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UTILIZATION OF CONCENTRATED AND LACTOSE HYDROLYZED WHEY IN THE PREPARATION OF BUNS

Somashekara Reddy P. V.*, Surendra Nath B. and Priyatam Reddy K.[1]

Dairy Chemistry and Bacteriology Section, National Dairy Research Institute, Bangalore-560 030.

[1]Dairy Science College, KVAFSU, Bidar – 585401.

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***Correspondence for Author**
Somashekara Reddy P.V.
Dairy Chemistry and Bacteriology Section, National Dairy Research Institute, Bangalore-560 030.

ABSTRACT

Whey is a major byproduct of the dairy industry generated during the manufacture of cheese, *paneer, chhana, chakka* and casein. It is highly nutritious, containing about 40-50% of total solids, 80-90% lactose, 20% proteins, 70% minerals and almost all the water soluble vitamins of whole milk from which it is obtained. Disposal of whey as practiced by the dairies not only causes the loss of these valuable nutrients but also incurs cost for the treatment of whey. Utilization of whey in the preparation of food products often requires concentration to increase the total solids (TS) level, which results in an increased lactose level in the products. In the present study, process was optimized to hydrolyze lactose in concentrated paneer whey and utilize the same for the preparation of buns, an important bakery product. Colorimetric methods for estimation of lactose and thereby evaluation of degree of hydrolysis (DH) of lactose in concentrated paneer whey were standardized. Lactose in concentrated paneer whey could be hydrolyzed up to ~60% in 60 min using lactozyme under optimal conditions of hydrolysis. Concentrated paneer whey (up to 20%TS) could be utilized in the preparation of buns with desirable quality. Trials showed that replacement of maida with 25% wheat flour yielded buns with quality comparable to that of control product. Due to hydrolysis of lactose and release of sweeter monosaccharides, sucrose required in the bun preparation could be reduced from 10 to 7%. Utilization of concentrated lactose hydrolyzed whey (20% TS and 60% DH) and wheat flour (25% replacement of maida) required necessary modifications for achieving optimal proofing and baking. The yield of buns calculated on the basis mass balance of ingredients was 73.5 and 76.86% for control product

prepared using water and experimental buns prepared using concentrated, lactose hydrolyzed paneer whey respectively. Sensory and textural quality of the experimental buns was observed to be better than that of the control product. The experimental buns had 28.90, 9.95, 12.30, 1.72, 47.43 and 1.42% respectively of moisture, fat, protein, lactose, total carbohydrates and ash. The corresponding values for the control were 30.46, 9.64, 11.81, 0.75, 46.9 and 1.3% respectively. Experimental and control samples packed in LDPE pouches had a shelf life of 4 days at 30^0C. This investigation showed that concentrated (20% TS) and lactose hydrolyzed (≈60% DH) paneer whey and wheat flour (25% replacement of maida) could be successfully utilized for the production of buns.

KEYWORDS: Whey, Lactose hydrolysis, Buns, concentration of lactose.

INTRODUCTION

Whey is the largest by-product of the organized dairy industry, generated during the manufacturing of cheese, *paneer, chhana, chakka* and casein. The world production of whey is estimated to be about 165 million tonnes per annum (Gupta and Singh, 2007). In India, the production of whey was estimated to be about 4.84 million tonnes per annum, consisting 290 million kilograms of valuable milk nutrients (Naik et al, 2007). Whey is usually disposed by the dairies after treatment in effluent treatment plants. This not only causes the loss of valuable nutrients but also incurs cost for the treatment of whey before disposal.

Whey is a major source of lactose and nutritionally superior proteins. It also contains minerals and water soluble vitamins. Considering the nutritional and functional virtues of whey, several attempts have been made earlier to utilize whey solids, which include extraction of whey proteins (Werner, 1981) and preparation of soups (Arora and Jha, 2005), beverages (Keerthana and Reddy, 2006), coffee drinks (Dhaka *et al*., 2002), cream yoghurt (Kulkarni *et al*., 1990), bakery products (Jarita and Kulkarni, 2007), cereal and millet based health foods (Pradeep, 2009; Rasool, 2009).

