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RHEOLOGICAL, STORAGE STABILITY AND SENSORY PROFILING OF LOW-FAT YOGHURT FORTIFIED WITH RED CAPSICUM CAROTENOIDS AND INULIN

SHALINI GAUR RUDRA[1,4], PRERNA NATH[2], CHARANJIT KAUR[1] and SANTANU BASU[3]

[1]Division of Food Science and Postharvest Technology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
[2]Horticultural Crops Processing Division, Central Institute of Postharvest Technology, Abohar, Punjab, India
[3]Department of Chemical Engineering and Technology, Panjab University, Chandigarh, India

[4]Corresponding author.
TEL: +91-11-25848428;
FAX: +91-11-25842155;
EMAIL: gaurshalini@gmail.com

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ABSTRACT

Inulin and color imparting carotenoid pigments are candidate functional ingredients for development of a low-fat functional yoghurt. The study evaluates the potential of carotenoid-rich extract from red-capsicum (5%) and different levels of inulin (4, 6 and 8%) on functional and structural properties of low-fat set-yoghurt. Changes in pH, syneresis, sensory and rheological parameters were monitored for 14 days at 6 ± 2C. The variations in sensory acceptability and syneresis were related to rheological properties. Hysteresis area in the flow curve (shear stress–shear rate) increased until 10th day of storage. Inulin fortification significantly reduced syneresis by 59% over control. The time sweep and frequency sweep experiments confirmed stability of protein networks in yoghurt fortified with inulin at high levels. Consistency index of yoghurts was higher for inulin-fortified yoghurts and kept increasing up to 10 days. Results suggest promising applications of natural carotenoids in conjunction with inulin for improving quality of low-fat yoghurt.

PRACTICAL APPLICATIONS

Development of low-fat functional yoghurt enriched with carotenoids from red capsicum. Addition of carotenoid extract had structural destabilizing effect. The effect was mitigated by addition of inulin. Functional yoghurt showed improved sensory profile and storage stability.

INTRODUCTION

Yoghurt is the most nutritious, healthy and popular fermented dairy product widely produced all over the globe by lactic acid coagulation of milk and has health benefits owing to presence of high protein and calcium contents (Smug *et al.* 2014). It is normally produced using skimmed milk as raw material with variable adjustments of fat level (Crispín-Isidro *et al.* 2015), suited to consumer requirements. However in recent past, there is big demand for low-fat variants due to rising risk of cardiovascular diseases, obesity, cancer and diabetes. Therefore, consumers are seeking low-fat variants of yoghurt with accustomed sensory attributes similar to full-fat yoghurts. However, very low fat levels in milk can possibly result in the yoghurts with impaired physicochemical and sensory properties. Inulin has widely been used as a low-calorie, fat and sugar replacing (Rodríguez-García *et al.* 2014), bulking and texturizing agent. When used as fat replacers it improves the perceived creaminess of the yoghurts (Brennan and Tudorica 2008). It is a unique functional food additive due to its prebiotic properties and its physiological features as a soluble dietary fiber (Bernat *et al.* 2014; Karimi *et al.* 2015).

Quite few studies in recent years have focused on improving the functionality of yoghurt using fruit purees for phenolic and dietary fiber enrichment. Food ingredients such as dietary fibers, peach, pomegranate, agave fructans, carrot, citrus fibers are commonly added (McCann *et al.* 2011; Trigueros *et al.* 2014; Crispin-Isidiro *et al.* 2015; Oliveira *et al.*

2015) to yoghurts for enhancing its health benefits. However, no studies are available on use of carotenoid rich vegetable extracts in yoghurt and its effect on rheology and storage stability.

Overwhelming epidemiological evidence indicates the role of dietary carotenoids as antioxidants which demonstrate anti-carcinogenic, anti-inflammatory and anti-allergic functions (Nadeem *et al.* 2011). Red capsicum, among commonly consumed vegetables, has rich bioactive composition; being a rich source of carotenoids, ascorbic acid, phenolics, flavonoids and capsaicin (Nath *et al.* 2016). It is a unique source of oxygenated carotenoids, capsanthin and capsorubin, which are exclusive to this genus and precursors of β-carotene (Deepa *et al.* 2007). Among vegetables, red capsicum has the highest content of total carotenoids (30.37 mg/100 g fw) which far exceeds that of any other preferred sources of vegetable for carotenoids such as carrots (8.0–10.0 mg/100 g) and tomato (4–8 mg/100 g) (Schweiggert *et al.* 2014). Considering its dense carotenoid composition, it is a suitable candidate vegetable for extraction of natural pigments and other bioactives. Enzymatic liquefied aqueous carotene extract from red capsicum (ALECC) was therefore explored for formulation of a functional low-fat yoghurt. However, low pH ALECC has hindering effect on the structure formation of set yoghurt. Therefore, the objective of this study was to evaluate the physicochemical properties, rheological properties of yoghurt fortified with inulin and carotenoid rich extract and to optimize the best concentration of inulin based on its rheological quality, storage behavior and sensory quality.

