Pakistan J. Zool., vol. 49(1), pp 27-34, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.1.27.34

Influence of Hydrocolloid Gums on Textural, Functional and Sensory Properties of Low Fat Cheddar Cheese from Buffalo Milk

Mian Shamas Murtaza[1], Aysha Sameen[1], Nuzhat Huma[1] and Fatma Hussain[2]

[1]*National Institute of Food Science and Technology, University of Agriculture, Faisalabad-38040, Pakistan*

[2]*Department of Biochemistry, University of Agriculture, Faisalabad-38040, Pakistan*

ABSTRACT

Reduced fat cheeses are desired based on composition but fell in acceptability and functionality as the fat contributes the desirable flavour and texture. The addition of gums in low fat cheese softens the structure by the interference of the casein-casein interaction and cellulose particles that function similar to fat globules. The present study was aimed to assess the impact of hydrocolloid gums on functional, textural and sensory attributes of low fat Cheddar cheese. Buffalo milk was standardized at 2% and 4% fat levels to manufacture Cheddar cheese. Cheese samples were manufactured by adding xanthan gum and guar gums individually @ 1.5, 3.0 and 4.5% in low fat cheese (2% fat) besides the negative (2% fat) and positive (4% fat) control samples. The cheese samples were ripened at 6-8°C for 30 days and analyzed for physico-chemical composition, functional, textural and sensory quality. The results showed that reduction in fat significantly ($p < 0.05$) increased the moisture and protein content. The addition of gums further augmented the moisture level owing to owing to their water retention properties. The melt-ability, flow-ability and yield of cheese decreased significantly ($p < 0.05$) on reducing the fat level, as anticipated. However, the addition of gums gradually improved these aspects with higher values for cheese containing guar gum as compared to xanthan gum. The full fat cheese showed the minimum (1270g) while the negative control had the maximum (1604.64 g) hardness. The hardness decreased gradually on increasing the concentration of gums and the samples having guar gum were less hard. On sensory evaluation, the maximum scores were awarded to full fat cheese, while the negative control attained the minimum liking. Addition of gums improved the sensory acceptability of cheese. The sample containing 0.45% guar gum was awarded the scores comparable to the full fat cheese for most of the traits. Hence, it was concluded that hydrocolloids particularly guar gum can effectively be used up to 0.45% to improve the functionality and acceptability of low fat Cheddar cheese.

Article Information
Received 06 June 2016
Revised 25 June 2016
Accepted 15 August 2016
Available online 22 September 2016

Authors' Contributions
AS, NH and FH perceived, designed and supervised the study and helped in article writing. MSM executed the cheese manufacturing, its quality evaluation and statistical analysis of the data as well as wrote the article.

Key words
Buffalo milk, Cheddar cheese, Hydrocolloids, Texture, Functionality

INTRODUCTION

Pakistan is the 4th largest milk producing country in the world with annual production 52.6 million tones; out of which 19 percent of milk is wasted (GOP, 2015). Most of the milk is consumed in raw form except 4%, which is processed. Shelf life of milk can be increased by converting it into different products like pasteurized, sterilized, condensed and/or powder milk, yoghurt, butter, ice cream, cheese etc. (Varnam and Sutherland, 1994).

Cheeses are getting more popularity in the world due to their nutritional value, variety in texture and flavour, functionality and multidimensional uses. Approximately a third of the world's milk produced is used in cheese manufacturing (Farkye, 2004). The milk from cow, camel, goat, sheep and buffalos or blends of these is used to produce different types of cheeses (Hussain *et al*., 2012).

* Corresponding author: shamasmurtaza@yahoo.com
0030-9923/2017/0001-0027 $ 9.00/0

Buffalo milk is at the top in Pakistan's milk production with annual value of 31.25 million tonnes (GOP, 2014) and has promising research interests because of its nutritional profile and buffering capacity that offers remarkable prospects for fermented products like cheese (Murtaza *et al*., 2015; Tahira *et al*., 2014).

A wide range of cheese varieties exists in the world, each with unique characteristics (Falegan and Akere, 2014). Cheese is a complex food made from few simple ingredients. It is the coagulated and concentrated form of milk manufactured at appropriate temperature and humidity (Murtaza *et al*., 2014). Cheese varieties are classified on the basis of origin of milk sources, chemical composition, manufacturing procedure, shape, texture and ripening (Manish and Srivastava, 2002; Walstra *et al*., 2006).

Cheddar is a hard ripened cheese produced by acidification and concentration followed by gel formation with protease (Murtaza, 2016). It is highly nutritious and a complex mixture and is rich in fat, protein, vitamins and minerals (Murtaza *et al*., 2014). Microbial, biochemical and metabolic processes referred as glycolysis, lipolysis and proteolysis are held responsible for flavor and texture development in Cheddar cheese during ripening (Murtaza *et al*., 2012; Smit *et al*., 2005).

Cheese is rich in saturated fats, which in excess can increase cardiovascular problems, high cholesterol level, arthritis, memory loss, weight gain and obesity. In Pakistan, these chronic diseases are cause of 42% deaths (GOP, 2013). Consumers have certain health concerns owing to changing life style, like less fat, fewer calories, less cholesterol or less sugar. Even though consumers are repeatedly told they should reduce their dietary fat consumption, they are not willing to sacrifice taste or functionality in the foods they eat (Verbeke, 2006).