One of the limitations to utilize liquid whey for the preparation of food products is its low level of total solids (5-6%). Hence, whey needs to be concentrated for increasing the level of solids to an optimum level. However, when whey is concentrated, lactose, the chief ingredient of whey, would also increase. High level of lactose in food products may cause problems in lactose intolerant people as well as cause some undesirable textural changes in

food products due to lactose crystallization. Lactose hydrolysis in concentrated whey can alleviate this problem.

Indian bakery industry is the largest among the processed food industries. Annual turnover to this industry is estimated to be is more than Rs.3000 crores. The unorganized sector contributes to about 70% of the total production in India. The per capita consumption of bakery products in India is about 2.3 kg per annum as against 50-100 kg of bread and 10-15 kg biscuits in western countries (www.bakerymag.com). The growth rate for bakery products is estimated at 10% per annum.

Bread is one of the most widely consumed processed foods in the country. Because of changing lifestyles a large number of people especially in urban areas are adopting bread as a regular food and are willing to pay a price for the quality. As a result many new food chains have sprung up specializing just in bread and offer up to 100 varieties (Rao, 2005). Bun is a small, usually sweet and dome shaped bakery product, with a flat bottom, soft crust and crumb, spongy body, light texture and golden brown colour of the outer shell or crust. All the characteristics of bun are similar to bread and they differ only in the size, shape and hardness. In the southern region of India the traditional and organized bakery industry has grown considerably. These businesses are running on small and medium scale and the processors are constantly on the look out for newer products, cost reduction and value addition. The use of whey solids in an appropriate manner is likely to provide low cost solids to the bakery product manufacturers besides resulting in newer and high nutritional value products. As already indicated *paneer* whey is available in large quantities as a byproduct of the Indian dairy industry. Since most of it is presently being drained out causing a burden on the effluent treatment plant, it is worthwhile to study its application in bakery products. While several attempts have been made to enrich the nutritional quality of bakery products like bread and biscuits by utilizing wheat flour, multi grain flour, milk solids, supplements such vitamins and minerals, few attempts were made on the utilization of *paneer* whey in these products.

Nutritional quality and functional properties of buns can be enhanced by utilizing concentrated lactose hydrolyzed whey. Utilization of whole wheat flour in place of refined wheat flour can further enhance the nutritive value of the buns. A project on these lines is proposed with the following objectives.

- Optimization of the process for utilization of concentrated and lactose hydrolyzed whey in the preparation of buns.
- Evaluation of quality of buns made utilizing concentrated and lactose hydrolyzed whey.

MATERIALS AND METHODS

Preparation of paneer whey

Milk from the experimental dairy of the institute standardized to 4.5 per cent fat and 8.5 per cent SNF was used for preparation of paneer. Forty liters of milk was boiled and allowed to cool to about 80^0C with occasional stirring to avoid skin formation. Three litres of 2% citric acid solution was added for coagulation of milk. Whey was separated from coagulum by filtration using a clean musclin cloth. The whey was held for another 2 min at 85^0C before drawing it into a clean container for further processing. About 35 litres of whey was obtained in each batch.

Concentration of whey

Concentration of whey was done in a pilot scale batch type vacuum evaporator (APV, Calcutta) of 20 lit capacity. Twenty liters of paneer whey was cooled to 55-60^0C, and fed into the evaporator. Care was taken to avoid foaming of whey in the evaporator and its escape along with the condensate. The whey was condensed at 55^0C under vacuum (24" Hg) for approximately 40 min. Steam under 10 lb pressure was passed through the calendria to heat the whey and maintain a temperature of 55^0C. Whey concentrated, condensed to about 6 times, was checked for approximate level of total solids by refractometer. The condensed whey was drawn into a clean container and level of total solids was adjusted to desired level by addition of distilled water.

