African Journal of Biotechnology Vol. 10(75), pp. 17265-17274, 28 November, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.2049

Full Length Research Paper

Development and optimization of sweet cream butter from buffaloes at cottage scale

Farzana Siddique[1], Kiran Sultan Khan[1], Asif Ahmad[1], Anwaar Ahmed[1], Muhammad Gulfraz[2] and Feroza Hamid Wattoo[2]

[1]Department of Food Technology, PMAS-Arid Agriculture University Rawalpindi, Pakistan.
[2]Department of Biochemistry, PMAS-Arid Agriculture University Rawalpindi, Pakistan.

Accepted 17 October, 2011

The research was intended to optimize and scientifically evaluate the traditional/ household butter making methods for getting good quality and yield of butter by standardizing cream fat levels and altering churning temperatures during butter making. In the present study, cream fat levels were standardized at 30, 35 and 40% and they were churned at different temperatures (8, 10 and 12°C) for making butter samples. The parameters used for quality assessment of butter were significantly influenced by cream fat levels and churning temperature and their interactions. Higher yield (88%) of butter with more total solids (89.17%) was obtained when cream standardized at 35% fat level and churned at 10°C while less non fat solids and moisture content was observed at these levels. A decreasing trend in pH was accompanied with an increase in fat level and churning temperature in all samples. Free fatty acids increased as a function of cream fat levels and churning temperatures. Most of the organoleptic parameters received higher scores when butter samples were prepared from the cream at 35% fat level and churned at 10°C. Using these conditions of fat levels and churning temperature, high quality butter can be produced at cottage scale.

Key words: Butter quality, churning temperature, optimization, cottage scale, sweet cream.

INTRODUCTION

Butter is a vital dairy product of Pakistan. It is extensively used by the bakery, chocolate and confectionary industries and the people utilize to spread on bread and in cooking. The manufacturing of butter with attractive characteristics has long been a problem (Douma, 2008). Preparation of butter from cream rather than whole milk is more efficient because of the high fat content (O'Mahony, 1988) present in the cream. Cream having fat crystals of 3-dimensional network shape (DeMan et al., 1988) gives a higher butter yield (Bot, 2008). If the size of fat globule is large then it tends to make softer butter than with small fat globules (Winton and Winton, 2006). Hence, the extent of solidification, and ratio of solid to liquid fat, size and shape of fat network (Hunt et al., 2000) is the primary determinant of butter consistency (Rohm and Weidinger, 1993).

Fat globules, crystalline fat, and an aqueous phase dispersed in a continuous oil phase form a multiphase emulsion called butter (Juriaanse and Heertje, 1988). The textural properties are linked to the underlying structures of fat globules, crystalline fat, and an aqueous phase dispersed in a continuous oil phase (Wright et al., 2001). The desired smoothness in the butter texture is obtained by working/kneading of butter during processing at appropriate temperatures, to establish fat crystalline network which is responsible for this smoothness in the butter texture (Hubner et al., 1957).

The most suitable treatment for the uniform butter consistency is mechanical treatment of butter (DeMan et al., 1988). During this process, cream undergoes a phase inversion as fat globule membranes are disrupted, globules coalesce and oil leaks out to form a continuous phase (Wright et al., 2001). Many physical and chemical factors are involved in achieving desired consistency and yield of butter: A physical treatment of cream such as

*Corresponding author. E-mail: farzanasiddiqueft@gmail.com. Tel: +92 321 566 9878.

churning is done (Bornaz et al., 1995). Churning of 40% cream yields almost equal amount of butter and butter milk (Morin et al., 2008). A high temperature during the churning process reduces the butter yield, as some of the butter fat liquefies and is lost with the buttermilk (Bot, 2008).

Pakistan is the 5th largest milk producing country with the annual gross production of 46,440,000 tons milk (GOP, 2010-11). In this region, due to poor infrastructure of dairy sector only 4% of the total milk production is converted into value added products in 19 dairy industries (PDDC, 2009; Pakissan, 2009; Siddique, 2010) of which only a few are engaged in butter production. In Pakistan, per capita consumption of butter is 3.08 kg so it is being imported annually (FAO, 2010). Most of the butter producers at cottage scale in the countryside using hand separator, in some developed areas having facility of electricity mechanical separator are also in use. On commercial scale, butter is being produced mechanically by some local dairy industries of Pakistan but this butter production is far less than the per capita consumption figure, so a lot of revenue had been spent over its import annually.

In Pakistan, most of the butter production is through traditional methods at household scale in countryside so there is a dire need to optimize butter making conditions at cottage level. The objective of present study was to analyze the effect of cream fat levels and churning temperature on the physiochemical characteristics of butter and evaluate scientifically the butter making method at cottage scale/ household level. Keeping in view all the problems faced during butter manufacturing at cottage level and its consumption status in Pakistan, present study was planned to improve quality and yield of butter by using different combinations of cream fat levels and churning temperatures.

