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EFFECT OF MICROFLUIDIZATION ON MANGO FLAVOURED YOGHURT: RHEOLOGICAL PROPERTIES AND pH PARAMETER

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ABSTRACT

Mango flavoured yoghurt was manufactured using milk which was homogenised and micro fluidized at two different pressures (22000 and 15000psi). The main objectives of this study were to enhance the viscosity, gelling and syneresis property of mango flavoured yoghurt by using micro fluidizer at different pressure. The yoghurt samples were analysed for steady state, time dependent and dynamic rheology at three different temperatures 5, 15 and 25°C using MCR 52 Rheometer (Anton Paar, GmbH, Germany) and also effect of pH on the rheological characteristics. Micro fluidized mango flavoured yoghurt showed shear-thinning properties and depicted pseudoplastic behaviour. Rheological data was verified by power law model and the nature of experimental yoghurt was elastic in nature. With increase in temperature, viscosity of micro fluidized mango flavoured yoghurt decreased. Change in pH of micro fluidized mango flavoured yoghurt was negligible when yoghurt milk was subjected to high micro fluidized pressure of 22000Psi. Micro fluidization helps in formation of more complex structure between the small molecules of protein and fat which significantly decreases the water holding capacity of yoghurt and hence prevent syneresis.

Key words: Yoghurt, Micro fluidization, Rheology, pH.

INTRODUCTION

India, the largest milk producing country in the world, (Annual report of NDDB, 2010-11), is having a subtropical climate and during summer temperature reaches as high as 45°C. Growth of non-lactic acid formation bacteria under the harsh climatic conditions turns milk into sour-milk which also shows the defects like coagulation and off-flavour within a short time. Whilst, controlled fermentation of milk can increase the shelf life and can be served by converting it into different fermented products like curd, yoghurt, cheese etc. Yoghurt is easily digestible and highly nutritive milk product which is made by fermentation using bacterial culture: *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*. Yoghurt has multi-nutrient and health-improving properties related to boosting the immune system, increase in high-density lipoprotein-cholesterol and prevention in ulcer (Fabian and Elmadfa, 2006).

Annual per capita consumption of yoghurt in India (2.3kg) is very low with respect to others country like France (25kg), Germany (24kg) and Holland (23kg). Low consumption of yoghurt in India can be attributed to the presence of other dairy products like lassi, Ice-cream etc. Domestic market of Delhi, India has presence of such products like frozen yogurt (Amul Flaavyo), Nestle Real Fruit yogurt (Mango and strawberry flavours) by Nestle, while Mother Dairy's in flavours such as mango, blueberry, raspberry, and plum. Texture of yoghurt depends on heat treatment and homogenization of the milk at different pressure (Ciron et al., 2010). One of the major factors for determining the texture of yoghurt is milk protein. Basically mango pulp and pectin (2g) are used during manufacture of mango flavour yoghurt. In this study mango powder and pectin (0.2%) were used for the manufacture of mango flavoured yoghurt and was studied for attributes like pH, structure of fat globule of homogenized milk and rheology at different microfluidization pressure.

Microfluidized milk gives equal and continuous homogenization of fat globules in milk and formation of strong gel network of protein and fat during yoghurt formation (Ciron *et.al.,* 2012). Many researchers have modified the milk protein and used it as fat replacer substance (Seydim et al., 2005). A large number of small fat globules and peptides are obtained through microfluidization of milk and which are attached with enhancer and gives strong network of gel during yoghurt manufacturing (Augustin *et.al.,* 2007). The main objectives of this study was to enhance the viscous, gel and synersis property of mango flavoured yoghurt by using microfluidizer at different pressure.

MATERIALS AND METHODS

MATERIALS

Commercially homogenized mango flavoured yoghurt was obtained from local market of Delhi, India. Spray dried mango powder, pectin and sugar (99.92%, w/w, sucrose) was purchased from the local market which was used to manufacture microfluidized mango flavoured yoghurt. Yoghurt culture consisting of a mixed strain of *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus* was procured from CHR-Hansen, India. Commercial mango flavoured yoghurt was manufactured by using homogenized milk and referred as Homogenized Pressure (HP) sample in this article.

