culture supplier available in DVS form. Indigenous strains were obtained from the culture collection of Dairy Microbiology department, SMC college of Dairy Science, Anand. The cultures were propagated in sterile reconstituted skim milk (11% TS) at 39 °C for 16 h and stored at 5 ± 2 °C. DVS cultures were stored at -20 °C.

Table 1: Culture combinations used in present study

Culture code	Strain name	Combination of type of strains and their proportion of addition
A	ST = *Streptococcus thermophilus* SL = *Streptococcus lactis*	(ST 505 + ST 503 + ST820) + (SL 216 + SL 69 + SL 225) (75:25)
B	ST = *Streptococcus thermophilus* SL = *Streptococcus lactis*	(ST 505 + ST503 + ST820) + (SL119 + SL195 + SL232) (75:25)
C	*V_3 = *Lactobacillus helveticus* MTCC 5463 MD_2 = *Streptococcus thermophilus* MTCC 5460	V_3 + MD_2(50:50)
D	*NS_6= *Lactobacillus rhamnosus* MTCC 5946 MD_8= *Streptococcus thermophilus* MTCC 5461	NS_6 + MD_8(50:50)

**V_3 and NS_6 were exopolysaccharide producing strains.*

Preparation of *dahi*

Dahi was prepared using the procedure optimized in the department. Accordingly, cow milk was standardized to 14% total solids, homogenized (1st stage = 1500 psi, 2nd stage = 500 psi) and heated to 90 °C / 10 min. Milk was then cooled to 39 °C and inoculated with culture @2%. It was then packaged in culps and incubated at 39 °C till the pH reached to 4.6. The product was then cooled and stored at refrigerated temperature (5 + 2 ◎C).

Physico-chemical Analysis: *Dahi* samples stored at 5 + 2 °C were analyzed at an interval of 0, 7, 14 and 21 days. Titratable acidity as lactic acid was measured according to the standard methods of AOAC (1995). The pH of *dahi* was determined using electronic pH meter, Model CYBERSCAN series 600 waterproof portable meter manufactured by EUTECH Instruments, Singapore.

Sensory Evaluation: All products were coded and arranged in random order. The products were subjected to sensory evaluation by an expert trained panel of judges for colour and appearance, flavour, body and texture overall acceptability criteria on the basis of 9 point hedonic scale.

Microbiological analysis: Lactic count of *dahi* samples was determined as per the method described by De man *et al*. (1960). Procedure followed for yeast and mold count was according to Indian Standards, IS 5403, (1969).The lactic count, yeast and mold count and coliform count were taken at an interval of 7 days upto 21st day of storage.

Texture Profile Analysis (TPA): Texture analyser model TAHD plus made by Stable Microsystems was used for determining the textural properties of *dahi*. The instrument is having in built software (macro) for calculations and presentation of measurements. During Texture profile analysis force measured in compression, trigger force was 5 gm. The cylindrical probe of P36R (36 mm in diameter) was used for TPA. Pre-test, test speed and Post-test speed was kept1.0 mm/sec, 1.0 mm/sec and 2.0 mm/sec respectively. Measurement depth was 25 mm.

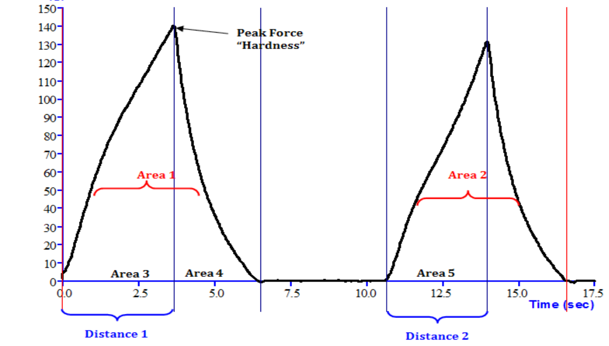

Fig. 1: Two cyclic graph for texture profile analysis

The experiments were conducted by compression test that generated plot of force (gm) vs. Time (sec), from which texture values were obtained using different formula that was programmed in TAHD plus software. The parameters were quantified and defined by Bourne (1982) which includes hardness, fracturability, cohesiveness, gumminess, springiness, adhesiveness and chewiness (Bourne 1978; Chen and Stokes 2012). These parameters were measured during entire period of study. Properties analysed are shown in Fig. 1.

Hardness value was the peak force that occurs during the first compression. The force at the first peak was measured as fracturability. Adhesion was measured as the negative work between the two cycles.