MATERIALS AND METHODS

Samples preparation

The research was carried out in the laboratory of department of Food Technology PMAS-Arid Agriculture University, Rawalpindi. Cream samples were collected from the vicinity of Rawalpindi and Islamabad. The cream was analyzed for different physiochemical parameters to assess the quality of raw cream. The pH and acidity of the cream was adjusted by using mild acid and base solution. Then cream had been adjusted at 3 different fat levels (30, 35 and 40%). When the cream fat level was adjusted then pasteurization of cream was carried out by heating it at 63°C for 30 min. After pasteurization, it was kept in refrigerator overnight for aging. Cream container was put in warm or cold water bath to bring cream at appropriate churning temperature in the laboratory. Then churning was done at 3 different temperatures and butter was prepared. Now butter was scooped out. It was worked and shifted in different sizes of molds. Butter cutting was done by cutting knives then packaged and stored in refrigerator.

Physicochemical analysis of raw cream and butter

The samples of raw cream and butter were analyzed for fat by the method described by Pearson (1970), whereas acidity, pH, total solids, solids nonfat and free fatty acid were analyzed by using standard methods of AOAC (AOAC, 1990, 1996). Polenski and Riechert-Miessel value were determined for the samples of cream (AOAC, 1990). Additionally, ash, protein and lactose were analyzed in butter samples by following AOAC methods (AOAC, 1990).

Organoleptic evaluation

The butter samples were subjected to organoleptic analysis by a panel of five expert panelists (Guven and Karaka, 2002). Each sensory property including color, appearance, flavor, taste and texture was scored on a 9-point hedonic scale ranging from extremely unacceptable (1) to extremely acceptable (9) according to the method described by Larmond (1977).

Statistical analysis

The data thus obtained was statistically analyzed by applying analysis of variance under complete randomized design (CRD). To determine the effect of different cream fat levels and churning temperatures on physicochemical analysis of butter samples, two factor factorial analysis of variance was applied (Steel et al., 1997) by using MSTAT-C statistical software.

RESULTS AND DISCUSSION

Physicochemical analysis of cream

The physicochemical analysis (Table 1) of cream showed fat percentage of cream up to 46% (FLR, 1996). The pH and the acidity of the cream was 6.86 and 0.0108%, respectively and it was similar as that of the sweet cream (Douglas, 2006). The protein content was found to be in close association to the double cream that is 0.368% as reported by Collins (2007). The sweet cream contains 0.20% free fatty acid which was found in the range as studied by Walstra et al. (1999). Riechert Miessel and Polenski Value of cream were found in the range of 26-34 and 1.5-3.5, respectively (Malhotra, 2003).

Fat

The statistical results regarding the fat content of the butter samples made by different cream fat levels and churning temperatures (Table 2) revealed that fat content of the butter differed significantly (*$P<0.05$*) between different cream fat levels and churning temperature treatments. The Figure 1 reflected that highest butter fat (89%) was achieved by using cream of 35% fat level and churning the samples at 10°C temperature.

The present study shows increasing trend in the butter yield with decreased temperature; this might be due to the reason that low temperature churning ends in rapid fat coagulation and it leads to large butter granules which have more fat content. These findings are well supported by Sun et al. (2008) who reported that low temperature churning gives rapid coagulation of butter fat. While, in

Table 1. Raw cream composition and other analysis.

Analysis	Cream*
Fat (%)	46%
Ash (%)	0.8%
Acidity (%)	0.108%
pH	6.86
Protein (%)	0.368%
Lactose (%)	2.696%
Total solids (%)	49.6%
Non fat solids (%)	3.6%
Free fatty acids (%)	0.20%
Polenski value	2.7
Riechert Miessel value	29.2

*All the values are means of three replications.

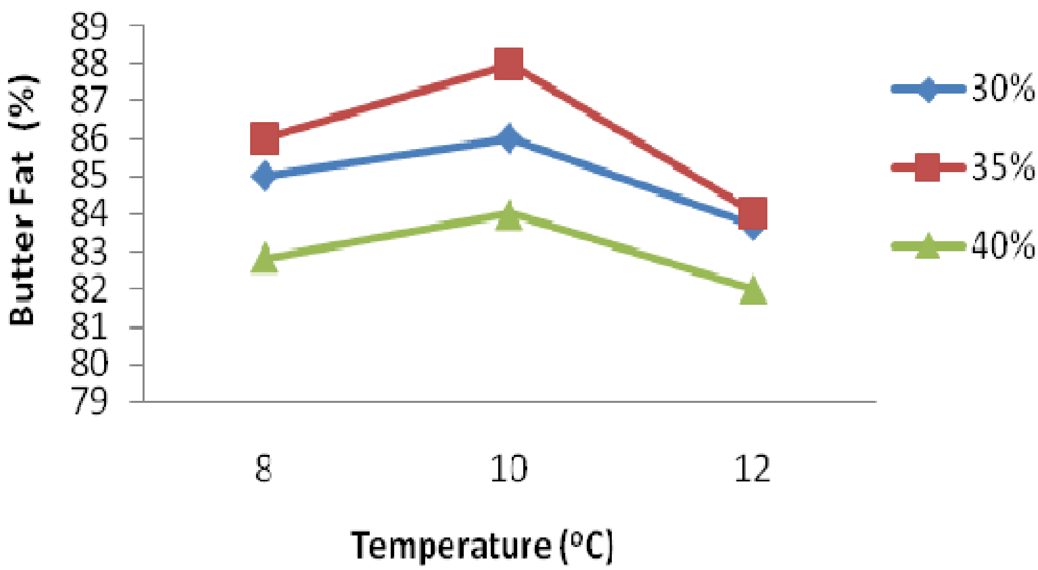

Figure 1. Effect of different cream fat levels and temperatures on fat percentage of butter samples.