MATERIALS AND METHODS

Low-fat milk (fat 1.5%, SNF 9%) was procured from Mother Dairy, Delhi. Commercial starter culture (*Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*) for yoghurt preparation was obtained from Chr Hansen, Denmark. Skim milk powder (96% SNF) was obtained from Verka, Punjab, India. Inulin was obtained from Beneo Orafty with inulin $\geq$90% and average DP > 10. Aqueous liquid extract from red capsicum (ALECC, 20°brix) was obtained by concentrating single strength red capsicum juice (8–9°brix) obtained after enzymatic liquefaction (viscozyme, Novozymes) in a vacuum evaporator operating at 30C (Nath *et al.* 2016).

Yoghurt Preparation

Set yoghurt was prepared using double toned milk using procedure outlined in Fig. 1. Treatments included both negative control (set yoghurt made with no ALECC or inulin) and positive control (set yoghurt incorporated with ALECC @5% but no inulin). Set yoghurts with ALECC and inulin at 4, 6 and 8% levels were prepared in triplicates and kept for storage studies. Yoghurt cups from refrigerator (6 ± 2C) were removed from each batch on 0, 4, 7, 10 and 14th day of storage for analysis. The samples were analyzed for pH, acidity, syneresis, sensory and rheological parameters.

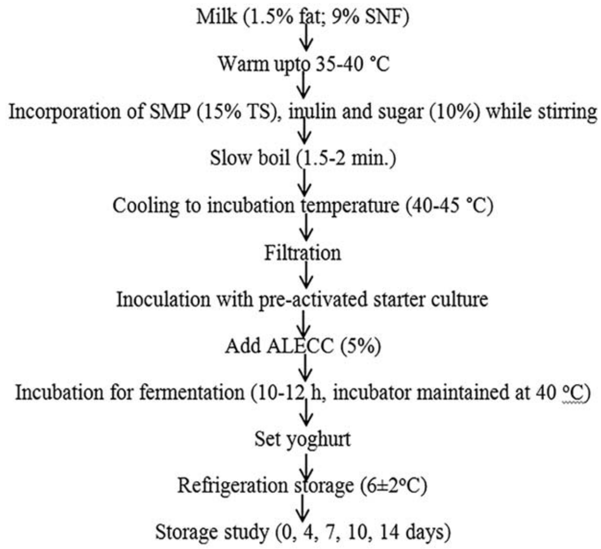

FIG. 1. PROCESSING STEPS IN THE MANUFACTURE OF SET YOGURT IN COMBINATION WITH ALECC AND INULIN

Syneresis, pH and Acidity

Syneresis measurement was done using the method proposed by Keogh and O'Kennedy (1998) with slight modification. Forty gram set yoghurt was centrifuged at 350 × g for 10 min at 4 ± 1C. The clear supernatant was poured off, weighed and expressed as percent weight relative to original weight of yoghurt.

$$\text{Syneresis (\%)} = \frac{\text{Mass of serum}}{\text{Mass of gel}} \times 100$$

The pH of the yogurt samples was measured using pH meter (GeNei, Bangalore, India) at room temperature and titratable acidity as percent lactic acid was determined by the method as described in AOAC (1995). All analysis was carried out in triplicates.

Sensory Analysis

Descriptive sensory analysis was performed by a semi-trained panel comprising of 10 people aged 28–35 years from Division of Food Science and Postharvest Technology, IARI to determine the sensory profiles of reduced-fat functional yoghurts based on descriptors: shininess, surface water, aroma, spoon viscosity, firmness, taste, thickness and mouthfeel. A 9-point hedonic scale was provided to rate the preferences with 0 as not acceptable and 9 as most acceptable.

Rheological Properties

The rheological properties of set yoghurts were measured using Anton Paar dynamic rheometer (MCR-52, Anton Paar, Germany), fitted with cone and plate measuring system (50 mm diameter) at 5C. An equilibration time of 5 min was provided for yoghurt to attain measurement temperature after placing sample between the cone and plate assembly. Shear rate measurements were done in the range of 0.1–100/s with ramp linear profile in triplicate. The flow curves were fitted with a Herschel–Bulkley model through nonlinear regression using Eq. 1 to obtain consistency coefficient (k) and flow behavior rate index (n)

$$\tau = \tau_o + K\dot{\gamma}^n. \qquad (1)$$

Hysteresis area was determined using (i) step up profile: 0.1–50/s shear rate (linear mode); (ii) holding time: 50–50/s; (iii) step down: 50–0.1/s and again (iv) step up: 0.1–50/s. Hysteresis area was computed using Anton Paar software (Rheocompass).