Cohesiveness = Area 2/Area 1.

Springiness = Distance 2 / Distance 1.

Gumminess = Hardness × Cohesiveness.

Resilience = Area 4/Area 3.

Chewiness **=** gumminess × Springiness.

Statistical Analysis: The data obtained from the physicochemical, textural, microbiological and sensory analyses of the samples were statistically evaluated by FCRD (Factorial Completely Randomised Design) (Steel and Torrie 1980)

RESULTS AND DISCUSSION

Present study investigated the changes in physicochemical, textural and sensory properties of *dahi* made using EPS and non-EPS producing strains during storage. It also aimed to see the difference in textural properties of set *dahi* in relation to different strains used. Quality of *dahi* was judged on the basis of its sensory, physico-chemical, textural characteristics and microbiological profile through-out the storage. It is well known that during the storage time changes in pH and acidity values occur. These changes are closely connected to changes in the sensory and textural properties as well as microbial profile of the product.

Chemical Changes during Storage

Freshly prepared *dahi* samples do not show any significant difference in the titratable acidity and pH irrespective of whether the cultures were EPS producing or not. Acidity of all *dahi* samples increased gradually depending on the storage time (Table 2). A corresponding decrease in the pH values of products were observed. The average acidity of *dahi* samples prepared cultures from A, B, C and D were 1.04, 1.05, 1.1 and 1.08% LA respectively. *Dahi* prepared using EPS culture C showed highest increase in acidity with storage. The significant increase in acidity during storage for all the cultures clearly indicated that they are able to metabolize lactose and continue production of lactic acid at refrigerated temperature. This increase in acidity was the main reason for termination of the shelf-life of the products which was reflected in their sensory evaluation scores also. Such a trend in the acidity of *dahi* samples during storage study was reported by many researchers (Ghosh and Rajorhia 1987, Cardoso *et al*. 1991; Dave 1993; Sarkar *et al*. 1996).

Sensory evaluation

Good quality *dahi* should possess a pleasing flavour obtained from a blend of clean acid taste and a delicate aromatic flavour. It should be free from any undesirable off flavours. For set *dahi* the surface should be smooth and glossy, while the cut surface should be clean and free from gas bubbles. But on storage at refrigerated conditions, the product characteristics are affected due to a number of physical, chemical, microbiological and biochemical changes, which influence the sensory characteristics of product. *Dahi* samples were judged for various sensory attributes *viz*. (i) flavour, (ii) body and texture, (iii) acidity, (iv) colour and appearance and (v) overall acceptability by an expert channel of judges (Table 3). The flavour score of *dahi* prepared using EPS culture C was significantly higher ($p<0.05$) compared to other products. *Dahi* made using EPS producing cultures C and D gave a rich mouth-feel compared to *dahi* made using cultures A and B. All *dahi* samples received the highest scores in the beginning of storage. While with advancement of storage period the increase in acidity decreased the flavour score. Body and texture scores decreased during storage. *Dahi* made using culture A showed significantly ($p<0.05$) higher body score as compared to rest of the cultures. Slight decrease in the body score was observed after 7 days of storage after that the difference was non-significant. Colour and appearance is one of the important attributes of the sensory quality. Little variation in color and appearance scores of *dahi* samples were observed during refrigerated storage. Nahar *et al.* (2009) reported that the colour and appearance of *dahi* remained acceptability up to 21 days of storage at refrigerated temperature. Overall acceptability of *dahi* samples differed significantly ($p<0.05$). *Dahi*

Table 2: Changes in the physico-chemical properties of *dahi* during storage

Property	Storage days	Cultures			
		A	**B**	**C**	**D**
pH	**0**	4.63 ± 0.01	4.65 ± 0.01	4.66 ± 0.01	4.62 ± 0.01
	7	4.24 ± 0.01	4.23 ± 0.01	4.13 ± 0.05	4.08 ± 0.01
	14	4.02 ± 0.01	4.0 ± 0.01	3.95 ± 0.01	3.93 ± 0.02
	21	3.85 ± 0.01	3.83 ± 0.04	3.76 ± 0.02	3.74 ± 0.03
CD(0.05) P=0.02, C=0.02; P×C=Significant					
Acidity (% LA)	**0**	0.72 ± 0.01	0.71 ± 0.01	0.72 ± 0.01	0.72 ± 0.01
	7	0.93 ± 0.01	0.92 ± 0.01	1.01 ± 0.01	1.04 ± 0.01
	14	1.21 ± 0.01	1.23 ± 0.01	1.26 ± 0.01	1.27 ± 0.01
	21	1.34 ± 0.01	1.36 ± 0.01	1.37 ± 0.01	1.32 ± 0.04
CD(0.05) P=0.01, C=0.01; P×C=Significant					

All data are mean of three independent replications; P= Storage period, C= Cultures.

