

## INFLUENCE OF PARTIALLY HYDROLYZED GUAR GUM AS SOLUBLE FIBER ON PHYSICOCHEMICAL, TEXTURAL AND SENSORY CHARACTERISTICS OF YOGHURT

Deepak Mudgil\*

Address(es):

Department of Dairy and Food Technology, Mansinhbhai Institute of Dairy and Food Technology, Mehsana, Gujarat-384002, India.

\*Corresponding author: [dsmudgil@yahoo.com](mailto:dsmudgil@yahoo.com)

doi: 10.15414/jmbfs.2018.8.2.794-797

### ARTICLE INFO

Received 17. 6. 2018  
Revised 22. 8. 2018  
Accepted 28. 8. 2018  
Published 1. 10. 2018

Regular article



### ABSTRACT

The effect of partially hydrolyzed guar gum fortification on physicochemical, textural and sensory characteristics of yoghurt was investigated. Fiber fortification was done at 1-5% levels to study the effect of soluble fiber fortification on the quality of yoghurt. Fiber addition significantly influenced the textural characteristics of yoghurt such as hardness, adhesiveness, cohesiveness, springiness and gumminess ( $p < 0.05$ ). Water holding capacity and viscosity was highest in yoghurt sample with 3% fiber while syneresis was lowest for the sample ( $p < 0.05$ ). The viscosity of the yoghurt samples increased with the fiber addition upto 3% level fortification, thereafter it decreased ( $p < 0.05$ ). Inclusion of soluble dietary fiber at 3% level in milk produced yoghurt with improved texture, physicochemical, higher nutritive value and desirable sensory characteristics.

**Keywords:** soluble fiber; syneresis; yoghurt; texture; sensory

### INTRODUCTION

Yoghurt also known as *Dahi* in India is well known fermented dairy product in the Indian sub-continent and forms an important part in Indian diet. Yoghurt is known with different names in different countries such as *Leben* (Iran), *Jugurt* (Turkey), *Roba* (Iraq), *Shosim* (Nepal) etc (Tamime and Robinson, 2007). Yoghurt is so popular in India that a meal is considered incomplete without consuming it towards the end of the meal. In southern parts of India, yoghurt is eaten with rice and is popularly known as curd rice and is used to prepare several culinary dishes. The beneficial aspects of yoghurt and other fermented dairy products are well documented in the literature (Yadav *et al.*, 2008; Bhat and Bhat, 2011). Few lactobacilli were also isolated from yoghurt which produced bacteriocins effective against human pathogens (Bhattacharay and Das, 2010). Thus, the therapeutic properties of yoghurt are well known, hence yoghurt is used in several of Ayurvedic formulations which is a traditional Indian medicinal system (Devi *et al.*, 2010). Yoghurt is prepared from buffalo milk as well as cow milk. Yoghurt prepared from buffalo milk is white in colour and possesses firm body and slightly granular texture, whereas yoghurt prepared from cow milk is less firm and smooth in texture. Hence mixed milk is generally used for making yoghurt. These differences in final product quality are attributed to inherent variations in the protein make up of both the milks (Aneja *et al.*, 1965). The organized sector dairies are major players in yoghurt market. It is estimated that 6.9% of total milk produced in India is utilized for yoghurt making in India (Tamime and Robinson, 2007). Yoghurt is also used as a vehicle to incorporate probiotics into the health conscious consumers because of the fact that it is consumed by people daily (Yadav *et al.*, 2008).

Yoghurt is good source of calcium, phosphorus, vitamin B<sub>2</sub>, vitamin B<sub>12</sub>, pantothenic acid-vitamin B<sub>5</sub>, zinc, potassium, protein, iodine and molybdenum. All these nutrients make yoghurt a nutritious and health-supportive food. Yoghurt has been attributed nutraceutical, therapeutic and probiotic effects, such as digestion enhancement, immune system boosting, anti-carcinogenic activity and reduction in serum cholesterol. Yoghurt is deficient in iron, vitamin C & dietary fiber like milk and milk products.