case of cream fat levels, high cream fat gives low fat content. These results further supported by the findings of Funahashia and Horiuchi, (2008) who reported that in high fat cream small butter globules formation occur with high moisture and low fat content. The results further showed that more fat percentage was found at cream of 35% fat level and 10°C churning temperature. These findings were in accordance with the work of earlier scientists Bilal et al. (2000) who reported that maximum fat percentage was found in butter prepared by 35% fat cream and churning temperature of 10°C. The present study was further supported by Hunziker (1940) who suggested that optimum cream fat level lies between 30 and 35% for making butter. Mathur (1968) also conducted the study on butter and concluded that 40% fat cow cream is suitable for making butter in Sub-Continent. The findings of the other scientist (Douglas, 2006) confirmed the pre-sent results about the churning temperature treatments that good fat content was obtained by churning within the range of 7-12°C. While, O'Mahony (1988) confirmed that the best temperature for churning is between 10-12°C.

pH

The statistical results regarding the effect of the fat levels of cream and churning temperatures presented in Table 2 exhibited that the pH of butter samples was significantly ($P<0.05$) influenced by these two factors. Further, Figure 2 shows a decreasing trend in pH with the churning temperatures. The interactive effect of different cream fat levels and churning temperature also varied significantly

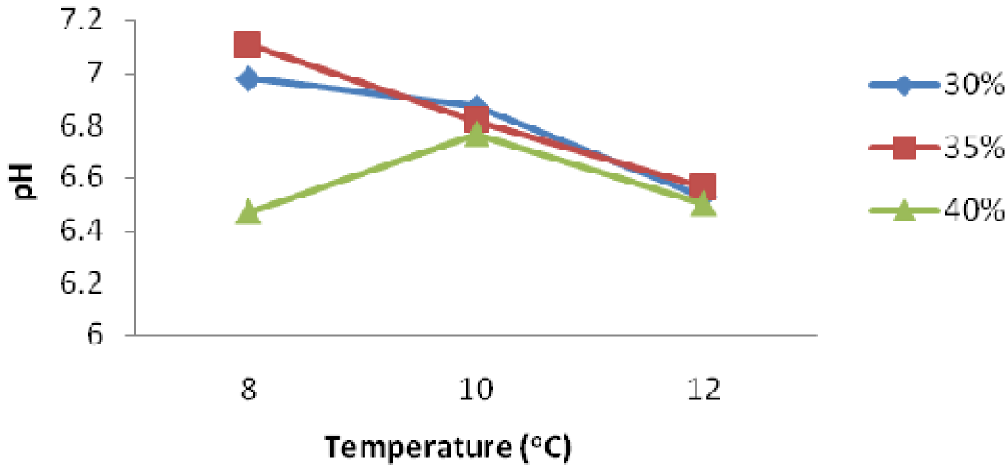

Figure 2. Effect of different cream fat levels and temperatures on pH of the butter samples.

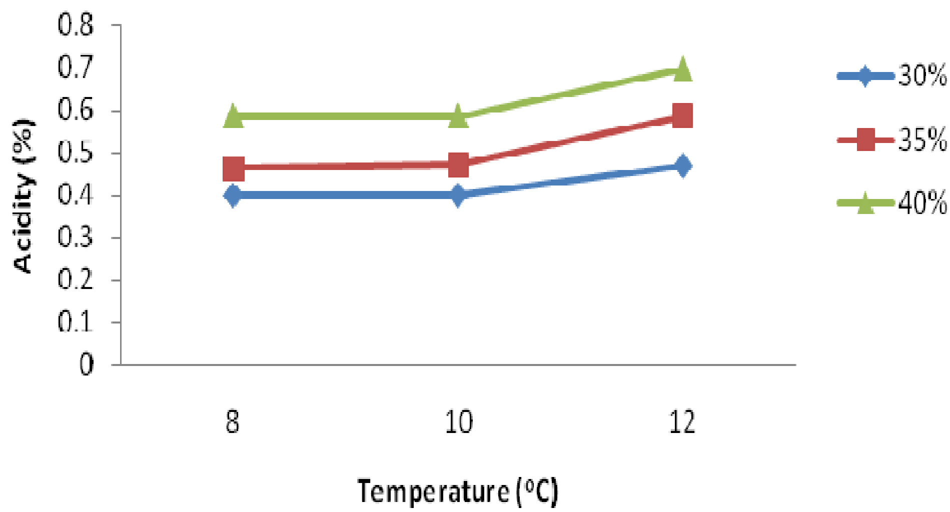

Figure 3. Effect of different cream fat levels and temperatures on acidity of the butter samples.

(P<0.05) for fat contents (butter yield) of the butter samples.

A deceasing trend in pH with increase in fat level and temperature (Figure 2) may be attributed to water addition for washing butter granules. Large fat granules of high fat cream comes to the surface rapidly and require less water for washing so low pH was recorded. This study was well supported by Fox and McSweeney, (1998) that extent of dilution reduces acidic ions concentration and tends to increase the pH. While, a declining trend in pH with increase in temperature might be attributed to the change in the salt system. These results are also supported by Fox and McSweeney, (1998) who reported that with the increase in temperature calcium phosphate concentration increases and pH decreases. The range of pH in the present study is confirmed by the results of the Riel et al. (1956) who found that pH of fresh washed sweet butter ranged between 6.4- 7.2.