Table 3: Changes in the sensory score of *dahi* samples with storage

Property	Storage days	Cultures			
		A	B	C	D
Flavour	**0**	8.18 ± 0.03	8.12 ± 0.02	8.27 ± 0.03	8.04 ± 0.01
	7	7.70 ± 0.01	7.65 ± 0.01	7.67 ± 0.02	7.62 ± 0.01
	14	6.70 ± 0.01	6.34 ± 0.03	6.64 ±0.01	6.35 ± 0.02
	21	5.95 ± 0.02	5.63 ± 0.01	5.83 ± 0.02	5.23 ± 0.02
CD(0.05) P=0.05, C=0.05; P×C=Significant					
Body & Texture	**0**	8.28 ± 0.02	8.21 ± 0.02	8.24 ± 0.02	8.13 ± 0.02
	7	8.21 ± 0.09	8.11 ± 0.01	8.20 ± 0.05	8.03 ± 0.02
	14	8.2 ± 0.1	8.16 ± 0.03	8.15 ± 0.04	8.07 ± 0.02
	21	8.12 ± 0.02	8.08 ± 0.03	8.12 ± 0.01	8.1 ± 0.01
CD(0.05) P=0.06, C=0.06; P×C=NS					
Color and appearance	**0**	8.25 ± 0.03	8.22 ± 0.03	8.25 ± 0.01	8.2 ± 0.01
	7	8.16 ± 0.04	8.15 ± 0.02	8.13 ± 0.04	8.08 ± 0.01
	14	7.92 ± 0.08	7.83 ± 0.02	7.92 ± 0.03	7.83 ± 0.03
	21	7.77 ± 0.03	7.7 ± 0.03	7.73 ± 0.01	7.68 ± 0.01
CD(0.05) P=0.03, C=0.03; P×C=NS					
Overall acceptability	**0**	8.23 ± 0.02	8.13 ± 0.03	8.27 ± 0.02	8.07 ± 0.02
	7	7.93 ± 0.05	7.7 ± 0.02	7.95 ± 0.02	7.63 ± 0.03
	14	6.8 ± 0.02	6.58 ± 0.06	6.72 ± 0.02	6.33 ± 0.02
	21	5.97 ± 0.03	5.73 ± 0.02	5.92 ± 0.01	5.49 ± 0.03
CD(0.05) P=0.03, C=0.03; P×C=Significant					

All data are mean of three independent replications; P= Storage period, C= Cultures.

prepared using EPS culture C showed a significantly ($p<0.05$) higher overall acceptability score. With increase in period of storage the acceptability score of all the samples decreased significantly. The changes in the physico-chemical parameters such as increase in acidity adversely affect the sensory parameters and hemce the overall acceptability of *dahi* samples. A number of research studies have highlighted that EPS producing lactococcal cultures had significant effect on physico-chemical, rheological and sensory properties of *dahi*. EPS elaborated by the cultures reduce whey separation in *dahi* by binding significant amount of water and hence improve the *dahi* characteristics. The water binding ability of EPS in yoghurt was also reported in the previous studies (Wacher-Rodarte *et al.* 1993; Marshall & Rawson 1999; Doleyres *et al.* 2005).

Textural properties

The textural properties of the *dahi* samples prepared using different starter cultures are shown in (Table 4). *Dahi* samples prepared using EPS producing culture exhibited higher values for cohesiveness, springiness, chewiness, resilience and adhesiveness in comparison to *dahi* made using non-EPS producing cultures which showed higher values for fracturability, hardness and gumminess. Significant difference in the textural properties of *dahi* samples were observed during storage period (Table 5). The texture profile varied with the type of culture used.