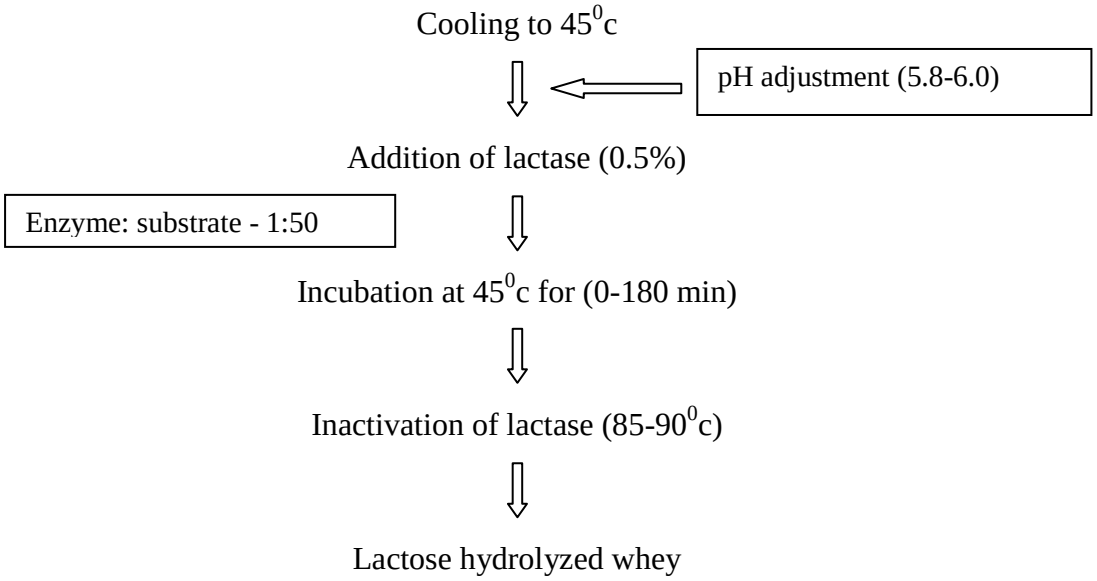
Lactose hydrolysis: Lactose in the concentrated paneer whey was hydrolyzed using lactase (Lactozyme Pure 2600L, with declared activity of 2600 LAU/g from Novozymes) and the process of hydrolysis was given in Fig 1.1. (Somashekara reddy P.V. and Surendra nath B., 2011)

Concentrated paneer whey (15%, 20% and 30% TS)

⇩

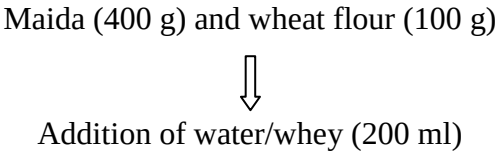
Pasteurization (72^0c/15 sec)