The demand of low fat cheese is increasing day by day. Reduced and low fat cheeses are desired based on composition but often fall short on overall quality (Murtaza, 2016). Fat imparts the functional, textural and sensory properties of cheese; hence, reducing or replacing fat in cheese is not an easy job (Gunasekaran and Ak, 2003). Some of the major problems with fat reduction in cheese are the development of a firm texture that does not break down during mastication, weak gel network between protein and fat, bland flavor and taste and yield reduction, which are undesirable (Correll, 2011). These problems can be overcome by adopting different techniques like use of adjunct culture, modify the procedure, use of fat replacers like hydrocolloids (Rogers *et al*., 2010).

Hydrocolloid gums are the most effective carbohydrate-based fat replacers having the ability to control the rheology of water based systems and syneresis inhibition. These are added to dairy products to stabilize their structure, enhance viscosity and alter textural characteristics (Simeone *et al*., 2004).

Most commonly used hydrocolloids are xanthan gum and guar gum. Xanthan gum is a microbial hetero-polysaccharide of high molecular weight with 1-4 β-D-glucose backbone, a trisaccharide of mannose, glucuronic acid and mannose. It is produced by fermentation of carbohydrate using naturally occurring *Xanthomonas compestris* (Nateghi *et al*., 2012a; Tiwari *et al*., 2010). Guar gum, galactomannan is a non-gelling neutral polysaccharide composed of a linear (1→ 4)-β-D-mannan backbone, mainly obtained from the endosperm of many leguminous seeds like *Cyamopsis tetragonolobus* L. (Srivastava and Kapoor, 2005; Volikakis *et al*., 2004).

Keeping in view the production and prospects of buffalo milk, consumers' demand for low fat cheese and functionality of hydrocolloid gums, the study was aimed to assess the impact of gums on functional, textural and sensory properties of buffalo milk cheddar cheese.

MATERIALS AND METHODS

Raw materials

Raw buffalo milk was procured from dairy farm,University of Agriculture, Faisalabad. Hydrocolloid gums (xanthan gum and guar gum), freeze dried mesophilic starters (Lactococcus lactis ssp. lactis and Lactococcus lactis ssp. cremoris) and rennet (Double strength Chy-max, 500000 MCU/mL, Pifzer Inc, Milwaukee, WI, USA) were purchased from local market.

Cheddar cheese manufacturing

Buffalo milk was standardized at 2% and 4% fat levels for different batches of (low and full fat) cheddar cheese. Cheddar cheese was manufactured by following the method detailed by Murtaza (2016) with slight modification in order to incorporate hydrocolloid gums for development of different low fat cheese samples. The samples prepared were stored for 30 days at 6-8°C for ripening.

The detail of various cheese samples prepared for the study is as given below:

C+, cheese with 4% fat level (positive control); C-, cheese with 2% fat level (negative control); X1, cheese with 2% fat level and 0.15% xanthan gum added; X2, cheese with 2% fat level and 0.30% xanthan gum added; X3, cheese with 2% fat level and 0.45% xanthan gum added; G1, cheese with 2% fat level and 0.15% guar gum added; G2, cheese with 2% fat level and 0.30% guar gum added; G3, cheese with 2% fat level and 0.45% guar gum added.

Quality evaluation of cheese

After 30 days of ripening, cheese samples were analyzed for different quality parameters (physico-chemical composition, functional and textural characteristics and sensory perception) in triplicate (n=3) as detailed below.

Physico-chemical analysis

The cheese samples were analyzed for moisture by oven drying (AOAC, 2000), pH using pH meter (Ong *et al*., 2007), acidity by titration method (AOAC, 2000), protein by Kjeldhal method (IDF, 2006), fat by Gerber method (Marshal, 1993) and ash content by igniting the cheese samples (AOAC, 2000).

Functional properties

Melt-ability: Melt-ability of each cheese sample was determined by using glass tube of known length and thickness. Cheese samples were compressed in glass tubes by plunger and length was noted by using vernier-caliper. Glass tubes were stored at 4°C for 4 hrs. Afterwards, heating was done at 110°C for 100 min. Melt length was again noted for each sample using vernier-caliper (Zisu and Shah, 2007).

Flow-ability: Flow-ability of each cheese samples was determined by cutting a cheese disk of a specified dimension and heating at 280°C for 4 min. The percent increase in diameter of a cheese disc was expressed as flow-ability (Guinee *et al*., 2002).

Cheese yield: Cheese yield was calculated for each sample as the percent of the weight of finished cheese obtained divided by the weight of the milk used (Sipahioglu *et al*., 1999).

Textural profile analysis

Texture profile of each cheese sample was assessed by performing the texture profile analysis (TPA) on TA-XT Plus Texture Analyzer (Stable Micro Systems, Godalming, Surrey, UK) using compression plate. Cheese samples were placed in air tight plastic bags and equilibrated at 8°C for 18 h. Cubes of 25mm length, width and height were cut from each sample using a stainless steel wire cutter and equilibrated at 8°C for a further 30 min before analysis.

Samples were removed from the incubator and immediately compressed to 30% of the original height in 2 consecutive cycles (*i.e*., double compression) at a rate of 1 mm/s (Zisu and Shah, 2007).