Fracturability value was higher for *dahi* sample made using non-EPS producing culture A. The changes in the fracturability of samples during storage was non-significant. Our observation was in agreement with Ayar and Gurli (2014) who reported that the

Table 4: Changes in the textural properties of *dahi* with storage

Property	Storage days	Cultures			
		A	**B**	**C**	**D**
Fracturability (g)	**0**	320.87± 7.98	278.94 ± 13.07	311.81 ± 5.21	284.34 ± 2.0
	7	326.43 ± 4.58	282.56 ± 3.69	310.55 ± 4.92	284.17 ± 3.11
	14	325.59 ± 4.9	282.55 ± 3.53	310.88 ± 4.08	284.17 ± 5.14
	21	326.89 ± 3.16	278.23 ± 3.74	313.92 ± 4.62	286.82 ± 3.54
CD(0.05) P=5.35, C=5.35; P×C=NS					
Hardness (g)	**0**	463.71 ± 9.9	420.6 ± 12.04	362.92 ± 4.08	357.21 ± 14.36
	7	489.41 ± 5.84	469.42 ± 2.19	376.41 ± 3.61	381.47 ± 2.23
	14	495.12 ± 3.0	483.15 ± 3.66	389.65 ± 1.86	395.48 ± 3.78
	21	522.03 ± 2.68	513.01 ± 3.58	395.82 ± 2.46	406.17 ± 4.23
CD(0.05) P=6.29, C=6.29; P×C=Significant					
Cohesiveness	**0**	0.39 ± 0.009	0.39 ± 0.004	0.40 ± 0.002	0.40 ± 0.002
	7	0.38 ± 0.001	0.38 ± 0.003	0.41 ± 0.003	0.41 ± 0.002
	14	0.38 ± 0.002	0.38 ± 0.004	0.41 ± 0.002	0.41 ± 0.004
	21	0.38 ± 0.001	0.38 ± 0.01	0.41 ± 0.002	0.40 ± 0.002
CD(0.05) P=NS, C=0.004; P×C=Significant					
Gumminess (g)	**0**	177.67 ± 9.05	166.05 ± 3.25	152.06 ± 4.80	144.9 ± 5.50
	7	185.06 ± 2.5	177.94 ± 2.8	152.99 ± 0.62	154.74 ± 0.54
	14	187.29 ± 1.69	182.19 ± 0.44	158.02 ± 1.47	163.29 ± 1.1
	21	199.2 ± 1.32	197.49 ± 5.36	160.65 ± 1.74	163.89 ± 2.14
CD(0.05) P=3.66, C=3.66; P×C=Significant					
Springiness (mm)	**0**	1 ± 0	1 ± 0	2.27 ± 0.15	2.14 ± 0.12
	7	1 ± 0	1 ± 0	2.43 ± 0.05	2.45 ± 0.03
	14	1 ± 0	1 ± 0	2.55 ± 0.03	2.48 ± 0.05
	21	1 ± 0	1 ± 0	2.55 ± 0.04	2.51 ± 0.05
CD(0.05) P=0.06, C=0.06; P×C=Significant					
Chewiness	**0**	177.67 ± 9.05	166.05 ± 3.24	346.13 ± 7.35	310.24 ± 6.33
	7	185.06 ± 2.5	177.94 ± 2.81	372.77 ± 6.23	380.15 ± 3.97
	14	187.28 ± 1.69	182.19 ± 0.43	403.76 ± 6.13	404.87 ± 5.92
	21	199.2 ± 1.32	197.49 ± 5.36	409.78 ± 6.38	412.05 ± 9.66
CD(0.05) P=9.63, C=9.63; P×C=Significant					
Resilience	**0**	0.029 ± 0.002	0.029 ± 0.001	0.187 ± 0.001	0.204 ± 0.005
	7	0.033 ± 0.001	0.033 ± 0.003	0.183 ± 0.002	0.194 ± 0.002
	14	0.035 ± 0.001	0.034 ± 0.001	0.184 ± 0.0004	0.194 ± 0.002
	21	0.037 ± 0.004	0.037 ± 0.002	0.185 ± 0.002	0.193 ± 0.002
CD(0.05) P=0.002, C=0.002; P×C=Significant					
Adhesiveness (g.sec)	**0**	-1030.4 ± 15.61	-990.29 ± 7.96	-1317.75 ± 9.27	-1324.24 ± 4.19
	7	-1010.43 ± 3.92	-971.23 ± 5.13	-1308.86 ± 8.1	-1323.01 ± 5.6
	14	-994.85 ± 3.72	-937.12 ± 7.76	-1311.94 ± 5.91	-1319.62 ± 9.04
	21	-950.73 ± 6.1	-918.04 ± 5.97	-1316.86 ± 4.93	-1320.19 ± 4.26
CD(0.05) P=7.68, C=7.68; P×C=Significant					

All data are mean of three independent replications; P= Storage period, C= Cultures.