For dynamic rheological tests of the yoghurt, linear viscoelastic region (LVR) was established by conducting a strain test in the range of 0.1–100% at constant frequency of 10 rad/s. Then frequency sweep tests (0.1–100 rad/s) in linear progression were performed at constant strain of 1%, which lies within the linear viscoelastic region (Ciron *et al.* 2011). Cross-over point was computed using Anton Paar software (Rheocompass).

RESULTS AND DISCUSSION

Red capsicum extract obtained from viscozyme treatment (at 0.3%) and vacuum concentrated to 20°B resulted in 85.23 mg/100 mL carotenoids yield. The red capsicum concentrate (ALECC) had pH 4.0, total phenolics (165.67 mg GAE/100 mL) and antioxidant activity expressed as TEAC of 6.12 μmol TE/mL. Being rich in carotenoids capsanthin and capsorubin, this concentrate can be a suitable eco-friendly solution to present method of product development hitch to not only enhance color, but also improved bioactivity of yoghurts (Nath *et al.* 2016). Inulin has been used as fat replacer and thickener in low-fat yoghurts at 2–6% levels (Brennan and Tudorica 2008) besides being a prebiotic which has been reported to have a synergic effect on the fermentation by positively affecting the growth of lactobacilli. Inulin concentration in set yoghurts was kept at levels 4–8% on the basis of preliminary trials at 1–6%, in which observable effect of inulin was found only at levels above 4%. ALECC was incorporated at 5% level on the basis of sensory trials mainly based on color and taste perception.

TABLE 1. PHYSICOCHEMICAL PROPERTIES OF FUNCTIONAL SET YOGHURT DURING REFRIGERATED STORAGE

Inulin (%)	Storage period (days)	pH	Acidity (%)	Syneresis (mL)
Control (−)	0	4.6	0.66	10.0
	4	4.55	0.69	11.6
	7	4.51	0.71	12.4
	10	4.47	0.75	13.0
	14	4.21	0.8	13.5
Control (+)	0	4.35	0.81	10.1
	4	4.23	0.87	11.5
	7	4.18	0.91	12.2
	10	4.1	0.95	13.1
	14	3.9	1.00	13.7
4	0	4.3	0.82	6.2
	4	4.25	0.88	6.5
	7	4.19	0.92	7.0
	10	4.12	0.96	7.5
	14	3.89	1.01	7.8
6	0	4.32	0.85	5.0
	4	4.25	0.89	5.4
	7	4.2	0.93	5.8
	10	4.15	0.98	6.0
	14	3.91	1.02	6.5
8	0	4.34	0.83	4.0
	4	4.24	0.87	4.5
	7	4.2	0.91	4.8
	10	4.14	0.98	5.1
	14	3.9	1.01	5.5

Physicochemical Properties of Yoghurt

The set yoghurts with ALECC at the end of fermentation period had a pH of 4.33 ± 0.02. However the negative control yoghurt, without any inulin or ALECC had higher pH of 4.6. Lower pH in ALECC fortified yoghurts may be mainly attributed to the acidic pH of the ALECC (pH 4.02). During storage, the acidity of the yoghurts continued to increase as fermenting microorganisms continue to produce lactic acid (Table 1). Although the rate of acidification decreased during later phase as lactic acid exerted inhibitory effect on further multiplication of microorganisms (McCann *et al.* 2011). The rate of acidification during storage was 0.01% per day for negative control yoghurt. However ALECC fortified yoghurts' acidification rate was higher (0.0135–0.0149% per day). For inulin fortified yoghurts, the rate of acidification was proportional to concentration up to 6% (0.0149% per day); however, lower acidity and acidification rates were recorded for 8% inulin fortified yoghurts. These trends are in consonance to other researchers (Ramirez-Santiago *et al.* 2010; Shakerian *et al.* 2014) as inulin as soluble polysaccharide exerts beneficial effect on growth of fermenting organisms by serving as their food source. At higher level of 8%, because of inulins' thickening property, there might have been hinderance in transport of metabolites to fermenting cells (Oliveira *et al.* 2009). With increase in levels of added inulin, no significant variation in the pH of functional yoghurts was observed. Besides, the rate of increase of acidity upon storage of yoghurts was also similar.