Sensory evaluation

Cheddar cheese samples were evaluated for sensory perception on a hedonic rating scale (0–9) by a panel of judges drawn from faculty members and post-graduate students to assess the influence of fat reduction and addition of gums on sensory parameters as described by Awad *et al*. (2004).

Statistical analysis

The results obtained were subjected to statistical analysis using completely randomized design and Duncan's multiple range test using *Statistica 8.1* to assess the significance of work (Montgomery, 2013).

RESULTS AND DISCUSSION

Physico-chemical analysis

The addition of gums showed a significant ($P < 0.05$) effect on the compositional parameters like moisture, fat, protein, pH and acidity (except ash content) of low fat cheese (Table I). Moisture content was recorded in the range of 38.40-45.8% and protein 26.45-31.18%. Minimum moisture and protein were present in positive control having 4% fat as 38.40% and 26.45%, respectively. By increasing the hydrocolloid level and decreasing the fat content, the moisture and protein content increased. As the fat content of cheese is reduced, moisture and protein content increase and play a greater role in texture development (Mistry, 2001; Oliveira *et al*., 2011). Moisture is important for cheese because it contribute softness, quality characteristics and serves as reactant in different reaction (Lee *et al*., 2006) and is bounded with the protein to maintain elasticity of cheese (McSweeney and Souse, 2000). Nateghi *et al*. (2012a) also reported that the use of fat replacers like xanthan gum and sodium caseinate increased the moisture and protein levels in Cheddar cheese, probably due to hygroscopic properties of the ingredients.

The fat content in cheese varied slightly between reduced fat cheese samples. As already mentioned that milk was standardized prior to cheese manufacturing, this minor variation might be owing to the fat retention property of the hydrocolloids. Increased moisture causes decrease in total fat content and dry matter fat in cheddar cheese (Esmaeil *et al*., 2010). The ash content of cheese fell in the range of 3.35-3.50% with statistically non-significant differences. The addition of gums had no effect on ash content of cheese samples since ash only represents the inorganic matter (Sengul *et al*., 2006).

The pH and acidity differed significantly with increase in concentration of gums and decrease in fat level. The lowest pH (5.20) and the highest acidity (0.91%) were found in positive control (full fat cheese). The fat replacers significantly affect the pH, acidity and total solids in cheese

Table I.- Physico-chemical composition of full fat and low fat cheddar cheese.

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	pH	Acidity (%)
C+	38.40±1.02d	26.45±0.72d	32.30±0.68a	3.44±0.15	5.20±0.04c	0.91±0.02a
C-	42.81±1.10c	30.34±0.67bc	16.14±0.42d	3.50±0.17	5.27±0.08b	0.86±0.04b
X1	44.6±0.97b	30.76±0.58b	16.52±0.38c	3.35±0.21	5.32±0.02ab	0.84±0.03b
X2	45.1±1.08ab	30.12±0.62c	16.81±0.42bc	3.40±0.16	5.38±0.03a	0.79±0.01c
X3	45.8±0.90a	29.60±0.60cd	17.06±0.61b	3.42±0.16	5.39±0.07a	0.79±0.04c
G1	43.3±1.05c	31.18±0.54a	16.78±0.48bc	3.38±0.18	5.31±0.02ab	0.85±0.03b
G2	43.9±0.94bc	30.54±0.56bc	16.90±0.46bc	3.40±0.20	5.33±0.04ab	0.82±0.03bc
G3	44.4±0.99b	30.08±0.61c	17.12±0.53b	3.39±0.12	5.37±0.06a	0.80±0.04bc

*The mean values having different letters within a column have statistically significant differences.
C+, cheese with 4% fat level (positive control); C-, cheese with 2% fat level (negative control); X1, cheese with 2% fat level and 0.15% xanthan gum added; X2, cheese with 2% fat level and 0.30% xanthan gum added; X3, cheese with 2% fat level and 0.45% xanthan gum added; G1, cheese with 2% fat level and 0.15% guar gum added; G2, cheese with 2% fat level and 0.30% guar gum added; G3, cheese with 2% fat level and 0.45% guar gum added.

(Kavas *et al*., 2004). Katsiari and Voutsinas (1994) also reported that the pH values of low-fat cheeses were slightly higher than that of the full-fat cheese.

Functional properties

Melt-ability and flow-ability are directly linked with the hardness parameter of the texture and both have the inverse relation with the cheese hardness. Maximum value of melt-ability and flow-ability was found in full fat cheese (positive control) as 61.5mm and 22.9%, and the lowest in reduced fat (negative control) cheese sample as 46.8mm and 16.4%, respectively. All other treatments had values in between these two samples (Table II). The results showed that the melt-ability and flow-ability increased with the increased concentration of hydrocolloid gums and samples having guar gum exhibited more values of both functional parameters. The gums as fat replacers increased the melting and flowing properties of cheese since xanthan gum improves melting properties and increases the moisture retention in cheddar cheese (Nateghi *et al*., 2012a). Hekken *et al*. (2007) showed an increase in melt-ability in cheese by increasing fat content. The decrease in fat resulted in decreasing the melt-ability; however, it increased gradually with the increased level of hydrocolloids added (Koca and Metin, 2004).

Table II.- Functional properties of full fat and low fat cheddar cheese.