PREPARATION OF MANGO FLAVOURED YOGHURT

Microfluidized yoghurt was manufactured by inoculating microfluidized mango flavoured milk by combination of equal amount of *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus* (1:1) at two different pressures 22,000Psi and 15,000Psi and will be referred as MP1 and MP2 respectively and incubated at 42 ± 1°C for 4-5 hours (Rahman *et.al.*, 1999) in the incubator (SSS-10, Scientific Sales Syndicate, India). After attending a pH of 4.6 the cups were cooled immediately to 8 ± 1°C (Pourahmad *et.al.*, 2005). There after curdling was observed and the product was tested for acidity by pH meter (LP-01, LABINDIA, pH analyser). 100g of sample was then packaged into 200ml sterile propylene cups with caps (Prudential Enterprises, India) for rheological measurements and 400g into 1lit sterile pots for sensory evaluation. All samples were prepared in duplicate, stored in a refrigerator (7 ± 1°C), and were also analyzed after 7 days of storage.

RHEOLOGICAL ANALYSIS

The rheological characteristics of commercially homogenized mango flavoured yoghurt (HP) and Microfluidized mango flavoured yoghurts (MP1 and MP2) were analyzed in duplicate at three different temperatures 5, 15 and 25°C with the help of MCR 52 Rheometer (Anton Paar, GmbH, Germany). The Steady State Rheology, Time Dependency and Dynamic Rheology of homogenized and experimental sample was analyzed with 50mm diameter parallel plate geometry (PP50) and Dynamic Rheology was carried out with 27mm inner diameter concentric cylinder geometry (CC27).

STEADY STATE RHEOLOGY

STEADY STATE RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED MILK

Steady state rheology of microfluidized milk and homogenized milk, viscous was determined within a range of shear rate from 1-1000s^{-1}. The rheological behaviour of all the samples was determined using the concentric cylinder geometry. The shear stress as a function of shear rate were continuously analysed during the test. In addition, the influence of temperature (25°C) on rheological behaviour of different samples was also studied. All rheological measurements were performed in duplicate.

STEADY STATE RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED YOGHURT

Measurements of Steady State Rheology for homogenized sample of mango flavoured yoghurts (HP) and Microfluidized mango flavoured yoghurts with different pressures MP1 and MP2 were carried out at three different temperatures 5, 15 and 25°C by using the parallel plate (PP50) geometry, the range of shear rate were applied from 0.1 to 100s^{-1} and obtained a relationship between shear rate Vs shear stress (τ) and shear rate Vs apparent viscosity (η). After getting experiment data of Steady State Rheology flow curves are verified with the help of Power law model.

TIME DEPENDENT RHEOLOGY

Measurements of time dependency for HP and MP1 and MP2 were carried out at three different temperatures 5, 15 and 25°C by using the parallel plate (PP50) geometry. Time dependency was carried out for 300s at constant shear rate 10s^{-1}. When sample was loaded over plate it was allowed to rest for 10min. to reach the desired temperature before the analysis was carried out.

DYNAMIC RHEOLOGY

DYNAMIC RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED MANGO FLAVOURED YOGHURTS

To determine the dynamic rheology of HP, MP1 and MP2, elastic property of yoghurt sample was determined within a range of strain sweep from 0.1-100% at a constant angular frequency (ω) 10rad/s. The linear viscoelastic range was determined using the parallel plate (PP50) geometry. The linear viscoelastic range is the range in which yoghurt shows a parallel straight line between G′ and G″ at some range of percentage of strain. In addition, the influence of temperature (25°C) on G′ and G″ values of different samples was also studied. All rheological measurements were performed in duplicate.

pH ANALYSIS

The pH of different mango flavoured yoghurts was determined in duplicate by using pH meter (LP-01, LABINDIA, pH analyser).