Acidity

The results pertaining to the effect of the cream fat levels and churning temperatures on the acidity of the butter samples presented in Table 2 showed that the acidity of butter samples is significantly (P<0.05) affected by fat levels of cream and churning temperatures. The interactive effect of cream fat level and churning temperatures also exhibit significant (P<0.05) effect on acidity of the butter samples. The increasing trend in the acidity of butter samples was observed with increase of temperature and cream fat percentage (Figure 3).

In the present study, a linear relation of acidity with

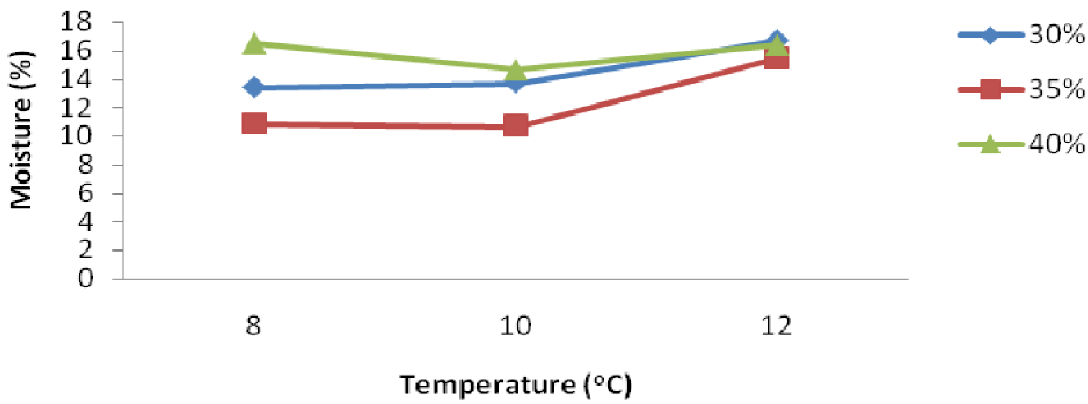

Figure 4. Effect of different cream fat levels and temperatures on moisture of the butter samples.

Table 2. Mean squares for fat, pH, acidity and moisture of butter samples.

SOV	d.f.	Fat	pH	Acidity	Moisture
Fat (F)	2	22.028*	0.160*	0.091*	18.782*
Temperature (T)	2	41.028*	0.276*	0.030*	34.289*
FxT	4	1.806*	0.094*	0.001*	1.548*
Error	18	2.435	0.006	0.003	2.095

* = Significant ($P<0.05$).

cream fat levels might be attributed to high fat content of the butter samples. These findings are in well accordance with Rodriguez et al. (2003) who reported that high fat content of butter, reaction due to phosphate, low minerals content and organic acids in butter samples contributed to low acidity. According to the present study, butter samples churned at lower temperature gives low acidity and high pH values with high fat content in butter samples. These results are further supported by Fox and McSweeney, (1998) that lowering the temperature tends to increase the pH and it ultimately decreases the acidity. The results are further confirmed by the study conducted by Baer et al. (2001) who concluded that acidity of the fresh cream butter samples were in the range of 0.3 to 0.6%.

Moisture

The effect of cream fat levels and churning temperatures on the moisture content of butter samples (Table 2) reflected that it differed significantly ($P<0.05$) due to these two factors. The interactions of cream fat levels and temperatures showed a significant ($P<0.05$) effect on the moisture content. Similar moisture content was assessed in butter samples when cream churned at 12°C temperature (Figure 4).

In the present case while observing moisture content with respect to cream fat levels, highest moisture content (16%) found in butter samples made from high fat cream (40%) might be due to the increase in free fatty acids. These findings are supported by Funahashia and Horiuchi, (2008) who reported that the increase in free fatty acids is due to the churning which influence the moisture content. Churning at low temperature resulted in low moisture content due to the formation of large butter globules with good drainage of butter milk. The more pronounced change in moisture (%) might be due to the significant change in fat level of butter samples (Walstra, 1999). The results of other researchers (Sukumar, 1968; Bilal et al., 2000) are closely associated with the present findings, who reported that lowest moisture content was obtained by the butter made from 35% fat cream and churned at 10°C temperature.

Total solids

The effect of different cream fat levels and temperatures on the total solids of butter samples depicted in Table 3 exhibited that these two factors significantly ($P<0.05$) influenced the total solids in butter samples. The total solids among butter samples also differed significantly ($P<0.05$) as a function of cream fat level and temperature treatments. The curvilinear trend was observed in the butter samples for total solids (Figure 5) when prepared from different fat levels and at different churning temperatures.