Syneresis

Water holding capacity of casein network decreases upon storage. The spontaneous whey separation can be attributed to an unstable network, arising due to an increase in rearrangements of the gel matrix or damage to the weak gel network (Lee and Lucey 2010) by lactic acid production during fermentation. The syneresis in yoghurts decreased in proportion to inulin added (Table 1). Compared to positive control, the average syneresis was 42.1% lower in 4% inulin added yoghurts on 14th day of storage, while for 6 and 8% inulin levels, the decrease in syneresis was 52.55 and 59.85%. Incorporation of ALECC also increased syneresis marginally. However, inulin as a polydisperse reserve polysaccharide served to strengthen the network and improved the whey binding capacity of the yoghurts. According to Saberi *et al.* (2014), interaction between casein and inulin leads to co-adsorption of water interface leading to increased electrostatic stability. High molecular weight polysaccharides strengthen the casein network by enhancing charge depletion interactions and immobilizing more protein (Corredig *et al.* 2011). Likewise, inulin polysaccharide surrounding the protein networks aids in rearrangement and relaxation of the protein–protein bonds by binding excess water and provides resistance to yielding of the casein strands (Lucey 2001). Crispin-Isidro *et al.* (2015) have demonstrated through SEM that inulin formed gelled particles outside the protein aggregates acting as fillers leading to enhanced G' and G'' values due to enhanced interactions with caseins.

Sensory Attributes

The sensory acceptance scores were clearly affected by the inulin concentration. Interactions between inulin and textural attributes were significant ($P < 0.01$). Followed by negative control, the most liked yoghurt was 8% inulin incorporated yoghurt owing to better spoon viscosity, firmness and mouthfeel (Fig. 2). Consistently during storage, 6 and 8% inulin added yoghurts were rated better than control. During the descriptive profile analysis, mouthfeel, firmness and spoon viscosity were found to be more predominant factors affecting yoghurts acceptability. Hence it can be concluded that inulin as fat replacer owing to texture

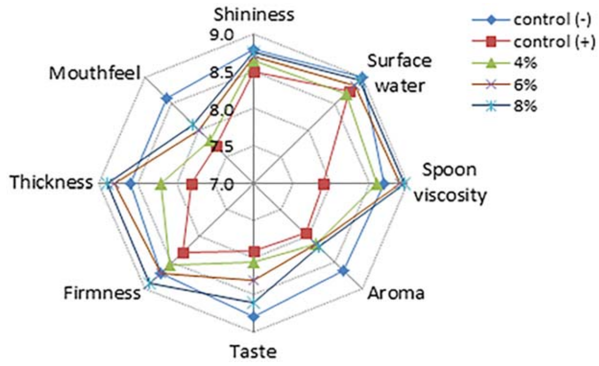

FIG. 2. SENSORY PROFILE OF ALECC YOGHURTS AT VARYING INULIN CONCENTRATIONS

modifying and water binding properties could confer accustomed sensorial properties to low fat ALECC fortified yoghurts by increasing spoon viscosity and contributing to the neatness of cuts by spoon. Owing to higher ratings of firmness, taste, mouthfeel and spoon viscosity, 8% inulin incorporated functional yoghurts were rated the best by the panelists. Higher flavor preference for inulin fortified yoghurts has also previously been reported by several researchers (Brennan and Tudorica 2008; Staffolo *et al.* 2004; Shakerian *et al.* 2014). In an investigation for inulin serving as fat replacer in cheese, Buriti *et al.* (2005) has reported that inulin decreased the perception of residual taste produced by *Lactobacillus paracasei* and improved cheese texture.

Rheological Attributes

For rheological measurements, yoghurt samples were stirred before sample application as consumers usually do before its consumption (Singh and Muthukumarappan 2008). Prior to placing the samples onto parallel plate geometry of rheometer, the yoghurts were preconditioned by setting a resting period of 5 minutes so that the structure disruption during sample handling could be minimized.

Steady State Rheology. The inulin and ALECC fortified yoghurts displayed shear thinning behavior during steady state as expected. Apparent viscosity at 32/s (Staffolo *et al.* 2004) was measured during steady shear rate studies (0–100/s). It can be clearly seen from Table 2, that incorporation of ALECC drastically decreased apparent viscosity of the yoghurts. During storage, the negative control yoghurts exhibited a clear decrease in apparent viscosity during storage. ALECC incorporated yoghurts showed a slight decrease in apparent viscosity until 4 days, while increase of apparent viscosity was observed on seventh day in all cases. This may be attributed to the fact that during initial period of storage,