Ever-growing consumer demand for convenience, combined with a healthy diet and preference for natural ingredients has led to a growth in functional beverage markets. Yoghurt is considered a healthy food and incorporating dietary fiber will make it even healthier. In the present study, soluble dietary fiber fortification of yoghurt was carried out to make it a complete food. The beneficial role of dietary fiber in human nutrition has led to a growing demand for incorporation of novel fiber into foods (Mudgil and Barak, 2013). There is little information about fiber fortification in cultured dairy products. Various fibers like psyllium, guar

gum, gum acacia, oat fiber and soy components can be used for fiber fortification in yoghurt. A lot of research work has been carried out on soluble fiber fortification of bakery products, processed foods, beverages etc, but research on fiber fortification in yoghurt is very limited. However, the effect of dietary fiber on *Misti Dahi* quality is reported in literature (Raju and Pal, 2014). Partially hydrolyzed guar gum is a low viscosity water soluble product which can be prepared by enzymatic hydrolysis of native guar gum (Mudgil *et al.*, 2014). Partially hydrolyzed guar gum contains magnificent amount of soluble fiber (Mudgil *et al.*, 2012a; Mudgil *et al.*, 2012b). Native guar gum is generally used as stabilizer and thickener in various food products such as tomato ketchup, ice cream, beverages etc (Mudgil *et al.*, 2011). Partially hydrolyzed guar gum is low molecular weight galactomannan having low viscosity, colorless, tasteless, odorless in nature and hence do not affect the product characteristics (Mudgil *et al.*, 2016a; Mudgil *et al.*, 2016b; Mudgil *et al.*, 2016c; Mudgil *et al.*, 2016d; Mudgil *et al.*, 2018). In present study, partially hydrolyzed guar gum was selected for soluble fiber fortification of yoghurt and its effect on the physicochemical, textural and sensory characteristics of yoghurt.

### MATERIALS AND METHODS

#### Raw materials and ingredients

Pasteurized standardized milk with 4.5% fat and 8.5% SNF was procured from Dudhsagar Dairy, Mehsana, India and stored in refrigerated conditions until use. A freeze-dried direct vat set (DVS) yogurt culture (RST-744 & CHN-11) containing a mixed strain of thermophilic and mesophilic homofermentative bacterial culture was obtained from Chr. Hansen Inc. (Milwaukee, WI). The culture was stored at -18°C until use. Partially hydrolyzed guar gum which is an enzymatically hydrolyzed guar gum with low viscosity was procured from Lucid Colloids Ltd., India.

#### Preparation of yoghurt

Control yoghurt sample was prepared using pasteurized standardized milk of 4.5 % fat and 8.5% SNF. The milk was heated to 42 °C on a bench-top stirring hot plate (Nova Instruments Pvt. Ltd.). Milk was inoculated with RST-744 (0.1 unit/litre) & CHN-11 (0.01 unit/litre) culture blend and mixed thoroughly in the milk. The milk was transferred to 50 ml, 100 ml & 250 ml cups with lids (Fig.1). The samples were incubated at 42 °C in incubator (Patel Instruments Ltd, India) for 7 hrs. For fiber fortified yoghurt, soluble dietary fiber was added to the standardised milk at 1-5% levels. To allow good dispersion of the fiber in milk,

the fiber was sprinkled in vortex of milk using laboratory stirrer at 800 rpm. The milk was processed further similarly as control yoghurt. After incubation, yoghurts were immediately cooled in an ice water bath and stored at 10°C for 16 h. All the yoghurts were prepared in triplicate and the results were expressed as mean.

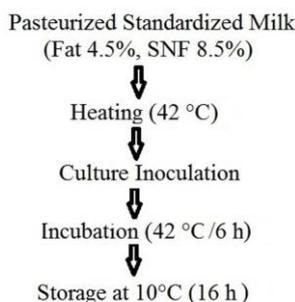


Figure 1 Process for preparation of yoghurt

**Titrateable acidity and pH**

The titrateable acidity values of yoghurt samples were determined after mixing 10 g of yoghurt sample with 10 ml of hot distilled water (90°C). Phenolphthalein was used as an indicator. The mixture was then titrated with 0.1 N NaOH to an end point of just appearance of faint pink color. pH of yoghurt samples were measured using glass electrode digital pH meter. All the measurements were made in triplicate and the results were expressed as mean.

**Syneresis**

Syneresis in yoghurt samples was determined using drainage method as described by Chawla and Balachandran (1994) with slight modifications. In present study, after about 16 h of storage under refrigeration, the set yoghurt cups were taken out and tempered at 25°C for 2 h. The contents of the yoghurt cups were loosened with the help of a spatula from the sides and directly emptied into a glass funnel with a Whatman No.1 filter paper. The funnel was placed on a graduated glass cylinder (17×2.5 cm) of 50 ml capacity. The funnel with cylinder was kept in a room maintained at 25°C. The quantity of whey collected in graduated glass cylinder after 2 h of drainage was measured and considered as syneresis, expressed as percent whey separated.