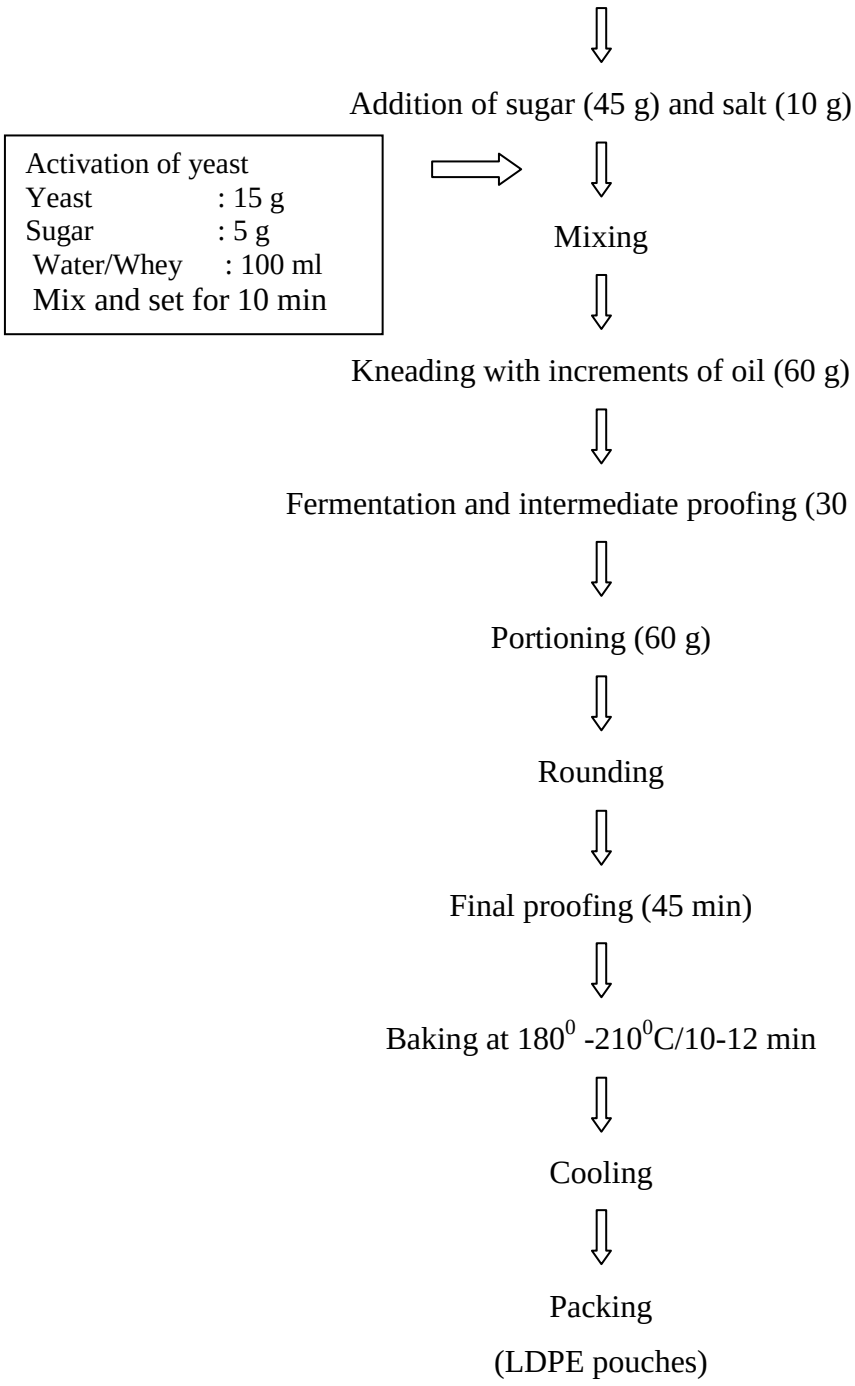
⇩



Preparation of bun

In the preparation of bun, fifteen grams of baker's yeast((Angels Company) was dissolved in 100 ml of luke warm water with about 5 g of sugar (Janata Bazaar) and was allowed to set for 10 min. Later 45 g of sugar and 10 g of salt (Tata) were mixed to the water containing yeast. Five hundred grams of maida (Ashirwada) was sieved and mixed with water containing yeast, sugar and salt along with 200 ml of water and mixed well. For the production of buns utilizing whey solids, paneer whey concentrated to 15, 20, 25 and 30% TS and lactose hydrolyzed to different degrees- 0, 30 and 60%, was used in place of water. Further, maida was partially replaced (25 and 50%) with wheat flour for production of buns with increased fibre content. Sixty grams of refined oil (Gemini) was used for kneading the dough into a smooth texture. The dough was kept aside at room temperature for 30 min for fermentation and intermediate proofing. The dough was kneaded back and forth and divided into small portions of approximately 60 g, followed by rounding of the divided portions. The rounded portions were then placed in a greased tray. The tray was maintained at 30^{0}C covered with cloth for final proofing until the dough rose to double of the initial size and then baked at 180^0- 210^{0}C for 10-12 min. The buns were then cooled slowly to room temperature. The product is packed in LDPE pouches and the process for the production of buns as flow diagram is given in Fig 1.2.