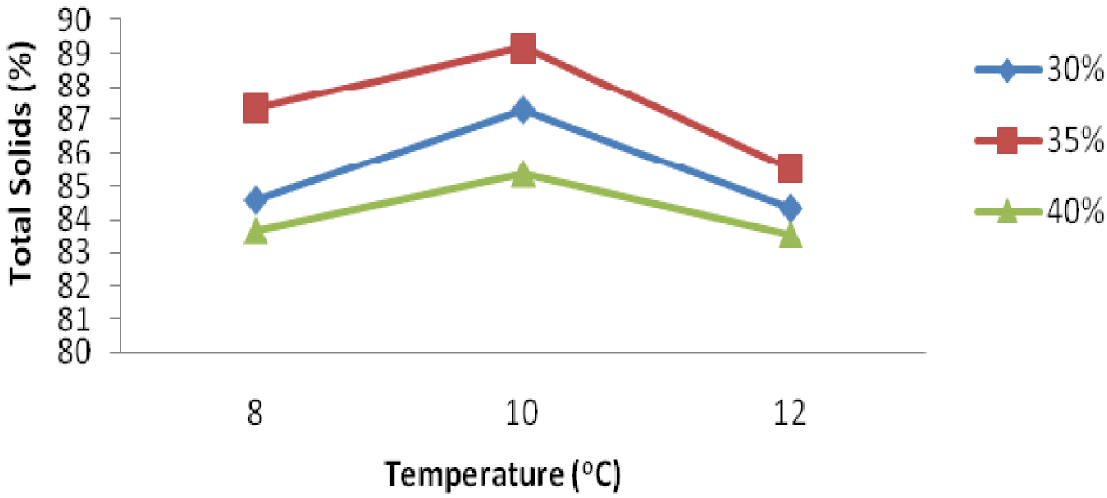

Figure 5. Effect of different cream fat levels and temperatures on total solids of the butter samples.

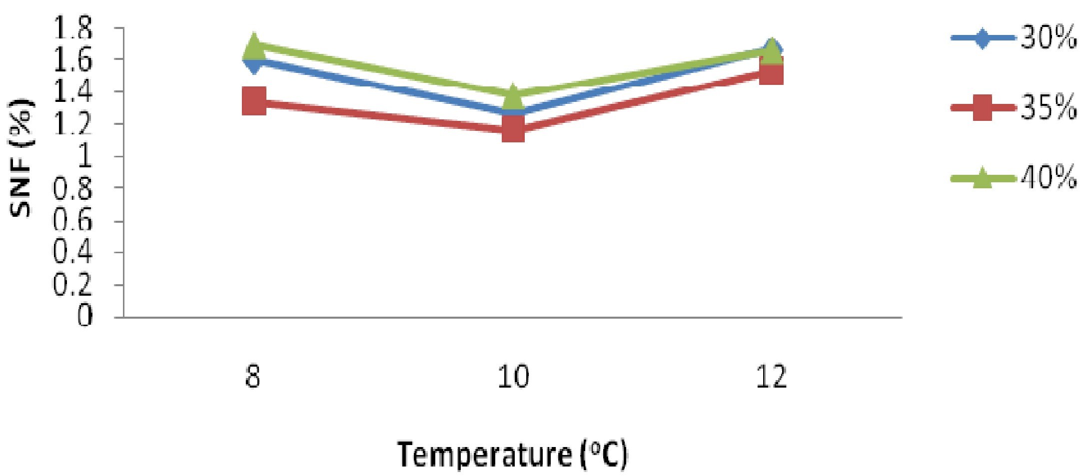

Figure 6. Effect of different cream fat levels and temperatures on SNF of the Butter Samples**.**

In present study, low total solids in case of butter made by churning at 12°C might be due to the low fat recovery in the butter samples. These results were associated with Yilma et al. (2007) who reported that low fat content indicated low total solids. Higher total solids content in butter samples was found at 35% cream fat level and 10°C churning temperature. This might be attributed to the lower moisture and high fat content in the butter samples at this combination of cream fat levels and churning temperatures. These results were also supported by the study of Wright et al. (2001) who reported that low temperature gives high total solids. The present results confirm the finding of Baer et al. (2001) that total solid content was found to be 83% for the butter containing 81% fat. The results of another researcher (Jinjarak et al., 2006) are also associated with the present findings, who observed the total solids content in different types of butter like cultured, whey and sweet cream butter; it was found 82-87% in sweet cream butter as observed in the present study.

Non fat solids

Non fat solids in the butter samples is significantly (*P<0.05*) affected by cream fat levels and churning temperature treatments (Table 3). The interaction among cream fat level and temperature treatments on non fat solids of butter samples also varied significantly (*P<0.05*). The Figure 6 reveals a curvilinear trend for non fat solids of butter samples.

The results of the present study for non fat solids was attributed to the butter texture containing large and good structure fat globules had fewer amounts of other solids