**Viscosity**

Apparent viscosity (expressed in cPs) of yoghurt samples were measured using viscometer (Brookfield, USA). Viscometer was auto zeroed in the air after fixing the spindle (ASTM Disk Spindle S-62 at room temperature). Yoghurt samples were tempered to 20°C and stirred gently 20 times in clockwise and anticlockwise direction using a spatula and filled into a beaker for measuring the viscosity. The spindle S-62 was selected for viscosity measurement of yoghurt based on the instructions described in supplier’s instruction manual. The viscosity of stirred yoghurt samples was measured at 5 rpm, after starting rotation and results were expressed in cPs. Apparent viscosity reading was recorded after 60 seconds rotation of the spindle. Viscosity was measured for each sample in triplicate and the results were expressed as mean.

**Water holding capacity**

The water holding capacity of yoghurt samples was determined using a modified method as reported by Sodini et al. (2004). Ten grams of yoghurt samples were taken in centrifuge tubes and then centrifuged at 1,250 × g for 10 min at 5°C in a refrigerated high-speed centrifuge (Remi Centrifuge, Mumbai). The amount of whey expelled (g) during centrifugation (W) was weighed, and WHC calculated as follows: WHC (%) = (10 – W)/10 × 100. The measurement was carried out in triplicate and the results were expressed as mean.

**Texture profile analysis of yoghurt**

Yoghurts were analyzed for textural characteristics such as hardness, adhesiveness, cohesiveness, springiness and gumminess. Texture Profile Analysis (TPA) was carried out using Texture Analyzer, TA-XT2i (Stable Micro Systems, Surrey, UK). The texture profile analysis was analyzed by performing two sequential compressions using a flat-end cylindrical plunger (25-mm probe) separated by a rest phase of 30 s that generated plot of force versus time. Samples were compressed upto 70% of their original length. Crosshead speeds of 4.0, 1.0 and 1.0 mm/s were maintained for pretest, test and post test settings, respectively. The speed of obtaining the data was 200 pps. Five independent observations were made. Hardness, adhesiveness, cohesiveness, springiness and gumminess values

were calculated from the obtained profiles using the software provided by Stable Microsystems.

**Sensory evaluation**

Sensory evaluation of control yoghurt and fiber fortified yoghurt was done using 9-point Hedonic scale. 25 panelists were selected on the basis of their previous experience and knowledge of sensory evaluation of dairy and dairy-associated products. Color and appearance, body & texture, flavor and overall acceptability were evaluated by panel. All samples were removed from the refrigerator 1 h before the beginning of every evaluation session. Serving temperature range for samples was 10 to 12°C. Each yoghurt was presented in a 100-g plastic cup fitted with lid and labelled with a 3-digit code. Order of presentation of samples was randomized. Water and expectoration cups were also presented to each panelist to rinse their mouths between samples. Evaluation was divided into 3 sections: visual, texture, and flavor evaluations. For visual attributes, the surface of each yoghurt was examined in terms of free whey. After that, texture and flavor evaluations were conducted.

**Statistical analysis**

The experimental data collected was analyzed for significant differences with the help of analysis of variance (ANOVA) conducted using SPSS 16.0 software.

**RESULTS AND DISCUSSION**

**Titrateable acidity and pH**

Titrateable acidity of control and fiber fortified yoghurt ranged between 0.76-0.78 (% lactic acid) as presented in Table 1. Titrateable acidity of yoghurt showed an increasing trend with increase in level of fiber fortification. pH of yoghurt samples ranged from 4.40 to 4.43. The results of titrateable acidity and pH showed no significant changes in control yoghurt and fiber fortified yoghurts. However, slight increase in the titrateable acidity and lower pH values could be attributed to enhanced levels of lactic acid development in yoghurt samples. The results were in concordance with the study reported in literature (Hashim et al., 2009).