Analysis: the total solids (TS) of whey (IS: 1981), degree of lactose hydrolysis by Malpress and Morrison (1949).The bun samples were analyzed for TS, fat, total protein, ash (AOAC, 2005) lactose based on calculation (level of TS used) and total carbohydrate (by difference), acidity (IS: 11766-1986), pH (Cyber Scan 2500 pH). A digital water activity meter (Rotronic Hygroskop, Switzerland model: BT-RS1) and the microbiological of buns for Standard plate count and Yeast and mold (IS 1981). The sensory evaluation was done by a select panel of judges on a 9-point scale (9 most and 1 least acceptable) for appearance, flavour, body and texture and overall acceptability.

The rheological parameters were assessed by using texture profile analyser (TA – XT plus, Stable micro system, England) as per the procedure outlined by the manufacturer. The results of 3 replicates were subjected to statistical analysis using one way ANOVA and employing MS-EXCEL computer package.

RESULTS AND DISCUSSION

Utilization of concentrated paneer whey in the preparation of buns

Investigations were carried out to find out the suitable level of total solids in concentrated *paneer* whey required for the preparation of buns of desired quality. For this, *paneer* whey concentrated to 30% TS and lactose hydrolysed to about 60% (1h of incubation) was diluted suitably to get whey samples with 15, 20 and 25% TS. Similarly concentrated *paneer* whey without lactose hydrolysis was also diluted. The diluted and undiluted whey samples were used in place of water for preparation of buns; product prepared using water served as control. Trials have shown that addition of concentrated *paneer* whey affected the proofing time and baking temperature as explained in sections 4.6 and 4.7 respectively of this Chapter. Accordingly, to achieve a reasonable time for optimal proofing, for every 100 ml of concentrated *paneer* whey with 20 and 30% TS, 8 and 12 ml of water respectively were added during dough preparation. The baking was carried out at 180^0C for 10-12 min. The buns thus obtained were evaluated for sensory parameters on a nine-point hedonic scale by a panel of judges and the scores are depicted in Table 4.6. The scores in general showed that buns prepared with concentrated *paneer* whey up to 20% TS compared well with the control product. The scores obtained for the control product and the buns prepared with concentrated *paneer* whey up to 20% TS did not differ significantly ($p<0.05$). However, the scores for colour and appearance, flavour, body and texture and overall acceptability were equal or even better for buns prepared with concentrated and lactose hydrolysed *paneer* whey than those obtained for control product. Concentrated and lactose hydrolysed *paneer* whey contains substances such as sugars (lactose, glucose and galactose) and proteins which interact during baking to cause Maillard browning (Sithole et al, 2005). The browning products thus produced gave a desirable colour and flavour to the buns. Proteins present in concentrated whey due to their ability of hydration may help in improving the body and texture of the product (Hutton and Campbell, 1981). Buns prepared using concentrated *paneer* whey (>20% TS), had lower scores especially for flavour and body and texture. These buns had higher degree of caramelised flavour and hard body. Therefore, concentrated *paneer* whey with 20%

TS was selected for preparation of buns. Meena (2007) also reported that the bun made using whey with 15% TS compared well with the control samples.

Table 4.6: Effect of degree of concentration of paneer whey on sensory quality of buns.