TABLE 2. APPARENT VISCOSITY, CONSISTENCY INDEX AND FLOW BEHAVIOR INDEX OF ALECC SET YOGHURTS WITH INULIN UPON STORAGE

Inulin (%)	Days	η_{32} (Pa s)	K (Pa s^n)	n	R^2	VE	Hysteresis area (Pa s/mL)
Control (−)	0	28.15	2115.45	0.6190	0.9403	88.41	39986.41
	4	22.50	1966.17	0.8863	0.9014	81.25	20246.95
	7	23.80	1927.83	0.5397	0.9441	89.13	46964.41
	10	17.75	2291.06	0.7632	0.9766	95.38	145800.12
	14	10.00	1718.39	0.7135	0.9523	83.15	85903.79
Control (+)	0	4.50	580.63	0.4679	0.8973	80.52	8426.10
	4	2.75	671.19	0.6478	0.9008	81.15	3271.26
	7	4.18	780.21	0.6825	0.9225	91.23	13226.84
	10	3.22	674.61	0.7533	0.8763	76.79	4677.55
	14	1.97	554.67	0.8511	0.9830	96.63	1966.45
4	0	5.04	581.95	0.4661	0.8981	80.65	9949.26
	4	2.59	1585.64	0.8923	0.8999	82.13	6897.06
	7	4.33	2512.13	0.8555	0.9312	84.67	5345.25
	10	3.24	1536.82	0.8826	0.8435	81.96	4512.66
	14	2.68	1107.05	0.8356	0.9424	92.35	4574.68
6	0	12.1	913.58	0.8231	0.9179	84.26	88883.98
	4	9.50	2702.08	0.6212	0.9221	85.02	27923.55
	7	9.89	2986.21	0.7496	0.8664	75.07	54049.27
	10	5.50	4486.89	0.9002	0.8019	78.12	69089.06
	14	5.10	2928.57	0.8531	0.9534	92.45	22574.76
8	0	21.00	1327.23	0.7575	0.9306	86.59	16087.01
	4	15.50	2705.45	0.6653	0.9388	88.13	38500.25
	7	17.00	2773.56	0.5756	0.8399	70.54	88193.09
	10	11.90	4619.97	0.8347	0.9798	95.99	103887.68
	14	11.00	3154.49	0.7709	0.9883	97.66	682491.78

η_{32} is apparent viscosity at 32/s, K is consistency index and n is flow behavior index. R^2 is coefficient of regression and VE is variance explained.

the structure of protein network is not well established. Similar observations have been reported by Sendra *et al.* (2010), as electrostatic attractions between casein particles are not as high as in aged gels. Further, increase during storage is attributed to stabilization of casein-inulin networks as well as exo-polysaccharide secretion by fermenting microorganisms especially *Lb. bulgaricus*.

Thereafter, decrease in apparent viscosity, indicative of structural breakdown was observed from the 10th day of investigation. This could be because of decrease in exo-polysacharide secretion after 7 days of storage (Purwandari *et al.* 2007) and hydrolysis of exo-polysaccharide (Deegest *et al.* 2002) and inulin by fermenting bacteria as a source of energy Also effect of increased lactic acid concentration in the matrix cannot be ruled out. Similar findings have been reported by Staffolo *et al.* (2004). The decrease of viscosity values after 7 days was sharper in control sample compared to the inulin fortified yoghurt samples.

The set yoghurts displayed a shear thinning behavior with apparent viscosity decreasing with shear rate. The shear strain data was found to fit well with Herschel–Bulkley model which gave a good fit ($R^2 > 0.85$). Flow behavior index as anticipated was always less than 1 indicating shear thinning behavior of all yoghurt samples. For control yoghurts, both with and without ALECC, the consistency index did not show much variation during storage. However for inulin containing yoghurts, increase in consistency index (K) values by up to 4–5 times in direct proportion to inulin levels was observed. Besides, wide variations were recorded during storage. After an initial increase in consistency index, a slight decrease was observed during storage period (Table 2).The initial increase in consistency index can be attributed to stabilization of structure and casein network after initial gel setting. This was however followed by a decrease on seventh day, may be due to increased lactic acid accumulation and subsequent effect on casein network. Though a slight increase in K values was still observed most probably due to exo-polysaccharides secretion by the bacterial strains, a dramatic decrease comparable to K values of control yoghurts was recorded at the end of 14th day. However in case of inulin fortified yoghurts, the η_{32} was almost stable after 10th day of storage, whereas both positive and negative control yoghurts continued to thin during storage. Thus it can be said that inulin was able to resist the effect of lactic acid formation on the casein networks leading to stabilized network upon storage. Flow behavior index values did not show any systematic trend during storage.