Table 1 Physicochemical properties of control and fiber fortified yoghurt

Dahi	Titrateable Acidity (%)	pH	WHC (%)	Syneresis (ml/50 g)	Viscosity (S-62, 5 rpm, 20°C)
Control	0.76±0.02 <sup>a</sup>	4.43±0.04 <sup>a</sup>	43.07±0.03 <sup>b</sup>	26±0.5 <sup>d</sup>	982±35 <sup>a</sup>
Y <sub>1</sub>	0.76±0.02 <sup>a</sup>	4.43±0.02 <sup>a</sup>	44.54±0.06 <sup>c</sup>	22±0.3 <sup>c</sup>	1590±25 <sup>d</sup>
Y <sub>2</sub>	0.76±0.03 <sup>a</sup>	4.42±0.05 <sup>a</sup>	45.02±0.04 <sup>d</sup>	20±0.3 <sup>b</sup>	1872±20 <sup>e</sup>
Y <sub>3</sub>	0.76±0.02 <sup>a</sup>	4.41±0.04 <sup>a</sup>	53.73±0.05 <sup>f</sup>	18±0.5 <sup>a</sup>	2191±35 <sup>f</sup>
Y <sub>4</sub>	0.77±0.04 <sup>a</sup>	4.41±0.03 <sup>a</sup>	48.30±0.03 <sup>e</sup>	20±0.4 <sup>b</sup>	1555±25 <sup>c</sup>
Y <sub>5</sub>	0.78±0.03 <sup>a</sup>	4.40±0.05 <sup>a</sup>	39.98±0.04 <sup>a</sup>	31±0.3 <sup>e</sup>	1238±40 <sup>b</sup>

Values are mean ±S.D. of determinations made in triplicate. The values followed by different superscripts are significantly different at P< 0.05, Y<sub>1</sub>= 1% fiber, Y<sub>2</sub>=2% fiber, Y<sub>3</sub>= 3% fiber, Y<sub>4</sub>=4% fiber, Y<sub>5</sub>= 5% fiber

**Syneresis**

Whey separation or syneresis is considered as a defect on the surface of yoghurt, set yoghurt and other set-style fermented dairy products and is defined as the expulsion of whey from the network which then becomes visible as surface whey and negatively affects consumer perception. The syneresis value of control yoghurt sample (Y<sub>1</sub>) was 26 ml, while it was 31 ml for yoghurt sample (Y<sub>5</sub>) with 5% soluble fiber. In the present study, the syneresis in yoghurt samples decreased with increase in level of fiber fortification upto 3% (18 ml) then showed a sharp increase. The fortification of partially hydrolysed guar gum (PHGG) as soluble fiber significantly decreased whey separation in all yoghurt samples. This effect could be attributed to the gelling capacity of the PHGG soluble fiber and its high ability to interact with the milk constituents (mainly proteins), and stabilize the protein network, preventing free movement of water. Functionality of hydrocolloids in yogurt is demonstrated by their ability to bind water. However, at higher concentration of partially hydrolyzed guar gum soluble fiber, there is higher tendency of whey separation or syneresis because it affects the network and textural properties.

**Viscosity**

Viscosity is resistance to flow of a fluid. It is a desirable characteristics in yoghurt as it contributes to mouthfeel and physical properties such syneresis, whey separation and water holding capacity. Yogurts fortified with soluble fiber had the higher viscosity values as compared to control yogurt, which showed the lowest viscosity. Viscosity values of yoghurt samples recorded were ranges between 982-2191 cPs. Fiber fortification upto 3% level in yoghurt samples increased the viscosity values whereas above this concentration there was observed a decrease in viscosity of yoghurt samples. While lower concentration of soluble fiber supported the network formation and contributed to high viscosity in yoghurt samples.

**Water holding capacity**

Water holding capacity of yoghurt is considered as an indicator of its ability to retain serum in the gel structure. The ability of yoghurt to exhibit minimal whey separation is an important factor with respect to consumer point of view as whey separation negatively affects consumer perception (Lee and Lucey, 2010). Water holding capacity of yoghurt fortified with fiber increased to 53.73 % as compared to 43.07 % of control yoghurt sample. This increase in water holding capacity of

yoghurt is due to higher water holding capacity of soluble fiber which also provided strength to yoghurt coagulum network and aids in more water retention. At 5% fiber concentration, the water holding capacity of yoghurt reduced to 39.9% which is even lesser than control curd sample. The lower water holding capacity at higher percentage of fiber was partially due to the unstable gel network of yogurt, in which the weak colloidal linkage of protein micelles could not entrap water within its three dimensional network (Donkor et al., 2007).