Samples	Colour and appearance	Flavour	Body and texture	Overall acceptability
C	7.5^{cd}	7.3^{d}	7.4^{d}	7.4^{d}
15%TS UH	7.5^{cd}	7.3^{d}	7.3^{d}	7.3^{d}
15%TS H	7.6^{d}	7.4^{d}	7.3^{d}	7.4^{d}
20%TS UH	7.4^{bcd}	7.35^{bcd}	7.42^{d}	7.43^{bcd}
20%TS H	7.6^{d}	7.4^{d}	7.7^{d}	7.5^{d}
25%TS UH	7.1^{bcd}	6.9^{bcd}	6.8^{bcd}	6.8^{bcd}
25%TS H	7.1^{bcd}	6.9^{bcd}	6.9^{bcd}	6.7^{bcd}
30%TS UH	6.8^{ab}	6.4^{a}	5.9^{ab}	6.3^{ab}
30%TS H	6.6^{a}	6.6^{ab}	5.4^{a}	6.2^{a}
F-value	2.89*	3.46*	8.32*	6.37*
Critical difference	0.5	0.53	0.58	0.53

C= Control UH= Unhydrolyzed whey H= Hydrolyzed whey ≈ 60% DH

* Mean of three trials

*: significant difference (P<0.05)

* Figures with different alphabets differ significantly

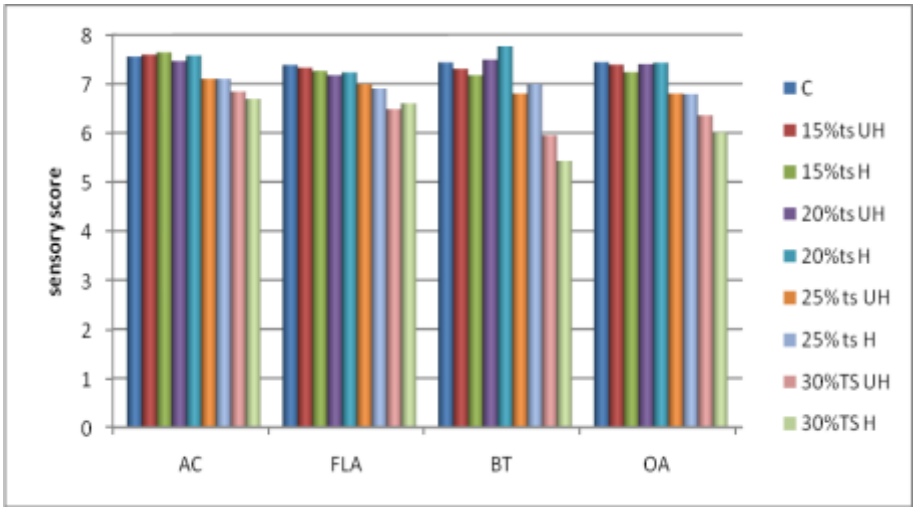


Fig. 4.3: Effect of degree of concentration of paneer whey on sensory quality of buns.

4.3.2. level of degree of hydrolysis of lactose used in buns preparation

The sensory scores obtained for buns prepared with concentrated *paneer* whey with and without lactose hydrolysis were almost the same (Table 4.6). Sensory scores obtained for buns prepared with 20% TS and lactose hydrolysed to an extent of 0, 30 and 60% did not differ statistically (Table 4.7 and Fig 4.4). Based on the results, concentrated (20% TS) and

lactose hydrolysed (DH ≈60%) *paneer* whey was selected for preparation of buns in further trials. Using lactose hydrolysed whey, Whalen et al (1987) and Matak (1999) reported the yoghurt and ice-cream respectively. Ogunrinola et al (1988) reported preparation of breads using hydrolysed whey permeate syrup; these breads were found to have quality equal or better than the control.