RESULTS AND DISCUSSION

RHEOLOGICAL MEASUREMENTS

STEADY STATE RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED MILK

Homogenized milk and microfluidized milk showed pseudoplastic nature through steady state rheology. Viscosity decreased with increasing shear rate from 1-1000s^{-1}. Hence it showed shear thinning behaviour in nature. Viscosity of microfluidized milk (MP1) was more with respect to microfluidized milk (MP2) and homogenized milk (HP) samples as shown in (Fig-1). The reason may be due to the adhering of small protein molecules on the surface of fat globules of high pressurized microfluidized milk and finally forming complex structure of microfluidized milk. This was compatible with the result of (Creamer et al., 2003) who observed similar effect.

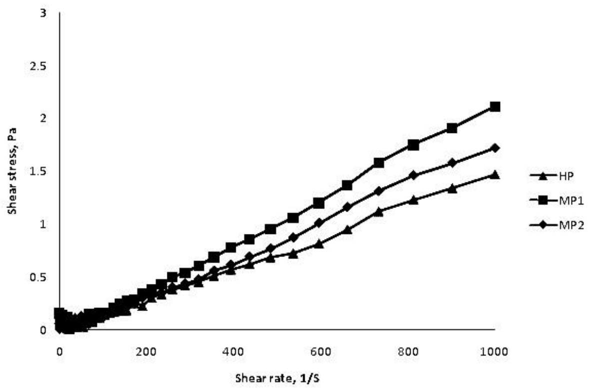

Figure 1- Rheogram of different homogenized milk at 25^{0}C temperature

STEADY STATE RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED YOGHURT

Homogenized mango flavoured yoghurts showed shear thinning behaviour through steady state rheology. All samples showed pseudoplastic nature as earlier described by (Ciron *et.al.,* 2011). At each and every shear rate have different shear stress (Fig.2-4). MP1 had more viscous and yield stress with respect to MP2 and HP sample at all three different temperatures 5, 15 and 25^{o}C (Fig-2-4). At high microfluidized pressure size of fat globules and proteins are reduce in very small size with respect to low microfluidized pressure because the small fat globules are tightly adhered with the protein matrix and forming highly compact structure (Schultz *et.al.,* 2004). In the experimental sample when temperature was increased from 5 to 25^{o}C then viscosity decreased and this similar pattern followed in all three samples HP, MP1 and MP2 samples as shown in (Fig-5-7). Viscosity continuously decreased with increasing temperatures at particular shear rate (100s^{-1}) as shown in (Fig-8).

The shear thinning behaviour of mango flavoured yoghurt was well described by Power law model. This similar type of shear thinning property and power law model was comparable to rheology of non-fat yoghurt (Hess et al., 2004). A Power-law is a mathematical relationship between shear rate and shear stress which described the behaviour of yoghurt.

Shear Stress = K (Shear Rate)^n

Where,

K = Flow Consistency constant (Pa$_*$s^n)

n = Flow Behaviour Index (Dimensionless).

The different parameters (Consistency constant, K and Flow behaviour index, n) of power law model at temperatures 5, 15 and 25^{o}C are mentioned in (Table 1). Value of K decreased with increasing temperatures (Fig-9) but value of flow behaviour index (n) was not following any particular trend.

Table 1- Power law parameters for homogenized and micro fluidized mango flavoured yoghurts

Sample	T (^{o}C)	*K (Pa.S^n)*	*n*
	5	22.66338	0.13
HP	15	12.56154	0.32
	25	8.1288	0.26
	5	67.75015	0.18
MP1	15	47.30949	0.57
	25	22.66338	0.47
	5	61.19219	0.12
MP2	15	46.87153	0.36
	25	10.13291	0.37