Treatments	Melt-ability (mm)	Flow-ability (%)	Yield (%)
C+	61.5±2.0a	22.9±0.71a	10.90±0.35a
C-	46.8±1.6f	16.4±0.69e	8.70±0.42e
X1	50.8±1.2e	18.3±0.52d	9.23±0.36d
X2	52.6±1.8d	18.7±0.62cd	9.81±0.45c
X3	55.5±1.6c	19.4±0.58c	9.90±0.41bc
G1	54.2±1.5cd	19.2±0.56c	9.61±0.39cd
G2	55.9±1.7c	19.7±0.73c	9.95±0.40bc
G3	57.3±2.1b	20.6±0.67b	10.30±0.32b

*The mean values having different letters within a column have statistically significant differences.
For abbreviations, see Table I.

The highest cheese yield was recorded in positive control sample (10.9%) having full fat while the lowest in negative control (8.70%). All other samples with hydrocolloids added showed more yield than negative control because of fat mimic properties of the hydrocolloids. By increasing the concentration of gums, the yield increased and cheese sample having 0.45% guar gum had yield closer to the full fat cheese (Table II). Fat plays an important role in cheese yield because of the network between fat and protein and lowering the fat content weakens the network and yield is reduced. The hydrocolloids can directly bind the water and interfere with the shrinkage of the casein matrix; therefore, lowers the driving force involved in expelling water from curd particles and improve yield (Rahimi *et al*., 2007).

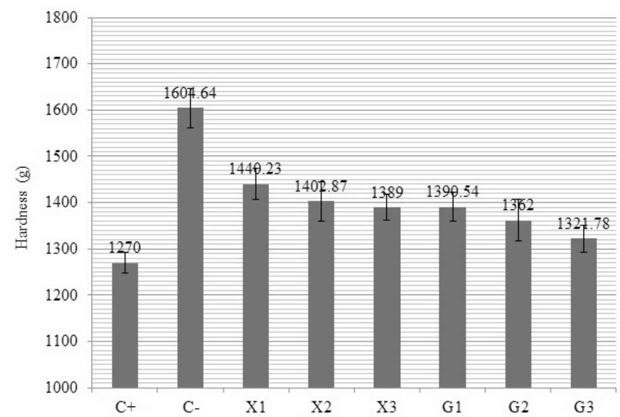

Fig. 1. For treatment details, see Table I. Effect of hydrocolloids on cheese hardness.

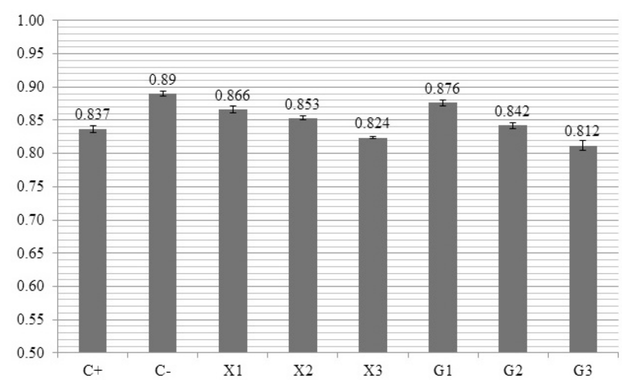

Fig. 2. Effect of hydrocolloids on cheese cohesiveness.

Textural profile analysis

Different parameters like hardness, cohesiveness, springiness, gumminess and chewiness were studied through texture profile analysis. The results indicated that full fat cheese had the minimum (1270g), while the low fat cheese (negative control) had the highest mean hardness value (1604.64 g). The hardness of low fat samples with added hydrocolloids reduced gradually with the concentration of gums. The cheese having guar gum had less hardness as compared to those having xanthan gum as fat replacer (Fig. 1). The decrease in hardness with increased concentration of gums might be due to increased water retention. Cohesiveness is the ratio between two forces while springiness is the ratio between two distances. Cohesiveness and springiness both show opposite trend in the cheese samples with added hydrocolloids (Figs. 2 and 3). Cohesiveness was reduced while springiness increased by increasing the level of gums. Gumminess and chewiness relate to cheese hardness (Figs. 4 and 5); since these are calculated from hardness, cohesiveness and springiness (Awad *et al*., 2013).

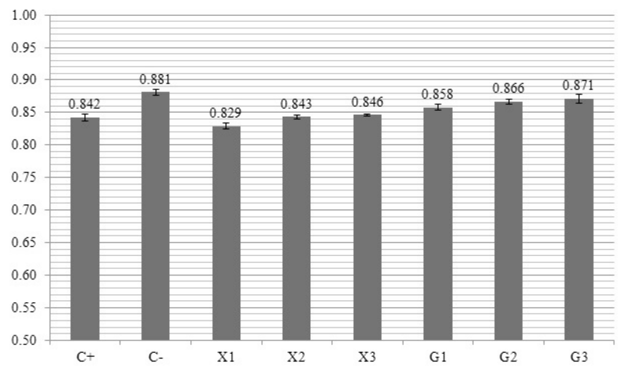

Fig. 3. Effect of hydrocolloids on cheese springiness.