Table 4.7: Effect of degree of lactose hydrolysis on sensory quality of buns

Parameters	Control	20% TS 0% DH	20% TS 30% DH	20% TS 60% DH	F-value
C & A	7.5 ±0.50	7.5±0.32	7.5 ±0.42	7.6±0.56	0.71^{NS}
FLA	7.3 ±0.40	7.1±0.24	7.1 ±1.00	7.2 ±0.98	0.24^{NS}
B & T	7.4 ±0.47	7.5±0.35	7.6 ±0.45	7.7 ±0.42	2.28^{NS}
OA	7.4 ±0.41	7.4±0.29	7.4 ±0.40	7.5±0.72	0.39^{NS}

NS: Not significant (P<0.05)

- Mean of three trials
- Scores based on 9 point hedonic scale

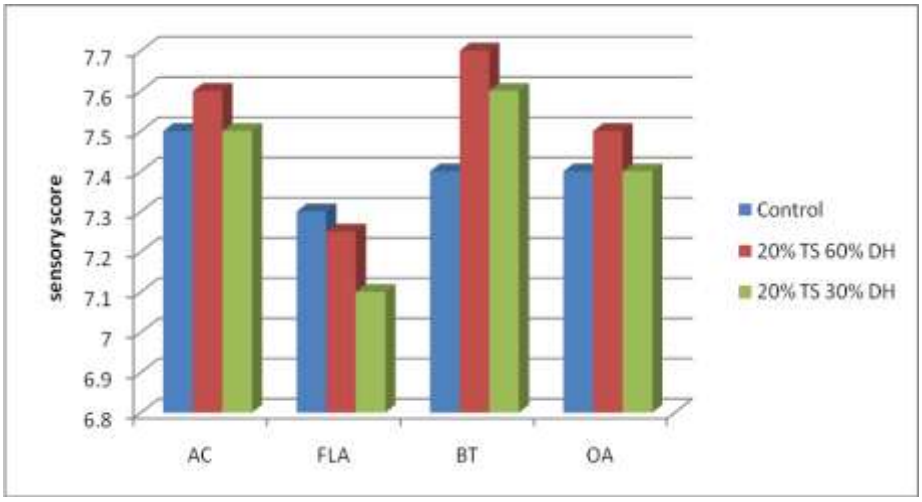


Fig.4. 4: Effect of degree of lactose hydrolysis on sensory quality of buns.

4.4. Utilization of wheat flour in the preparation of buns

Buns and bread, available commercially, are usually made using refined wheat flour (maida). However, now a days, brown bread or whole wheat bread and multigrain bread are available commercially. With regard to buns, the varieties range from plain bun through sweet bun to *masala* bun all made using maida. An attempt was made in the present investigation to incorporate wheat flour in the preparation of buns. Buns were prepared replacing maida at the rate of 0 (control), 25 and 50% and using concentrated (20% TS) and lactose hydrolysed (DH ≈60%) *paneer* whey. The products were evaluated for sensory parameters, the scores of

which are presented in Table 4.8 and Fig 4.5. The sensory scores showed maida replacement up to 50% with wheat flour was acceptable. However, buns prepared with 50% replacement had lower degree of flavour and hard body and texture. The sensory scores for colour and appearance of all the products did not differ significantly. The scores for flavour, body and texture and overall acceptability also did not differ significantly between the control and buns prepared with 25% replacement of maida with wheat flour. These scores for buns made using wheat flour replacing maida at 50% level, however, differed significantly. Under the conditions used for bun making, it could be possible to prepare buns with quality comparable to control buns by replacing maida with wheat flour up to 25%. A similar observation was also made on whole wheat bread (http://en.wikipedia.org/wiki/Whole_wheat_bread). Gur (1992) reported that replacement of maida with 10 to 30% of wheat, rice, oat or barly bran can be used for bread making. Harindar (2000) reported that acceptable whole meal bread could be developed using stabilizers.

Table 4.8: Effect of addition of wheat flour on sensory quality of buns.