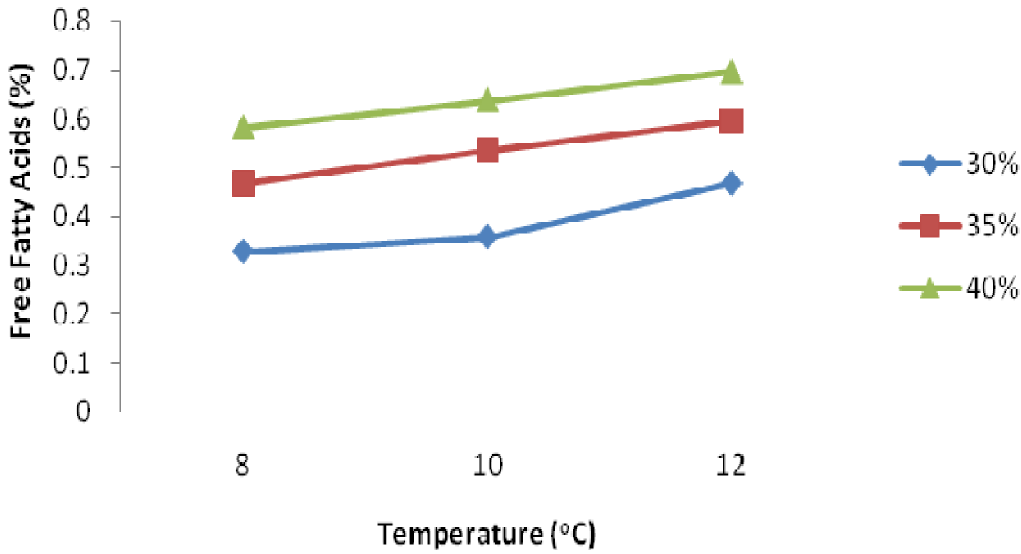

Figure 7. Effect of different cream fat levels and temperatures on free fatty acids of the butter samples.

Table 3. mean squares for total solids, non fat solids and free fatty acids of butter samples.

SOV	d.f.	Total solid	Non fat solids	Free fatty acid
Fat (F)	2	18.810*	0.129*	0.023*
Temperature (T)	2	34.338*	0.303*	0.056*
FxT	4	1.556*	0.012*	0.032*
Error	18	2.088	0.015	0.089

* = Significant (*P<0.05*).

(observed in the present study). The findings of the study are supported by Walstra et al. (1999) who reported that non fat solids were the amount of solids present in butter fat globule except fat. Further, the SNF ranged 1.5-2.0% (Figure 6) in the present study is in accordance with Keogh (2006) who reported that SNF in sweet butter samples would be up to 2%.

Free fatty acids

The statistical results regarding the effect of cream fat levels and churning temperatures on the free fatty acids of the butter samples given in Table 3 reveals that fat levels, churning temperatures and their interactions showed significant (P<0.05) influence on the free fatty acids of the butter samples. The ascending trend for free fatty acids as a function of cream fat levels and churning temperatures was ranged 0.3-0.6% (Figure 7) in different butter samples.

A declining trend in free fatty acids with decrease in temperature might be attributed to the finding of Hunziker (1948) who reported that free fatty acids value increased during churning and reduced with decrease in temperature. High fat content give rise to more free fatty acids content so with the increase in fat percentage of cream free fatty acids in end product also increased. These findings were closely associated with the findings of Walstra et al. (1999) who concluded that high fat cream churning give rise to more free fatty acids content. The present results is also confirm by Uphus (1996) who found that free fatty acids in sweet cream butter samples ranged between 0.3 to 0.6%.

Organoleptic evaluation

Color

The statistical results of the effect of cream of different fat levels and temperature treatments on the color scores of the butter samples in Table 4 depicted that scores assigned to the butter samples for color vary significantly (P<0.05) by the cream fat levels.

In the present study, the butter samples which obtained lowest score for color had high moisture content and it

Table 4. Mean squares for color, appearance, flavor, taste and texture of butter samples.

SOV	d.f.	Color	Appearance	Flavor	Taste	Texture
Fat (F)	2	1.767*	1.285*	0.148^{NS}	0.551*	0.568*
Temperature (T)	2	0.107^{NS}	0.267*	1.543*	0.723*	0.101^{NS}
FxT	4	0.061^{NS}	0.103^{NS}	0.089^{NS}	0.038^{NS}	0.197*
Error	36	0.023	0.031	0.035	0.032	0.024

* = Significant (*P<0.05*), NS = Non-significant.

might be attributed to dispersion of large air cells in the butter samples. These finding were well supported by Clark et al. (2008) that color of the butter is affected by high moisture content, presence of salt, large size of air cells and their dispersion in the butter fat granules.

Appearance

The statistical results regarding the effect of cream of different fat levels and temperature treatments on the appearance scores of the butter samples revealed in Table 4 that score assigned for the appearance of butter samples differ significantly (*P*<0.05) by the cream fat levels and churning temperature.

The findings of the present study regarding the appearance scores of the butter samples manufactured from 35% fat levels got the highest scores had more fat percentage, lowest moisture content, maximum total solids and low non fat solids that contributed towards the good appearance of butter. The results of the present work was confirmed by Douglas (2006) who concluded that butter which had good fat percentage, moisture percentage, solids, non fat solids, color, texture and taste would give good appearance.

Flavor

The statistical results of the effect of cream of different fat levels and temperature treatments on the scores assigned to the flavor of the butters in Table 4 revealed that they did not show significant (*P*>0.05) effect on the scores of butter flavor.

The results of the present study showed that fat level did not show significant change on the scoring of butter samples for flavor. These findings are supported by Mallia et al. (2008) who indicated that flavor of sweet butter was perceived as aroma by smell sensation and sweet cream butter have not as many aroma producing compounds. The present results of flavor scores are also supported by Clark et al. (2008) that lower flavor profile is associated with unsalted butter. The present results of lower scores for flavor at 12°C might be attributed to the volatile fatty acids in the butter samples which are influenced by the high temperature. These findings are supported by Mallia et al. (2008) who contributed that aroma is attributed to the presence of volatile acids. These findings are further supported by Wright et al. (2001) who reported that butter flavor loss is due to inter-esterification at high temperature.