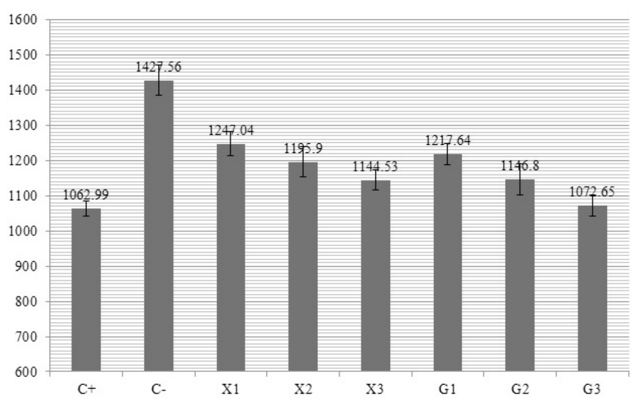

Fig. 4. Effect of hydrocolloids on cheese gumminess.

Texture of cheese is greatly influenced by both compositional and processing parameters (Wium *et al*., 2003). The fat reduction increases the cheese hardness (Awad *et al*., 2005) and results in rubbery texture due to relative deficiency of fat globules; hence, there is more structural matrix per unit cross sectional area which accelerates the synersis (Irudayaraj *et al*., 1999).

Konuklar *et al*. (2004) also reported the reduction in hardness of cheddar cheese made with hydrocolloidal suspensions as compared to its reduced fat control (C-). The use of fat replacers like xanthan gum and sodium caseinate increases moisture levels, reduces the hardness and affects other textural parameters in cheddar cheese, due to hygroscopic properties of these ingredients (Nateghi *et al*., 2012b).

The decrease in hardness of cheese containing xanthan gum might be owing to variation in protein matrix compactness since xanthan gum also increases the water binding capacity of protein matrix (Koca and Metin, 2004).

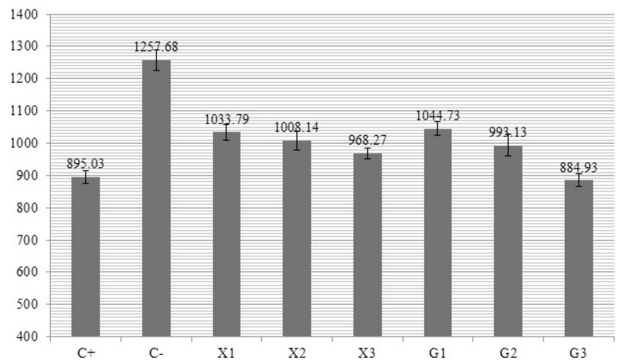

Fig. 5. Effect of hydrocolloids on cheese chewiness.

Sensory evaluation

The sensory evaluation of full and reduced fat chees samples was performed to access the reaction of judges by rating their liking on a scale. The panelists assigned the score for sensory attributes (appearance, flavour, firmness, stickiness, sliceability and overall acceptability). The maximum scores were awarded to full fat cheese (positive control) for all the parameters, while the negative control (low fat cheese) received the lowest scores (minimum liking). Addition of hydrocolloid gums improved the sensory perception of the low fat cheese samples (Fig. 6). The increase in concentration of xanthan and guar gums in cheese depicted different trends of liking and disliking for different attributes. The sensory scores comparable with the full fat cheese were attained by maximum concentration of guar gum (0.45%) followed by lowest concentration of xanthan gum (0.15%) for most of the traits.

Source of milk, age and fat contents have profound effects on the cheddar cheese flavor and among them, the fat is most responsible for the development of correct flavor (Hassan *et al*., 2013). Fat gives rich flavor and texture to the cheese and hence, improves perceptions like appearance, mouth-feel and overall acceptability (Kucukoner and Haque, 2006). Addition of fat mimetic results in higher appearance and overall acceptability score of low fat cheese similar to the full fat product (Romeih *et al*., 2002). Kavas *et al*. (2004) reported the increase in flavor of cheese made with different fat replacers as compared to low fat (control) cheese.