Hysteresis Area (HA). Hysteresis loop is assumed to be the difference between the energy required for structural breakdown and rebuilding. In general, greater the hysteresis

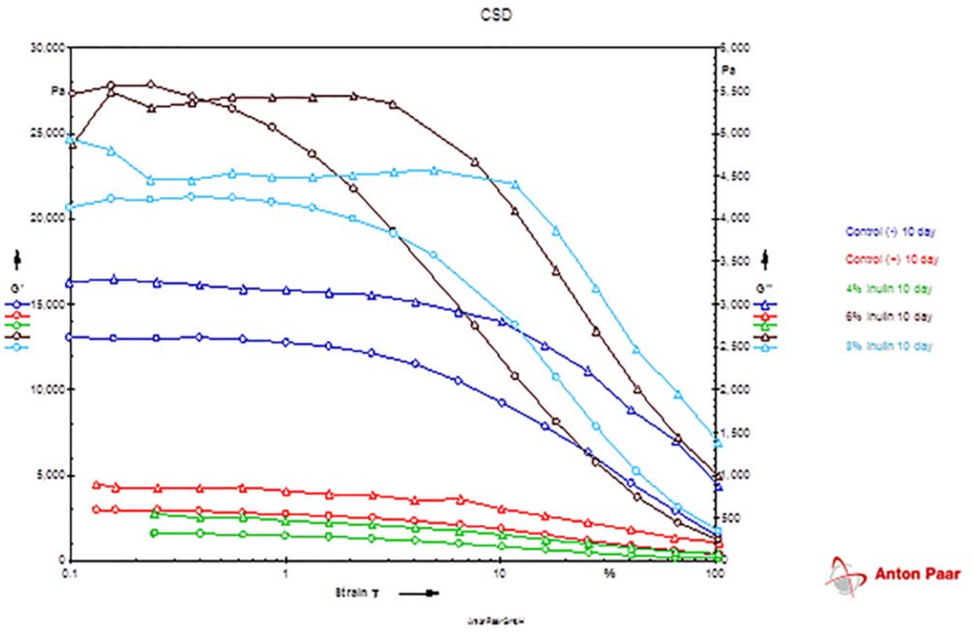

FIG. 3. AMPLITUDE SWEEP CURVES OF SET YOGHURTS ON 10TH DAY OF STORAGE

area better is the structural reversibility of the formed gel (Purwandari *et al.* 2007). Table 1 clearly indicates that during storage, levels of inulin higher than 4% were able to counteract the combined effect of ALECC and lactic acid production on the casein networks. Similar reports have been found in literature (Glibowski and Bochynska 2006) where they hypothesized that at low concentration of inulin, gelation of the whey proteins is inhibited due to the increased viscosity of aqueous phase by inulin. While, higher inulin concentration helps whey protein gelation through enhancing the attraction among proteins as a result of inulin hydration (Karimi *et al.* 2015). Thus shear stress values at a fixed shear rate become higher with increasing inulin concentrations.

However, structural reversibility was depleted after 10th day of storage, probably due to structural breakdown, accumulation of lactic acid along with depletion of inulin. Still the structural elasticity of 14 day stored fortified yoghurt manufactured with 6 and 8% inulin concentration level was