Taste

The statistical analysis regarding the effect of cream of different fat levels and churning temperature treatments on the taste scores of the butter samples in Table 4 exhibited that different cream fat levels showed significant (*P*<0.05) effect on the scores of taste. Similarly, churning temperature also showed significant (*P*<0.05) effect on taste scores of butter samples.

The findings of the present study showed that butter sample which achieved good texture scores (as observed in the present study) get good taste scores. These results are supported by the conclusion of Bouska (1934) who indicated that taste is attributed to the texture of the butter and how it taste in the mouth.

Texture

The results of the effect of cream of different fat levels and temperature treatments on the texture scores of the butter samples revealed that different cream fat levels showed significant (*P*>0.05) effect on the scores of texture. The texture of butter samples also differed significantly (*P*<0.05) as a function of cream fat level and temperature treatments.

The finding of the butter texture scores might be due to the low iodine value in the range of 25-27, as low iodine value attributed to less oxidation and good texture. These findings are also supported by facts given by Bornaz et al. (1993) who concluded that butter texture was dependent upon the low iodine value (25-27). Moreover, the butter with good fat content gives good texture scores. This result is also supported by Bobe et al. (2003) that fatty acids content of butter affect the texture of butter samples and 80% variation in texture is attributed to fatty acids, which gives desirable texture (Brunner et al., 1974).

Conclusively, the butter samples got highest scores prepared from the cream at 35% fat level and churned at 10°C for overall acceptability (Figure 8).

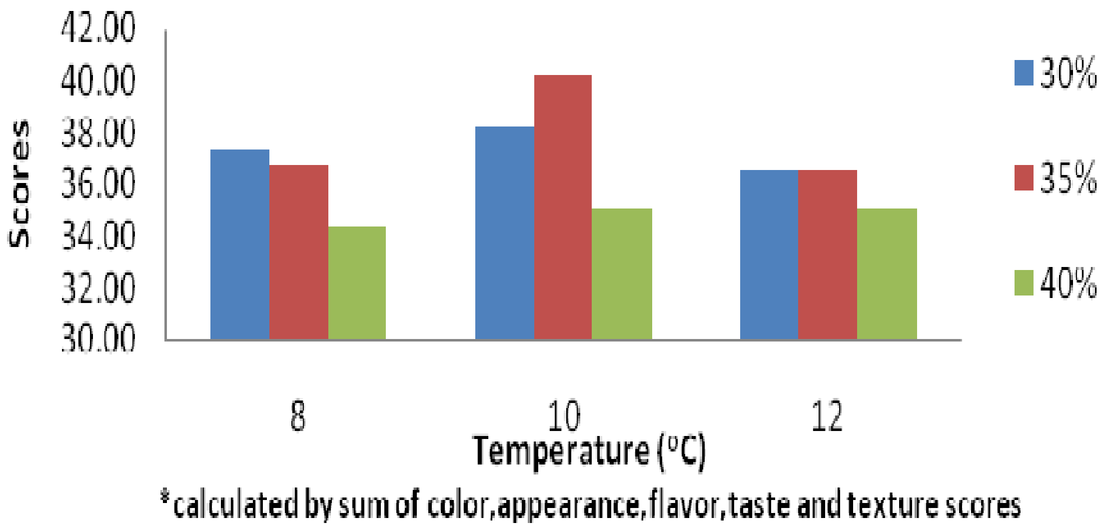

Figure 8. Effect of different cream fat levels and temperatures on overall acceptabilityof butter samples.

Conclusion

Higher yield of butter with more total solids was obtained when cream standardized at 35% fat level and churned at a temperature of 10°C which showed less non fat solids and moisture content. Organoleptic properties for color, appearance, taste and texture was optimized when butter samples were prepared with 35% fat at a churning temperature of 10-12°C. Thus, cream fat levels and churning temperature affected butter yield and quality by influencing the quality parameters. Conclusively, this work was helpful to develop good quality and yield of butter at cottage scale/ household level butter production in Pakistan.

REFERENCES

AOAC (1990). Official methods of analysis (15th ed.). Association of Official Analytical Chemists, Virginia. 22201, Arlington.

AOAC (1996). Official methods of analysis. Association of Official Analytical Chemists, Virginia, 22201, Arlington.

Baer RJ, Ryali J, Schingoethe DJ, Kasperson KM, Donovan DC, Hippen AR, Franklin ST (2001). Composition and properties of milk and butter from cows fed fish oil. J. Dairy Sci. 84(2): 345-353.

Bilal A, Khan R, Aziz T, Ullah J (2000). Study of butter, prepared at different conditions of temperature and cream fat level for optimization. Sarhad. J. Agric. 16(3): 347-351.

Bornaz S, Fanni J, Parmentier M (1995). Heat-treatment of cream: A model of the butter texture response in relation with triglyceride composition. J. Am. Oil Chem. Soc. 72: 163.

Bot C (2008). Butter making (Practical Action Brief). Website: http://www.appropedia.org/Butter_making_(Practical_Action_Brief). Accessed on 01 August, 2009.

Collins A (2007). Sodium in cream. Website: http://www.annecollins.com /sodium_diet/sodium-cream.htm. Assecced on 01 August, 2010.