Table 5: Changes in the lactic count of *dahi* with storage

Property	Storage days	Cultures			
		A	B	C	D
Lactic count (Log cfu/g)	**0**	9.14 ± 0.01	9.11 ± 0.01	8.93 ± 0.02	8.91 ± 0.02
	7	8.71 ± 0.02	8.65 ± 0.02	8.82 ± 0.02	8.78 ± 0.01
	14	8.38 ± 0.01	8.37 ± 0.01	8.58 ± 0.01	8.44 ± 0.01
	21	7.9 ± 0.01	7.83 ± 0.01	8.12 ± 0.02	8.04 ± 0.03
CD(0.05) P=0.02, C=0.02; P×C=Significant					

All data are mean of three independent replications; P= Storage period, C= Cultures.

fracturability of flavored spreadable yogurt did not show any significant change during storage.

Hardness values were higher in case of *dahi* made using non-EPS producing cultures. *Dahi* made using culture A showed maximum hardness value. During entire period of study, *dahi* made using EPS producing cultures C and D had lower values of hardness compared to *dahi* made using non-EPS cultures A and B. Hardness of all the *dahi* samples increased with increased period of storage and this increase in the hardness was less for *dahi* made using EPS producing cultures. La Torre *et al*. (2003) reported that probiotic fermented milk products made with starter cultures producing exopolysaccharides were firmer. Dinkci (2012) reported that hardness of *dahi*/ yogurt sample increased from 348 g at 0 day to 571 g at 14th day. Generally it was observed that EPS reduces the hardness of the curd. This is because EPS itself is mucous, which has very low hardness.

Cohesiveness indicates structural integrity and is often discussed in terms of the bond strength. Greater cohesiveness may be related to stronger gel structures, indicating greater structural integrity; perhaps due to increased charged groups on the amino acid groups-a function of whey protein denaturation (Megenis *et al.* 2006). Value of cohesiveness for products made using EPS producing cultures was higher compared to non-EPS producing cultures. The highest value of cohesiveness was observed for *dahi* made using EPS culture C than rest of the cultures. Van Hekken *et al*. (2004) reported that cohesiveness of yogurt remained unaffected during storage period of 15 days.

Gumminess was mutually exclusive with chewiness since a product would not be both a semi-solid and a solid at the same time (Yang and Li 2010). It is defined as the force needed to disintegrate a semisolid food to a state ready for swallowing (Tunick 2000; Yang and Li 2010). *Dahi* made using non-EPS culture A had the highest value of gumminess. Gumminess of *dahi* samples made using EPS producing cultures C and D were lower than A and B.

Springiness is the rate at which the sample returns to its original shape when the deforming force is removed (Kahyaoglu *et al*. 2005). The highest flexibility value was determined for *dahi* prepared using EPS producing cultures C and D. Springiness has slightly increased in the *dahi* samples prepared with EPS producing culture upto 21st day of storage. Lucey *et al*. (1997) noted that exopolysaccharides produced by starter culture can be used in yoghurt for higher elasticity.

Chewiness is the energy required to masticate a solid food product to make it ready for swallowing (Uprit and Mishra 2004). Large variation ranging from 166 to 412 was reported among *dahi* samples made using different cultures. *Dahi* made using EPS cultures C and D showed significantly ($p<0.05$) higher chewiness value. Results demonstrated that at 21st day of storage, the value of chewiness is higher for all the samples. EPS producing cultures C and D showed higher value of chewiness and has high potential to use in low fat fermented milks. There is evidence that starter organisms causes structural changes in the protein matrix, as storage period. The components that make up the fermented milks undergo rearrangement of bonds, associations, and interactions that result in the infrastructure of the product being altered (Van Hekken *et al*. 2004). *Dahi* made with cultures C and D showed a significantly ($p<0.05$) higher value of resilience than cultures A and B due to production of exopolysaccharides.

The maximum negative force on the graph indicates sample adhesive force; the more negative the value, the more "sticky" the sample. *Dahi* prepared using EPS cultures C and D showed more adhesiveness than *dahi* samples made using non-EPS cultures. The adhesive properties of yogurt samples showed variations during storage. With storage the values of adhesiveness significantly decreased for *dahi* samples made using non-EPS producing cultures. The lowest adhesiveness was reported for *dahi* prepared using culture B. Ayar and gurlin (2014) reported that adhesive force has increased in the yogurt samples prepared with carrot between the 1st and 10th days, at the end of the experiment, during the 20th day, a decrease was observed. Behare *et al*. (2013) reported that EPS producing cultures made *dahi* more adhesive which would indicate a contribution of EPS to the tendency of the product to adhere to the surface of other materials.