**Table 2** Texture profile analysis of control and fiber fortified yoghurt

Sample	Hardness (g)	Adhesiveness (g.s)	Cohesiveness	Springiness	Gumminess (g)
Control	45.5±0.27 <sup>c</sup>	43.8±0.18 <sup>c</sup>	0.48±0.08 <sup>a</sup>	0.72±0.02 <sup>a</sup>	21.8±0.10 <sup>a</sup>
Y <sub>1</sub>	53.9±0.32 <sup>e</sup>	43.6±0.20 <sup>c</sup>	0.52±0.06 <sup>a</sup>	0.78±0.04 <sup>b</sup>	28.0±0.12 <sup>c</sup>
Y <sub>2</sub>	54.2±0.24 <sup>e</sup>	43.7±0.16 <sup>c</sup>	0.53±0.10 <sup>a</sup>	0.79±0.05 <sup>b</sup>	28.7±0.14 <sup>c</sup>
Y <sub>3</sub>	49.9±0.22 <sup>d</sup>	43.6±0.18 <sup>c</sup>	0.58±0.12 <sup>a</sup>	0.85±0.04 <sup>c</sup>	28.9±0.11 <sup>c</sup>
Y <sub>4</sub>	47.4±0.18 <sup>b</sup>	42.8±0.10 <sup>b</sup>	0.59±0.10 <sup>a</sup>	0.91±0.03 <sup>d</sup>	27.9±0.14 <sup>c</sup>
Y <sub>5</sub>	38.5±0.20 <sup>a</sup>	42.1±0.12 <sup>a</sup>	0.60±0.14 <sup>a</sup>	0.92±0.04 <sup>d</sup>	23.1±0.16 <sup>b</sup>

Values are mean ±S.D. of determinations made in triplicate. The values followed by different superscripts are significantly different at P< 0.05, Y<sub>1</sub>= 1% fiber, Y<sub>2</sub>=2% fiber, Y<sub>3</sub>= 3% fiber, Y<sub>4</sub>=4% fiber, Y<sub>5</sub>= 5% fiber

**Texture profile analysis**

Texture profile analysis of food sample in a texture analyzer imitates the conditions in the mouth by compressing a product twice (Bourne, 1978). Results for texture profile analysis parameters such as hardness, cohesiveness, adhesiveness, springiness and gumminess are presented in Table 2. Results of texture profile analysis revealed that textural properties of yoghurt significantly improved on addition of soluble fiber. Hardness is used to estimate the maximum force of the first compression and is considered as a critical parameter for evaluation of textural characteristics of food. The highest hardness was measured in Y<sub>2</sub> yogurt sample (54.2 g), while the lowest one was observed in Y<sub>5</sub> and control yoghurt sample (38.5 g & 42.5 g, respectively). Textural and rheological characteristics of coagulated yogurt are generally determined by their internal structure. Tight and rigid internal molecular structure results in a firm protein gel. The microstructure of yoghurt consists of a three-dimensional network of casein particles containing spherical molecules of different sizes (Fizman et al., 1999). Results suggest that fiber fortification in yoghurt upto 4% level give strength to network architecture. Adhesiveness is commonly calculated as the area of a negative peak. Adhesiveness value was highest for control yoghurt sample (43.8) and lowest for Y<sub>5</sub> sample (42.1) which demonstrates that less force was required to remove the material adhered to the mouth during eating yoghurt samples fortified with fiber as compared to control yoghurt sample. Fiber fortification leads to decrease in adhesiveness of yoghurt samples. This may be due to the gummy nature of partially hydrolyzed guar gum which reduces the adhesiveness characteristic in yoghurt. Cohesiveness of yogurt samples were increased with increased level of fiber fortification which indicates that fiber fortification supports and enhances the strength of internal bonds of all samples. Gumminess is the multiplication of hardness and cohesiveness. With the increased values of cohesiveness and variable values of hardness, gumminess of yoghurt samples first increased and then decreased. Springiness of control and fiber fortified yoghurt samples showed an increasing trend with respect to fiber fortification levels. The springiness of Y<sub>5</sub> (0.92) and Y<sub>4</sub> (0.91) yogurt samples were higher than of the other samples indicating that yoghurt samples fortified with fiber returned more easily to its original shape after the deforming force was removed.