DeMan JM, Beers AM (1988). Fat crystal networks-Structure and rheological properties. J. Text. Stud. 18(4): 303-318.

Douglas G (2006). Butter Manufacture. Dairy Science and Technology Education, University of Guelph, Canada.

Douma M (2008). How do you make butter? In Butter through the Ages. Website: http://www.webexhibits.org/butter/making.html. Accessed on 01 August, 2009.

Food and Agriculture Organization (2010). Highlights of the OECD-FAO outlook 1970-2017. Website: http://www.stats.oecd.org/Index.aspx? DataSetCode=HIGH_ AGLINK_ Accessed on 23 August.

Food Labelling Regulations (1996). The Food Labelling Regulations. Website: http://www.opsi.gov.uk/si/si1996/uksi_19961499_en_1.htm. Accessed on 23 August, 2009.

Fox PF, McSweeney PLH (1998). Dairy chemistry and biochemistry. Blackie Acad. Professional. New York, USA.

Funahashia H, Horiuchi J (2008). Characteristics of the churning process in continuous butter manufacture and modeling using an artificial neural network. Int. Dairy J. 18: 323-328.

GOP (2011). Governament of Pakistan. Economic survey 2010-2011. Economic advisers wing, Fin. Div. Islamabad.

Guven M, Karaka OB (2002). The effect of varying sugar content and fruit concentration on the physical properties of vanilla and fruit ice cream-type frozen yoghurts. Int. Dairy Technol. 55: 27-31.

Hubner VR, Thomsen LC (1957). Spreadability and hardness of butter. II. Some factors affecting spreadability and hardness. J. Dairy Sci. 40(7): 834-838. (The year in the work does not correspond with year in reference).

Hunt N, Buckin V (2000). Temperature dependence and the effects of heat treatment on the rheological properties of various butters. Progr. Colloid Polymer Sci. 115: 320-324.

Hunziker OF (1948). The physical aspects of butter. Milchwissenschaft Milk Sci. Int. 3(3): 75-82.

Hunziker OF (1940). The Butter Industry, The Author, La Grange. Illinois.

Jinjarak S, Olabi A, Jimenez-Flores R, Walker JH (2006). Sensory, functional, and analytical comparisons of whey butter with other butters. J. Dairy Sci. 89: 2428–2440.

Juriaanse AC, Heertje I (1988). Microstructure of shortenings, and butter: A review. Food Microconstruct. 7: 181-188.

Keogh MK (2006). Chemistry and technology of butter and milk fat spreads. Adv. Dairy Chem. Lipids, 2: 333-363.

Larmond E (1977). Laboratory methods for sensory evaluation of foods. Ottawa. Canada. Dep. Agric. Pub. pp. 1637-1674.

Malhotra VK (2003). Biochemistry, 6th Edition. Jaypee Brothers Med. Pub. Ltd. New Delhi. (Provide page number).

Mathur BN (1968). Outlines of Dairy Technology. Oxford University Press, Delhi.

Morin P, Pouliot Y, Britten M (2008). Effect of buttermilk made from

creams with different heat treatment histories on properties of rennet gels and model cheeses. J. Dairy Sci. 91: 871–882.
O'Mahony F (1988). Rural Dairy Technology-Experience in Ethiopia. Manual Dairy Tech. Unit. International Livestock Center for Africa. Addis Ababa, Ethiopia, p. 4.
Pakistan Dairy Development Company (2009). The white revolution-Doodh darya. Township, Kotlakhpat, Lahore.
Pakissan (2009). Dairy sector shows huge potential for growth. Website: http://www.pakissan.com/english/news/newsDetail.php?newsid=21057. Accessed on 1 September.
Riel RR, White AH, McGugan WA (1956). Washed and non washed butter. II Chemical Factors. J. Dairy Sci. 40: 1351-1358.
Rodriguez A, Bunger A, Castro E, Sousa I, Empis J (2003). Development and Optimization of Cultured Goat Cream Butter. J. Am. Oil Chem. Soc. 80(10): 987-992.
Rohm H, Weidinger KH (1993). Rheological behavior of butter at small deformations. J. Text. Stud. 24: 157- 172.
Siddique F (2010). Studies on agegelation and sedimentation of UHT milk during storage. PhD. Thesis. National Instit. Food Sci. Technol. Uni. Agric. Faisalabad. Pakistan.
Steel RGD, Torrie GH, Dickey D (1997). Principles and Procedures of Statistics: A Biochemical Approach, 3rd Ed. Mc Graw-Hill, New York, USA.
Sukumar D (1968). Outlines of Dairy Technology. Oxford University Press, Delhi. p. 351.
Sun J, Kitamura Y, Satake T (2008). Application of stirling cooler to food processing: feasibility study on butter churning. J. Food Eng. 84(1): 21-27.
Uphus A (1996). Milk fat processing. Westfalia Separator Food Tech. GmbH. pp. 27.
Walstra P, Geurts TJ, Noomen A, Jellema A, Van Boekel MAJS (1999). Dairy Technol. Marcel Dekker, Inc. New York, pp. 498.
Winton AL, Winton KB (2006). Milk and milk products. Agrobios, Jodhpur, India. p. 160.
Wright AJ, Scanlon MG, Hartel RW, Marangoni AG (2001). Rheological properties of milkfat and butter. J. Food Sci. 66: 1056-1071.