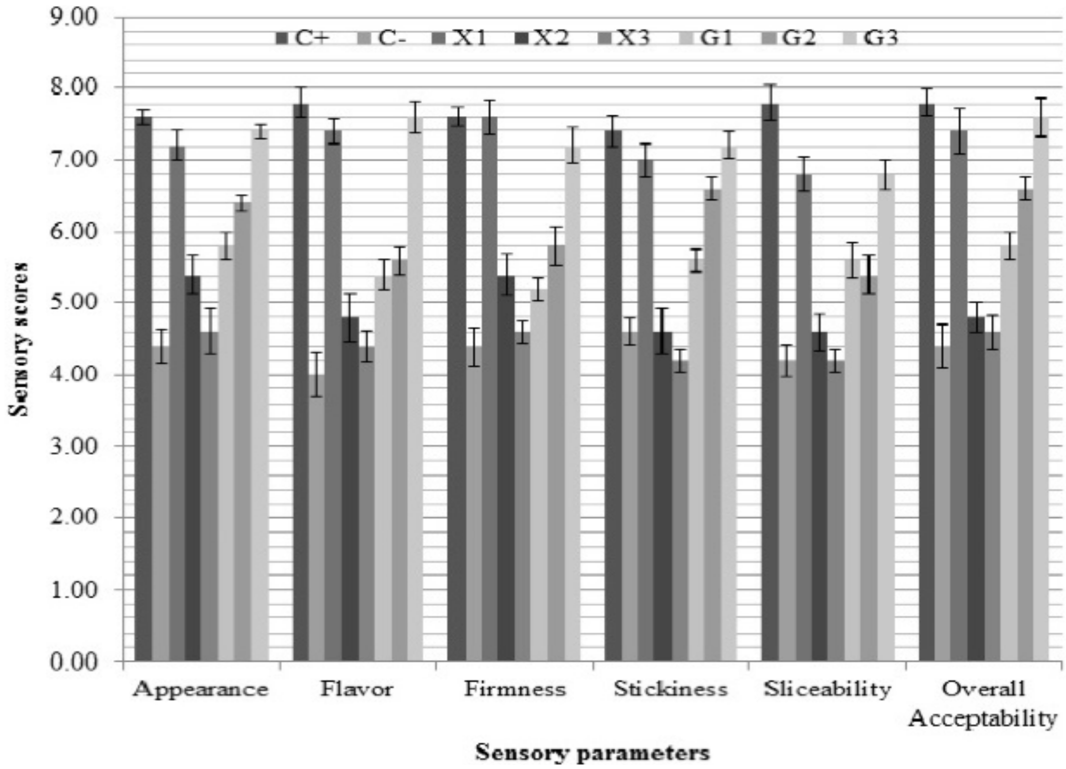

Fig. 6. Effect of hydrocolloids on sensory perception of cheddar cheese.

CONCLUSION

The study concluded that hydrocolloids gums particularly guar gum can effectively be used @ 0.45% to produce low fat cheddar cheese with functional, textural and sensory characteristics comparable to full fat product. Hence, it can be recommended that defects in quality and acceptability of low fat cheeses can be overcome by incorporating hydrocolloid gums as fat replacers without any adverse effects. In further work, different concentrations and combinations of these and some other gums should be explored for better results.

ACKNOWLEDGEMENT

The authors wish to thank NIFSAT and High Tech Laboratory, University of Agriculture, Faisalabad-Pakistan for providing all the facilities to carry out the research work.

Conflict of interest statement

We declare that we have no conflict of interest.

REFERENCES

AOAC., 2000. *Official method of analysis of association of official analytical chemists*. 17th Ed. Washington, DC, USA.

Awad, R.A., Abdel-Hamid, L.B., El-Shabrawy, S.A. And Singh, R.K., 2004. Physical and sensory properties of block processed cheese with formulated emulsifying salt mixtures. *Int. J. Fd. Prop.,* **7**:429-448. http://dx.doi.org/10.1081/JFP-200032934

Awad, S., Ahmed, N.E. and El-Soda, M., 2013. Application of salt whey from egyptian ras cheese in processed cheese making. *Fd. Nutr. Sci.,* **4**:79-86. http://dx.doi.org/10.4236/fns.2013.49A2011

Awad, S., Hassan, A. And Muthukumarappan, K., 2005. Application of exo-polysaccharide- producing cultures in reduced-fat cheddar cheese: Texture and melting properties. *J. Dairy Sci.,* **88**:4204-4213. http://dx.doi.org/10.3168/jds.S0022-0302(05)73106-4

Correll, J., 2011. *The original encyclopizza: Pizza ingredient purchasing and preparation*. Correll Consulting, LLC-dba, USA.

Esmaeil, G.S., Asl, A.K., Mortazavi, A., Tavakulipor, H., Afshari, H. and Ebadi, A.G., 2010. The effect of xanthan gum using on improving texture and rheological properties of Iranian low fat white cheese. *Middle-East J. Sci. Res.,* **6**:346-356.

Falegan, C.R. and Akere, G.A., 2014. Isolation of salmonella spp in 'wara' (local cheese) from three different locations in ado-ekiti, ekiti state, Nigeria. *Experiment,* **23**:1628-1634.

Farkye, N.Y., 2004. Cheese technology. *Int. J. Dairy Technol.* **57**:91-98. http://dx.doi.org/10.1111/j.1471-0307.2004.00146.x

GOP (Government of Pakistan), 2013. *Economic survey of Pakistan 2012-13.* Economic Adviser's Wing, Ministry of Finance, Islamabad, Pakistan.

GOP (Government of Pakistan), 2014. *Economic survey of Pakistan 2013-14.* Economic Adviser's Wing, Ministry of Finance, Islamabad, Pakistan.

GOP (Government of Pakistan), 2015. *Economic survey of Pakistan 2014-15.* Economic Adviser's Wing, Ministry of Finance, Islamabad, Pakistan.

Guinee, T.P., Feeney, E.P., Auty, M.A.E. and Fox, P.F., 2002. Effect of pH and calcium concentration on some textural and functional properties of Mozzarella cheese. *J. Dairy Sci.,* **85**:1655-1669. http://dx.doi.org/10.3168/jds.S0022-0302(02)74238-0

Gunasekaran, S. and Ak, M.M., 2003. *Cheese rheology and texture*. CRC Press, Boca Raton.

Hassan, F.A.M., Mona, A.M., El-Gawad, A. and Enab, A.K., 2013. Flavor compounds in cheese Rev. *Res. Prec. Instr. Mach.,* **2**:15-29.