Researchers have observed that the viscosity, adhesiveness and stickiness of fat-free *dahi* increased when EPS-producing cultures were used indicating that EPS contributed to the rheological properties (Rawson and Marshall 1997; Marshall and Rawson 1999; Dolyeres *et al.* 2005; Folkenberg *et al.* 2005). Adhesiveness is an important factor for the description of mouth feel for a given food material. *Dahi* made from EPS negative culture was firmer and required higher shearing force, due to the formation of strong protein-protein interactions as a result of the fermentation process (Hassan *et al.* 2002; Bouzar *et al.* 1997; Marshall and Rawson 1999). The contribution of the EPS producing strains to the textural properties is said to be a result of the secretion of extracellular polysaccharides and the ability of the polysaccharide to form strands which connect the bacteria to the casein micelles (Tamime *et al.* 1984). Sensory scores such as flavour, body and texture, colour and appearance and acidity of *dahi* were also improved by use of EPS-producing cultures. Folkenberg *et al.* (2005) reported that yoghurt fermented with EPS-producing cultures showed increased mouth thickness, shininess and tended to be creamier than yoghurt without these cultures (Behare *et al.* 2008).

Many researchers have reported that the exopolysaccharide could improve the texture of yogurt, because exopolysaccharide produced by LAB interacts with the free water in the gellike structure (De Vuyst and Degeest 1999; Guzel-Seydim *et al*. 2005; Patel *et al.* 2012; 24). In a study by Han *et al.* (2016), the yogurt fermented by SH-1 had the highest content of exopolysaccharide and the best texture than the yogurt fermented by the other starter cultures. The concentration of exopolysaccharide of SH-1 was the highest (423.05mg/L), corresponding to the highest firmness (55.77 g), highest cohesiveness (715.31 g.s), highest viscosity (27.83 g), and highest adhesiveness (364.30 g.s), respectively. It suggested that the EPS starter SH-1 could reduce some stabilizer addition and replace the imported commercial starters. Similar results were found by Patel *et al.* (2012). They reported that exopolysaccharide could improve the quality of yogurt, while having no effect on flavor of yogurt.

However it is difficult to compare Non-EPS strains with EPS producing strains when we talk about textural differences especially for products like *dahi*. Both types of cultures have different dynamics in the gel network. There are differences in firmness of a model system when different strains are used. Though its difficult to describe why, one possible reason could be the gradient of acidification which will have impact on demineralization of casein and resultant difference in gel network (interlinks). Though this needs to be investigated in a separate study.

Microbiological changes

Lactic count

Freshly made *dahi* samples had lactic count ranging from 8.91 to 9.14 log cfu/gm. All the *dahi* samples showed gradual decrease in log viable count over the period of storage . This may be due to inhibitory effect of lactic acid and other metabolites produced by the cultures. At the end of the storage period all *dahi* samples had a lactic count of more than 7 log cfu/g. a similar trend in lactic count during storage study in fermented milk products was reported by Nighswonger *et al*. (1996), Iniguez *et al*. (2001) and Mani-López *et al*. (2014). Coliforms were not detected in the *dahi* samples throughout the storage period of 21 days. The count of yeast and mold in the *dahi* samples were less than 10 log cfu/g during entire storage study.

CONCLUSION

The textural, sensory and physico-chemical properties of *dahi* samples are significantly affected by the type, rate of acid development and production of EPS by starter culture used for its preparation. *Dahi* made using EPS producing cultures as well as Non-EPS cultures differed significantly with respect to textural and sensory attributes. *Dahi* prepared using the EPS producing culture comprising of *Lactobacillus helveticus* MTCC 5463+ *Streptococcus thermophiles* MTCC 5460 scored the highest for sensory characteristics. Texturally, such *dahi* exhibited a higher cohesiveness, springiness, chewiness, resilience and adhesiveness in comparison to *dahi* made using non-EPS producing cultures which showed higher values for fracturability, hardness and gumminess. During the shelf-life study significant changes in the sensory, physico-chemical and textural properties of *dahi* samples were observed and the pattern of these changes remained almost similar in *dahi* samples irrespective of whether the products were prepared using EPS starters or non-EPS starters. As the overall acceptability of products such as *dahi* is largely influenced by consumer's taste preferences, it can be concluded that both EPS starters and non-EPS starters can be used for preparation of *dahi* having acceptable quality attributes.

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