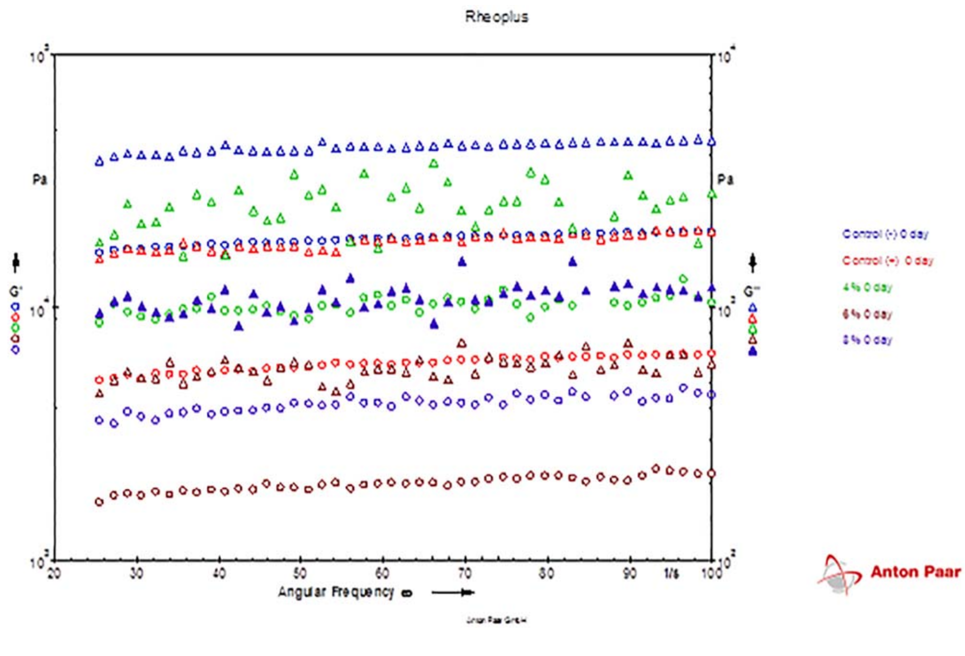

FIG. 4. FREQUENCY SWEEP PROFILE OF FRESH ALECC YOGHURTS

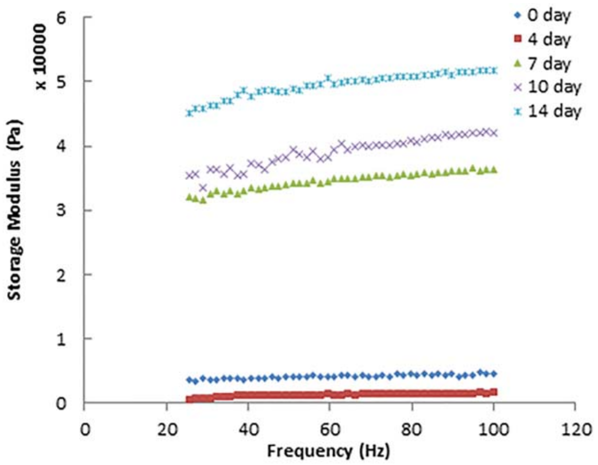

FIG. 5. STORAGE MODULUS OF ALECC FORTIFIED YOGHURT WITH 8% INULIN DURING STORAGE

higher than that of 7 day stored control yoghurt without any additive. Nguyen *et al.* (2015) have also reported a significant decrease in the hysteresis area and consistency coefficient after storage for specified time period along with a significant increase in the flow behavior index ($P < 0.05$).

Amplitude Sweep. The cross-over point (G' and G'') during amplitude sweep has been correlated as an indicator for yoghurt "initial" firmness as perceived by a trained panel (Harte *et al.* 2007). Guggisberg *et al.* (2009) have computed yield stress values using cross-over point in reduced fat yoghurts and found them to be affected by inulin levels. ALECC incorporation in control yoghurt resulted in a decrease of 15% yield stress on zeroth day, with the gap widening to 88% on 10th day, thus strongly indicating the detrimental effect of ALECC over the casein linkages (Fig. 3). Upon incorporation of inulin, yield stress incrementally increased in ALECC containing yoghurts. These findings are in concurrence to other researchers (Sendra *et al.* 2010; MaCann *et al.* 2011). Cross-over point was observed at 1,100, 1,430 and 1,750 Pa for 4, 6 and 8% inulin incorporation levels, respectively. According to Kealy (2006) for semi-solid dairy products, higher yield stresses are generally associated with a thicker, creamier appearance and are therefore suggestive of better product quality. Thus, higher inulin levels yielded creamier yoghurts as evidenced by sensory scores.

Until 10th day, only 6 and 8% inulin incorporated yoghurts retained yield stress or "firmness" equivalence comparable to fresh control yoghurts (1000 Pa). The