Hekken, D.L.V., Tunick, M.H., Malin, E.L. and Holsinger, V.H., 2007. Rheology and melt characterization of low fat and full fat Mozzarella cheese made from micro-fluidized milk. *J. Dairy Res.,* **40**:89-98.

Hussain, I., Grandison, A.S. and Bell, A.E., 2012. Effects of gelation temperature on Mozzarella-type curd made from buffalo and cows' milk. 1: Rheology and microstructure. *Fd. Chem.,* **134**:1500-1508. http://dx.doi.org/10.1016/j.foodchem.2012.03.062

IDF, 2006. *Determination of the nitrogen content and calculation of crude protein*. Int. Dairy Federation, Brussels, Belgium.

Irudayaraj, J., Chen, M. and Mcmahon, D.J., 1999. Texture development in cheddar cheese during ripening. *Canad. Agric. Engg.,* **41**:253-258.

Katsiari, M.C. and Voutsinas, L.P., 1994. Manufacture of low-fat Feta cheese. *Fd. Chem.,* **49**:53-60. http://dx.doi.org/10.1016/0308-8146(94)90232-1

Kavas, G., Oysun, G., Kinik, O. and Uysal, H., 2004. Effect of some fat replacers on chemical, physical and sensory attributes of low-fat white pickled cheese. *Fd. Chem.,* **88**:381-388. http://dx.doi.org/10.1016/j.foodchem.2004.01.054

Koca, N. and Metin, M., 2004. Textural, melting and sensory properties of low fat fresh Kashar cheese produced by using fat replacers. *Int. Dairy J.,* **14**:365-373. http://dx.doi.org/10.1016/j.idairyj.2003.08.006

Konuklar, G., Inglett, G.E., Warner, K. and Carriere, C.J., 2004. Use of a β-glucan hydrocolloidal suspension in the manufacture of low fat cheddar cheeses: textural properties by instrumental methods and sensory panels. *Fd. Hydrocoll.,* **18**:535-545. http://dx.doi.org/10.1016/j.foodhyd.2003.08.010

Kucukoner, E. and Haque, Z.U., 2006. Physicochemical properties of low-fat and full-fat cheddar cheeses. *Int. J. Dairy Technol.,* **59**:166-170. http://dx.doi.org/10.1111/j.1471-0307.2006.00240.x

Lee, S.C., Yu, J.H., Jeong, C.L., Back, Y.J. and Yoon, Y.C., 2006. The influence of mastitis on the quality of raw milk and cheese. *Korean J. Dairy Sci.,* **48**:1537-1543.

Manish, L. and Srivastava., 2002. *Hand book of milk microbiology.* Daya Publishing House New Dehli, India.

Marshal, R.T., 1993. *Standard methods for determination of dairy Products*. 16th Ed. American Public Health Association. Washington, D.C.

Mcsweeney, P.L.H. and Sousa, M.J., 2000. Biochemical pathways for the production of flavor compounds in cheese during ripening: A review. *Lait,* **80**:293-324. http://dx.doi.org/10.1051/lait:2000127

Mistry, V.V., 2001. Low fat cheese technology. *Int. Dairy J.,* **11**:413-422. http://dx.doi.org/10.1016/S0958-6946(01)00077-2

Montgomery, D.C., 2013. *Design and analysis of experiments.* 8th Ed. John Wiley and Sons, Inc. New York, USA.

Murtaza, M.A., 2016. Cheddar-type cheeses. In: *Reference module in food science*, 1st Ed. Academic Press, Elsevier Inc. pp. 1-8. http://dx.doi.org/10.1016/B978-0-08-100596-5.00659-4

Murtaza, M.A., Huma, N., Mustafa, I., Nawaz, H., Murtaza, M.S. and Ullah, M.I., 2015. Composition and microstructure of buffalo skim milk powder as influenced by concentration and drying temperatures. *Pakistan J. Zool.,* **47**:1157-1161.

Murtaza, M.A., Rehman, S.U., Anjum, F.M., Huma, N. and Hafiz, I., 2014. Cheddar cheese ripening and flavor characterization: A review. *Crit. Rev. Fd. Sci. Nutr.,* **54**:1309-1321. http://dx.doi.org/10.1080/10408398.2011.634531

Murtaza, M.A., Rehman, S.U., Anjum, F.M., Huma, N., Tarar, O.M. and Mueen-ud-Din, G., 2012. Organic acid contents of buffalo milk cheddar cheese as influenced by accelerated ripening and sodium salt. *J. Fd. Biochem.,* **36**:99-106. http://dx.doi.org/10.1111/j.1745-4514.2010.00517.x

Nateghi, L., Roohinejad, S., Totosaus, A., Rahmani, A., Tajabadi, N., Meimandipour, A., Rasti, B. and Manap, M.Y.A., 2012a. Physicochemical and textural properties of reduced fat cheddar cheese formulated with xanthan gum and/or sodium caseinate as fat replacers. *J. Fd. Agric. Environ.,* **10**:59-63.

Nateghi, L., Roohinejad, S., Totosaus, A., Mirhosseini, H., Shuhaimi, M., Meimandipour, A., Omidizadeh, A. and Abd-Manap, M.Y., 2012b. Optimization of textural properties and formulation of reduced fat cheddar cheeses containing fat replacers. *J. Fd. agric. Environ.,* **10**:46-54.