**Table 3** Sensory characteristics of control and fiber fortified yoghurt

Sample	Color & Appearance	Body & Texture	Flavour	Overall Acceptability
Control	7.0±0.45 <sup>b</sup>	7.1±0.10 <sup>b</sup>	7.1±0.14 <sup>a</sup>	7.05±0.17 <sup>b</sup>
Y <sub>1</sub>	6.9±0.30 <sup>b</sup>	7.5±0.22 <sup>b</sup>	7.0±0.12 <sup>a</sup>	7.13±0.15 <sup>b</sup>
Y <sub>2</sub>	7.1±0.25 <sup>b</sup>	7.9±0.15 <sup>b,c</sup>	8.0±0.18 <sup>b</sup>	7.66±0.12 <sup>c</sup>
Y <sub>3</sub>	8.5±0.30 <sup>d</sup>	9.0±0.17 <sup>d</sup>	9.0±0.20 <sup>c</sup>	8.83±0.15 <sup>d</sup>
Y <sub>4</sub>	7.5±0.22 <sup>c</sup>	8.1±0.11 <sup>c</sup>	8.0±0.15 <sup>b</sup>	7.86±0.10 <sup>c</sup>
Y <sub>5</sub>	6.0±0.14 <sup>a</sup>	6.5±0.15 <sup>a</sup>	7.0±0.15 <sup>a</sup>	6.50±0.11 <sup>a</sup>

Values are mean ±S.D. of determinations made in triplicate. The values followed by different superscripts are significantly different at P< 0.05, Y<sub>1</sub>= 1% fiber, Y<sub>2</sub>=2% fiber, Y<sub>3</sub>= 3% fiber, Y<sub>4</sub>=4% fiber, Y<sub>5</sub>= 5% fiber

**Sensory evaluation**

Sensory evaluation of control and fiber fortified yoghurt is presented in Table 3. Compared to control yoghurt sample, the sensory characteristics of yoghurt fortified with fiber markedly improved except in case of Y<sub>5</sub> sample in which fiber concentration was highest i.e.5%. Lower values for sensory characteristics of Y<sub>5</sub> sample can also be co-related with pH, acidity, water holding capacity, syneresis and viscosity of curd. Sensory evaluation as well as overall acceptability results of the yoghurt samples showed that Y<sub>3</sub> yoghurt sample (3% fiber level) was the most acceptable sample by judging panel members. Y<sub>3</sub> sample scored highest among all samples with respect to color and appearance, body and texture, flavor and overall acceptability.

**CONCLUSION**

Partially hydrolyzed guar gum as soluble fiber can be used as yoghurt improver as it improved textural, physicochemical and desirable sensory characteristics. Fiber fortification of yoghurt enhances the viscosity and water holding capacity of yoghurt samples. Moreover, it reduced the syneresis of yoghurt which can be an additional advantage to the yoghurt manufacturers. Fiber fortified yoghurt samples showed non-significant increase in acidity as compared to control sample but at acceptable level. Sensory evaluation results revealed that Y<sub>3</sub> yoghurt sample fortified with 3% soluble fiber was having highest acceptability. It is concluded that fortified yoghurt with 3% soluble fiber produced an acceptable product with improved characteristics.

**REFERENCES**

Aneja, R. P., Mathur, B. N., Chandan, R. C. & Banerjee, A. K. (2002). *Technology of Indian Milk Products*. New Delhi: Dairy India publication, 42 p. ISBN 9788190160308

Bhat, Z. F. & Bhat, H. (2011). Milk and dairy products as functional foods: A review. *International Journal of Dairy Science*, 6(1), 1-12. <http://dx.doi.org/10.3923/ijds.2011.1.12>

Bhattacharya, S. & Das, A. (2010). Study of physical and cultural parameters on the bacteriocins produced by lactic acid bacteria isolated from traditional Indian fermented foods. *American Journal of Food Technology*, 5(2), 111-120.

Bourne, M. (1978). Texture profile analysis. *Food Technology*, 32, 62–72.

Chawla, A. K. & Balachandran, R. (1994). Studies on Yoghurt from buffalo milk: Effect of different solids not fat content on chemical, rheological and sensory characteristics. *Indian Journal of Dairy Science*, 47, 762-765.

Devi, M. C. A., Rao, K. J. & Ravindra, M. R. (2010). Role of milk and milk products in traditional medicinal systems. *Indian Dairyman*, 62(3), 114-119.