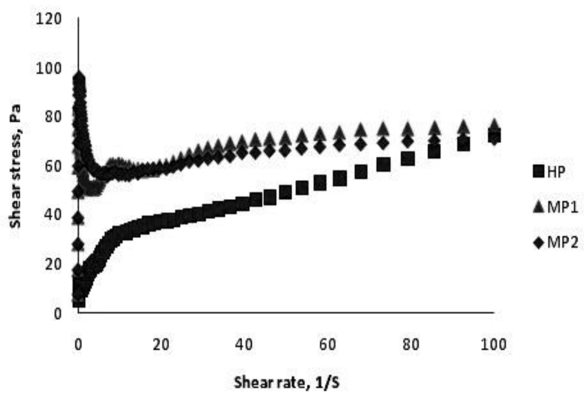

Figure 2- Rheogram of different homogenized yoghurt at 5^{0}C temperature

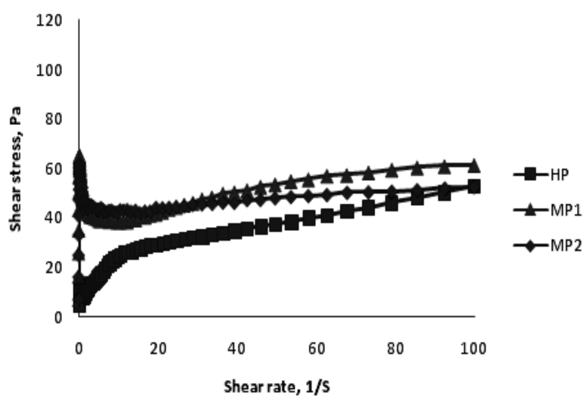

Figure 3- Rheogram of different homogenized milk at 15^{0}C temperature

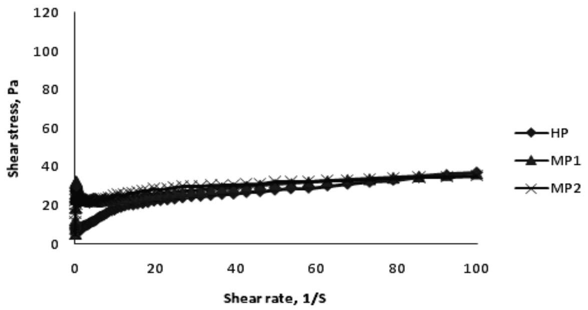

Figure 4-Rheogram of different homogenized yoghurt at 25^{0}C temperature

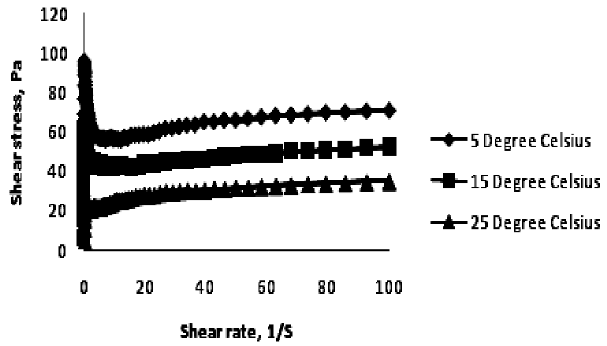

Figure 5- ***Rheogram of microfluidized (MP2) yoghurt at different temperatures***