Oliveira, N.M., Dourado, F.Q., Peres, A.M., Silva, M.V., Maia, J.M. and Teixeira, J.A., 2011. Effect of guar gum on the physicochemical, thermal, rheological and textural properties of green Edam cheese. *Fd. Bioproc. Technol.,* **4**:1414-1421. http://dx.doi.org/10.1007/s11947-010-0324-6

Ong, L., Henriksson, A. and Shah, N.P., 2007. Chemical analysis and sensory evaluation of cheddar cheese produced with *Lactobacillus acidophilus, Lactobacillus casei, Lactobacillus paracasei* or *bifidobacterium* sp. *Int. Dairy J.,* **17**:67-78. http://dx.doi.org/10.1016/j.idairyj.2007.01.002

Rahimi, J., Khosrowshahi, A., Maddadlou, A. and Aziznia, S., 2007. Texture of low-fat Iranian white cheese as influenced by gum tragacanth as a fat replacer. *J. Dairy Sci.,* **90**:4058-4070. http://dx.doi.org/10.3168/jds.2007-0121

Rogers, N.R., Mcmahon, D.J., Daubert, C.R., Berry, T.K. and Foegeding, E.A., 2010. Rheological properties and microstructure of cheddar cheese made with different fat contents. *J. Dairy Sci.,* **93**:4565-4576. http://dx.doi.org/10.3168/jds.2010-3494

Romeih E.A., Michaelidou, A., Biliaderis, C.G. and Zerfiridis, G.K., 2002. Low fat White brined cheese made from bovine milk and two commercial fat mimetics: chemical, physical and sensory attributes. *Int. Dairy J.,* **12**:525-540. http://dx.doi.org/10.1016/S0958-6946(02)00043-2

Sengul, M., Gurses, M., Dervisoglu, M. and Yazici, F., 2006. A survey on the some chemical and biochemical properties of Civil cheese, a traditional Turkish cheese. *Int. J. Fd. Prop.,* **9**:791-801. http://dx.doi.org/10.1080/10942910600596415

Simeone, M., Alfani, A. and Guido, S., 2004. Phase diagram; rheology and interfacial tension of aqueous mixtures of Na caseinate and Na alginate. *Fd. Hydrocoll.,* **18**:463-470.

Sipahioglu, O., Alvarez, V.B. and Solano-Lopez, C., 1999. Structure, physico-chemical and sensory properties of feta cheese made with tapioca starch and lecithin as fat mimetics. *Int. dairy J.,* **9**:783-789. http://dx.doi.org/10.1016/S0958-6946(99)00150-8

Smit, G., Smit, B.A., Wim, J.M. and Engels, J.M., 2005. Flavor formation by lactic acid bacteria and biochemical flavor profiling of cheese products. *FEMS Microbiol. Rev.,* **29**:591-610. http://dx.doi.org/10.1016/j.fmrre.2005.04.002

Srivastava, M. and Kapoor, V.P., 2005. Seed galactomannans: An overview. *Chem. Biodivers.,* **2**:295-317. http://dx.doi.org/10.1002/cbdv.200590013

Tahira, I., Mahmood, A., Saqlain, M., Hanif, N.Q. and Raja, G.K., 2014. Study of β-lactoglobulin milk protein variants in buffalo. *Pakistan J. Zool.,* **46**:549-552.

Tiwari, B.K., Muthukumarappana, K., O'donnell, C.P. and Cullen, P.J., 2010. Rheological properties of sonicated guar, xanthan and pectin dispersions. *Int. J. Fd. Prop.,* **13**:223-233. http://dx.doi.org/10.1080/10942910802317610

Varnam, A.H. and Sutherland, J.P., 1994. *Milk and milk products.* Chapman and Hall, New York. http://dx.doi.org/10.1007/978-1-4615-1813-6

Verbeke, W., 2006. Functional foods: Consumer willingness to compromise on taste for health? *Fd. Qual. Pref.,* **17**:126-131. http://dx.doi.org/10.1016/j.foodqual.2005.03.003

Volikakis, P., Biliaderis, C.G., Vamvakas, C. and Zerfiridis, G.K., 2004. Effects of a commercial oat-ı-glucan concentrate on the chemical, physico-chemical and sensory attributes of a low fat white brined cheese product. *Fd. Res. Int.,* **37**:83-94. http://dx.doi.org/10.1016/j.foodres.2003.07.007

Walstra, P., Wouters, J.T.M. and Geurts, T.J., 2006. *Dairy science and technology.* 2nd Ed. CRC Press, Taylor and Francis Group, Boca Raton, London, UK.

Wium, H., Pedersen, P.S. and Qvist, K.B., 2003. Effect of coagulation conditions on the microstructure and the large deformation properties of fat free Feta cheese made from ultra-filtered milk. *Fd. Hydrocoll.,* **17**:287-296. http://dx.doi.org/10.1016/S0268-005X(02)00079-6

Zisu, B. and Shah, N.P., 2007. Texture characteristics and pizza bake properties of low fat Mozzarella cheeses as influenced by pre acidification with citric acid and use of encapsulated and ropy exo-polysaccharide producing culture. *Int. Dairy J.,* **17**:985-997. http://dx.doi.org/10.1016/j.idairyj.2006.10.007