Donkor, O. N., Henriksson, A., Vasiljevic, T. & Shah, N. P. (2007). Rheological properties and sensory characteristics of set-type soy yoghurt. *Journal of Agricultural and Food Chemistry*, 55(24), 9868-9876. <https://doi.org/10.1021/jf071050r>

Fizman, S. M., Lluch, M. A. & Salvador, A. (1999). Effect of addition of gelatin on microstructure of acidic milk gels and yoghurt and on their rheological properties. *International Dairy Journal*, 9(12), 895–901. [https://doi.org/10.1016/S0958-6946\(00\)00013-3](https://doi.org/10.1016/S0958-6946(00)00013-3)

Hashim, I. B., Khalil, A. H. & Afifi, H. S. (2009). Quality characteristics and consumer acceptance of yogurt fortified with date fiber. *Journal of Dairy Science*, 92(11), 5403-5407. <https://doi.org/10.3168/jds.2009-2234>

Lee, W. J. & Lucey, J. A. (2010). Formation and physical properties of yogurt. *Asian Australian Journal of Animal Science*, 23(9), 1127–1136. <http://dx.doi.org/10.5713/ajas.2010.r.05>

Mudgil, D. & Barak, S. (2013). Composition, properties and health benefits of indigestible carbohydrate polymers as dietary fiber: A review. *International*

- Journal of Biological Macromolecules*, 61, 1-6.  
<https://doi.org/10.1016/j.jbiomac.2013.06.044>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2012a). Soluble fibre and cookie quality. *Agro Food Industries Hi Tech*, 23(3), 15-17.
- Mudgil, D., Barak, S. & Khatkar, B. S. (2012b). Process optimization of partially hydrolyzed guar gum using response surface methodology. *Agro Food Industries Hi Tech*, 23(1), 13-15.
- Mudgil, D., Barak, S. & Khatkar, B. S. (2011). Effect of hydrocolloids on the quality characteristics of tomato ketchup. *Carpathian Journal of Food Science and Technology*, 3(1), 39-43.
- Mudgil, D., Barak, S. & Khatkar, B. S. (2014). Optimization of enzymatic hydrolysis of guar gum using response surface methodology. *Journal of Food Science and Technology*, 51(8), 1600-1605. <https://doi.org/10.1007/s13197-012-0678-z>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2016a). Optimization of textural properties of noodles with soluble fiber, dough mixing time and different water levels. *Journal of Cereal Science*, 69, 104-110. <http://dx.doi.org/10.1016/j.jcs.2016.02.015>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2016b). Optimization of bread firmness, specific loaf volume and sensory acceptability of bread with soluble fiber and different water levels. *Journal of Cereal Science*, 70, 186-191. <https://dx.doi.org/10.1016/j.jcs.2016.06.009>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2016c). Effect of partially hydrolyzed guar gum on pasting, thermo-mechanical and rheological properties of wheat dough. *International Journal of Biological Macromolecules*, 93, 131-135. <https://doi.org/10.1016/j.jbiomac.2016.08.064>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2016d). Development of functional yoghurt via soluble fiber fortification utilizing enzymatically hydrolyzed guar gum. *Food Bioscience*, 14, 28-33. <http://dx.doi.org/10.1016/j.fbio.2016.02.003>
- Mudgil, D., Barak, S. & Khatkar, B. S. (2018). Partially hydrolyzed guar gum as a potential prebiotic source. *International Journal of Biological Macromolecules*, 112, 207-210. <https://doi.org/10.1016/j.jbiomac.2018.01.164>
- Raju, P. N. & Pal, D. (2014). Effect of dietary fibers on physico-chemical, sensory and textural properties of Misti Dahi. *Journal of Food Science and Technology*, 51(11), 3124-3133. <https://doi.org/10.1007/s13197-012-0849-y>
- Sodini, I., Remeuf, F., Haddad, S. & Corrieu, G. (2004). The relative effect of milk base, starter, and process on yogurt texture: a review. *Critical Reviews in Food Sciences and Nutrition*, 44(2), 113-137. <https://doi.org/10.1080/10408690490424793>
- Tamime, A. Y. & Robinson, R. K. (2007). *Tamime and Robinson's Yoghurt: Science and Technology*. (3<sup>rd</sup> ed.). Cambridge: CRC Press, 1 p. ISBN 9781845692131
- Yadav, H., Jain, S. & Sinha, P. R. (2008). Oral administration of dahi containing probiotic *Lactobacillus acidophilus* and *Lactobacillus casei* delayed the progression of streptozotocin-induced diabetes in rats. *Journal of Dairy Research*, 75(2), 189-195. <http://doi.org/10.1017/S0022029908003129>