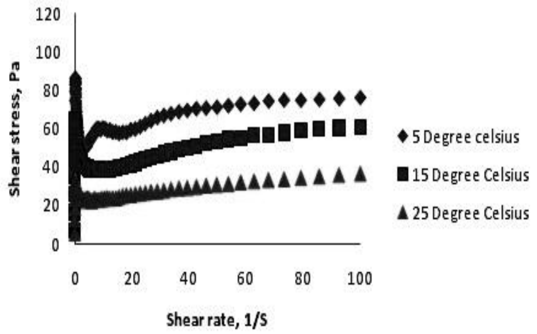

Figure 6- Rheogram of microfluidized (MP1) yoghurt at different temperatures

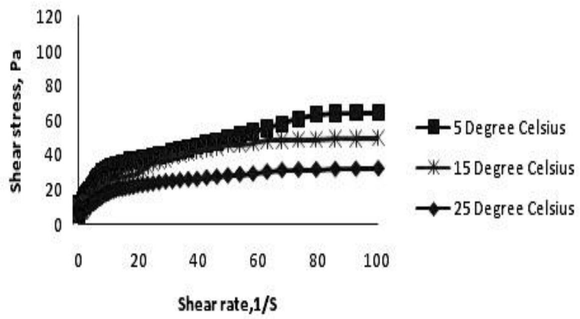

Figure 7- Rheogram of homogenized (HP) yoghurt at different temperatures

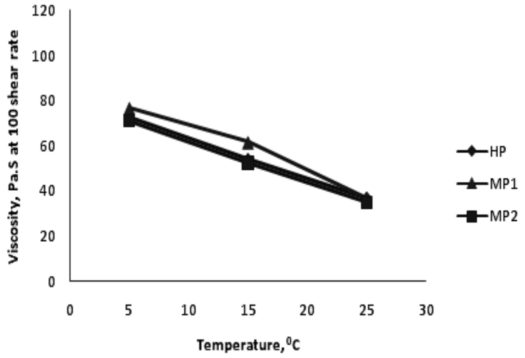

Figure 8- Rheogram of different homogenized yoghurt at 100 Shear rates (s^{-1})

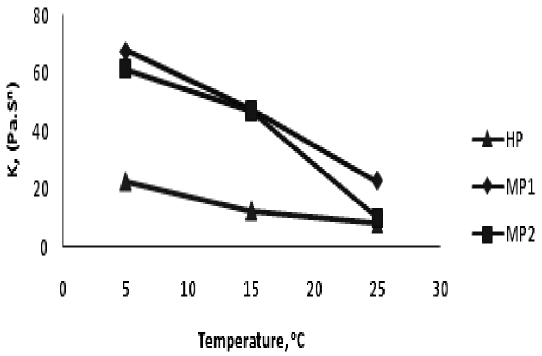

Figure 9- K value of homogenized and micro fluidized yoghurts as function of different temperatures

TIME DEPENDENT RHEOLOGY OF HOMOGENIZED AND MICROFLUIDIZED YOGHURT

The apparent viscosity of homogenized (HP) and microfluidized (MP1 and MP2) mango flavoured yoghurt as a function of time at different temperatures 5, 15 and 25^{o}C with constant shear rate 10s^{-1} as shown in (Fig-10-12). The results are in total agreement with the time dependent viscosity of mango flavoured yoghurt as described earlier by (Donnell et al., 2001). The apparent viscosity of all three samples decreased rapidly with time within the first 80s of shearing time and reached a constant value corresponding to an equilibrium state after 80s (Fig-10-12). The initial apparent viscosity of microfluidized yoghurt (MP1) had maximum value with respect to microfluidized (MP2) and homogenized (HP) yoghurt at different temperatures 5, 15, and 25^{o}C as shown in (Fig.10-12). In another study the initial apparent viscosity decreased with increase in temperature from 5 to 25^{o}C at constant shear rate 10s^{-1} in all three samples (Fig-13-15). The extent of reduction in viscosity of homogenized and microfluidized yoghurt samples may be depending on interaction of protein-fat molecules. This similar result was described earlier by (Abu-Jdayil, 2002).

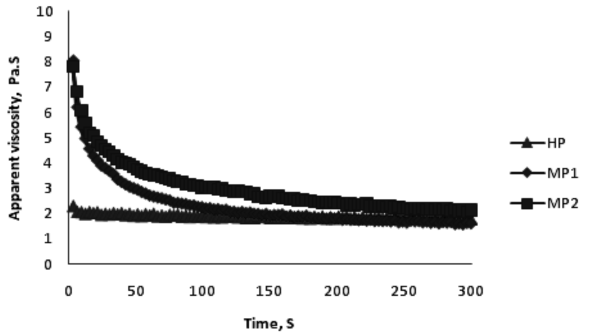

Figure 10- Apparent viscosity of yoghurt as function of time at 5^{0}C temperature