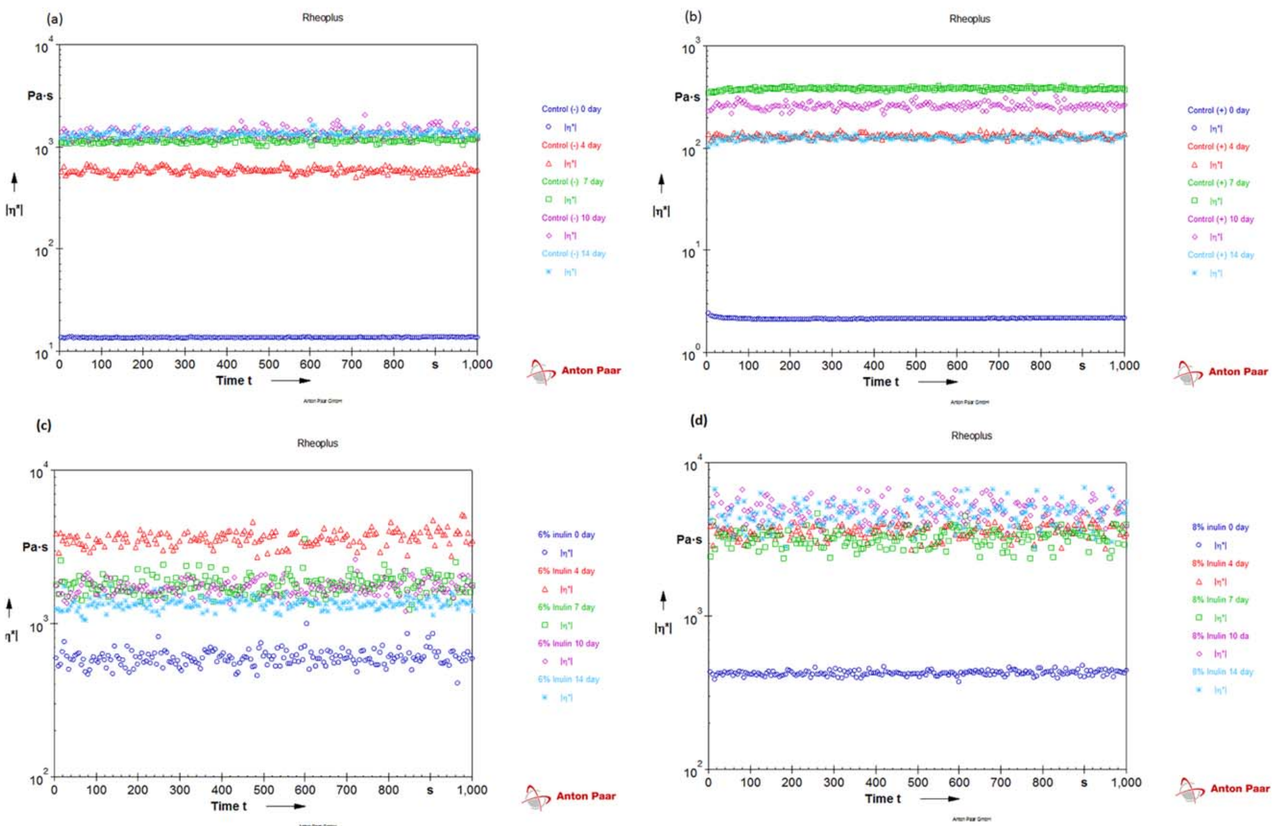

FIG. 6. TIME SWEEP ANALYSIS OF SET YOGHURTS (a) CONTROL (b) ALECC YOGHURT, 0% INULIN; (c) ALECC YOGHURT, 6% INULIN AND (d) ALECC YOGHURT WITH 8% INULIN UPON REFRIGERATED STORAGE UP TO 14 DAYS

amplitude sweep curves of yoghurts on the 10 day stored yoghurts are depicted in Fig. 3. As can be seen, the storage modulus of 6 and 8% inulin fortified ALECC yoghurts are closer or higher than the negative control yoghurt. Incorporation of inulin up to 4% level could not match the viscoelastic characteristics of control yoghurt.

Frequency Sweep. Frequency sweep analysis of the yoghurt samples provided an important insight into the structural organization and stability of gels. The elastic behavior of a sample is represented by G' value which is a measure of the deformation energy stored in the sample during the shear process (Cruz *et al.* 2013). Figure 4 shows the pattern of storage modulus (G') and loss modulus (G'') of yoghurts. Clearly the storage modulus G' values are higher than G'', indicating solid or elastic type behavior. The gap between G' and G'' was found to be less than a decade indicating elastic gel demonstrating typical behavior of a weak gel. The damping factor was found to sequentially decrease for 14 day stored yoghurts with increasing inulin levels from 0 to 8% (0.35, 0.32, 0.26 and 0.11, respectively). Also upon storage of yoghurts, the damping factor was found to increase by 0.58 times for control yoghurt to 2.33 times in 8% inulin fortified yoghurts.

Storage modulus was found to increase with increase in inulin percentage thus indicating its role in formation of reinforced network for casein providing elasticity to the structure. Also during storage, the G' was found to increase during storage for all samples. For 8% inulin incorporated ALECC yoghurts, the storage modulus pattern over storage in depicted in Fig. 5. These findings are in conformity to other researchers (Prasanna *et al.* 2013).

Time Sweep. An isothermal time sweep, with constant frequency and amplitude can indicate structural changes in thixotropic samples (Ramaswamy *et al.* 2015). For control yoghurt, the time sweep experiment revealed increasing values of complex viscosity upon storage as seen in Fig. 6a. The fresh yoghurts' complex viscosity though was comparable to control yoghurt, upon storage for four days, the complex viscosity increased, probably due to strengthening of casein networks followed by their partial disruption due to lactic acid production during further storage as evident from Fig. 6b. The viscosity finally attained after 7 days of storage remained constant upon further storage. Upon inulin incorporation @ 6% in ALECC yoghurts, the complex viscosity values increased up to 4 times (Fig. 6c). Upon storage of 8% inulin fortified yoghurts, the complex viscosity increased upon storage for 4 days but the network disruption due to lactic acid production could not take place as lesser acid was produced in the first place (Fig. 6d) and also inulin was able to compensate for the network strength imparted by casein alone by superimposing itself upon the structures (Corredig *et al.* 2011; Crispin-Isidiro *et al.* 2015).

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