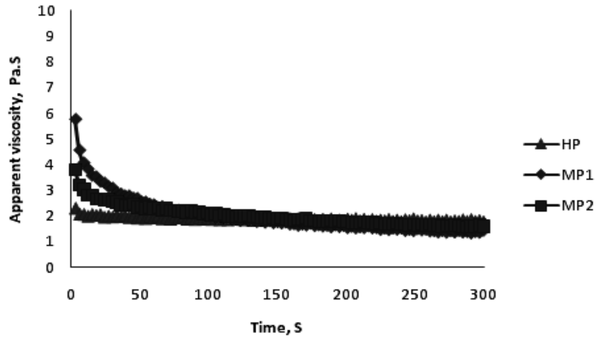

Figure 11- Apparent viscosity of yoghurt as function of time at 15^{0}C temperature

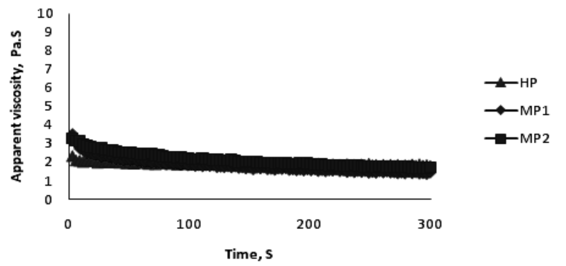

Figure 12-Apparent viscosity of yoghurt as function of time at 25^{0}C temperature

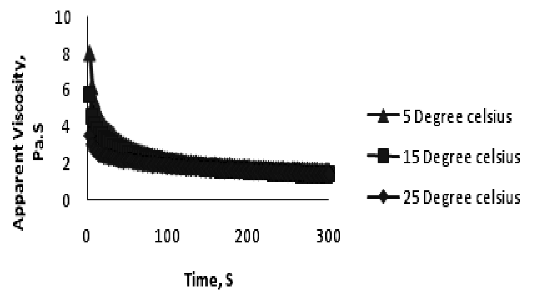

Figure 13- Apparent viscosity of micro fluidized (MP1) yoghurt as function of time at different temperatures

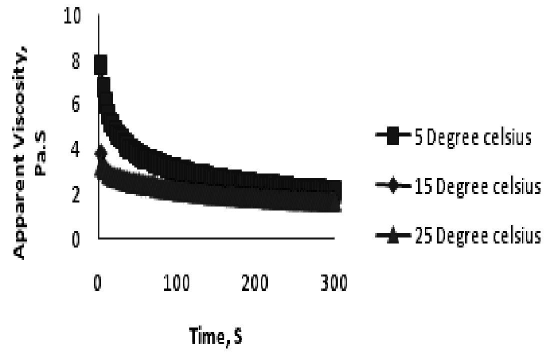

Figure 14- Apparent viscosity of micro fluidized (MP2) yoghurt as function of time at different temperatures

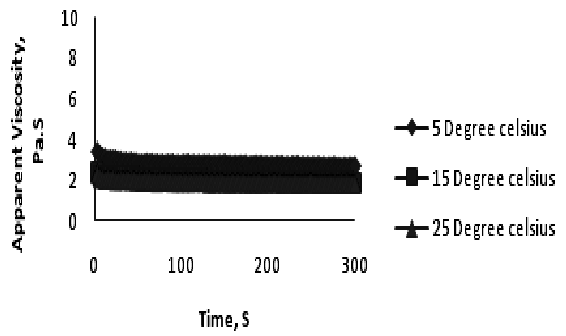

Figure 15-App. viscosity of homogenized (HP) yoghurt as function of time at different temperatures

DYNAMIC RHEOLOGY

Dynamic strain sweep was used to study the strain dependency of elastic and viscous module with Linear Viscous Region (LVR) for the experimental and homogenized sample. Elastic module and viscous module of homogenized (HP) and different microfluidized (MP1 and MP2) mango flavoured yoghurt samples was plotted against a wide range of 0.1 to 100 % strain (Fig. 16). It was found that the elastic module was slightly higher than viscous module in all three samples (HP, MP1 and MP2) and confirming the elastic nature of mango flavoured yoghurt. The range of Linear Visco-Elastic was exhibited between 0.48 to 1.18 % strains. MP1 mango flavoured yoghurt had more elastic (G′) and viscous module (G″) as compared to microfluidized (MP2) and homogenized (HP) mango flavoured yoghurt (Fig. 16) and was in full agreement with the observations of Ciron *et al*. (2011).

The reason would be due to the formation of complex structure in high microfluidized yoghurt by the interaction of small milk protein and fat molecules. Due to processing at high pressure, large milk fat globules are broken down into very small size and are tightly bounded with small molecules of milk protein under the influence of hydrophobicity of outer surface of fat globules which in turn forms a very complex elastic gel like structure and was compatible with the results of Ciron *et al.* (2012).

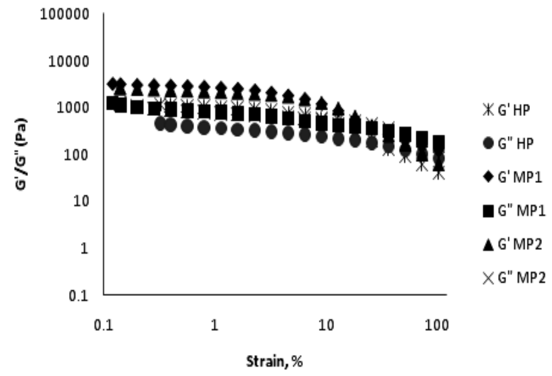

Figure 16-Dynamic Rheogram of different micro fluidized and homogenized mango flavoured yoghurt as function of strain (%) at constant angular frequency (10rad/s)

pH ANALYSIS

The pH of freshly prepared yoghurt was about 4.6 (Serra *et al.*, 2007 and Nazni *et.al.*, 2014). In this study pH of mango flavoured yoghurt was decreased with increasing pressure as discussed earlier by (Patterson, 2005, Nazni *et.al.*, 2014) (Fig-17). Changes in pH during storage analysis were mentioned in (Table 2). pH was varied during processing of mango flavoured yoghurt. The change in pH was occurred due to the action of active enzyme (lipoprotein lipase) (Walstra et al., 1999). After stage of about 2 days at a refrigerated temperature there were no significant changes in pH of all samples.

Table 2-Comparison of pH of mango flavoured yoghurt prepared by homogenized and micro fluidized process

Sample	pH at the time of manufacturing	pH after 2 days of manufacturing
HP	4.56	4.54
MP1	4.32	4.3
MP2	4.47	4.4

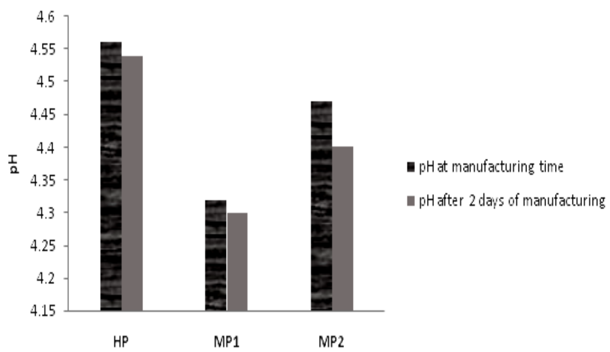

Figure 17- Effect of pressure on pH of homogenized and micro fluidized mango flavoured yoghurt

CONCLUSION

Microfluidized mango flavoured had shear-thinning properties and it also retained pseudoplastic behaviour. The experimental rheological data was verified by power law model and the nature of microfluidized yoghurt was elastic in nature which may be attributed to microstructure of milk protein and fat molecules. Viscosity of microfluidized mango flavoured yoghurt was found to decrease with increase in temperature. Change in pH of microfluidized mango flavoured yoghurt was observed to be significantly negligible when yoghurt milk is subjected to high microfluidized pressure (MP1). Microfluidization helps in formation of more complex structure between the small molecules of protein and fat which can significantly decrease the water holding capacity of yoghurt and prevent syneresis. This was compatible with the observation reported made by Serra *et al.* (2007) in case of plain yoghurt.

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