Parameters	Extent (%) of replacement with wheat flour			F-value	Critical difference
	0	25	50		
C & A	7.9±0.51	7.7± 0.56	7.5± 0.43	1.25^{NS}	
FLA	$7.8±0.47^{a}$	$7.6±0.56^{a}$	$6.9±1.22^{b}$	6.23*	0.12
B & T	$8±0.40^{a}$	$7.7±0.91^{a}$	$6.8±0.93^{b}$	12.31*	0.12
OA	$8±0.42^{a}$	$7.6±0.48^{a}$	$6.8±0.84^{b}$	8.34*	0.12

*: significant difference, NS: Not significant (P<0.05)

* Figures with different alphabets differ significantly

- Mean of three trials
- Scores based on 9 point hedonic scale

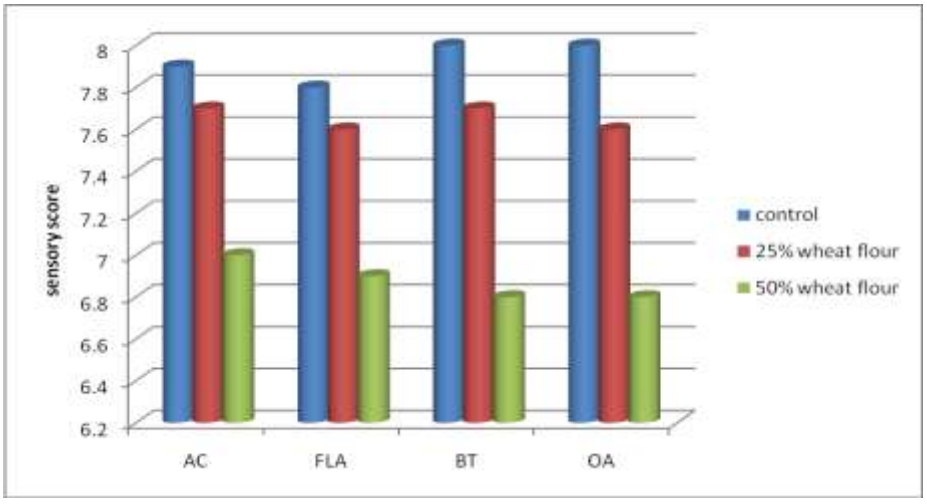


Fig. 4.5: Effect of addition of wheat flour on sensory quality of buns.

4.5. Optimization of sugar level in the preparation of buns

In the preparation of buns by standard procedure, 8% sugar was used. In the trials on preparation of buns utilising concentrated *paneer* whey (20% TS), sugar level was increased to 10% due to increase in the level of total solids. In the case of buns prepared with concentrated *paneer* whey (20% TS), this level of sugar was found to be acceptable. Mallik (2007) also reported sugar level needed to be increased in soup sticks and rusks prepared utilizing concentrated whey.

However, in the products prepared with concentrated (20% TS) and lactose hydrolysed (DH ≈60%) whey, there is a scope for reduction in the level of sugar due to the release of glucose and galactose. Accordingly the requirement of sugar level in the product was calculated based on the level of glucose and galactose, the hydrolytic products of lactose, and their sweetness factors.

This level was found to be 7%. Buns prepared using different levels of sugar were analysed for sensory parameters and the scores are shown in Table 4.9 and Fig 4.6. It may be seen from results that the sugar level did not have any significant difference on the sensory scores of buns. Therefore, in case of buns prepared with concentrated (20% TS) and lactose hydrolysed (DH ≈60%) *paneer* whey, 7% of sugar was used.

Table 4.9: Effect of sugar level on sensory quality of buns.

Parameters	Control Sugar (8%)	20% TS UH Sugar (10%)	20% TS H Sugar (10%)	20% TS H Sugar (7%)	F- value
C & A	7.5±0.46	7.4±0.41	7.2±0.36	7.5±0.46	0.46^{NS}
FLA	7.5±0.50	7.2±0.33	7.5±0.30	7.5±0.35	1.1^{NS}
B & T	7.6±0.44	7.3±0.47	7.3±0.44	7.6±0.66	1.22^{NS}
OA	7.5±0.42	7.3±0.43	7.4±0.50	7.5±0.38	0.57^{NS}

NS: Not significant (P<0.05%)

- Mean of four trials
- Scores based on 9 point hedonic scale

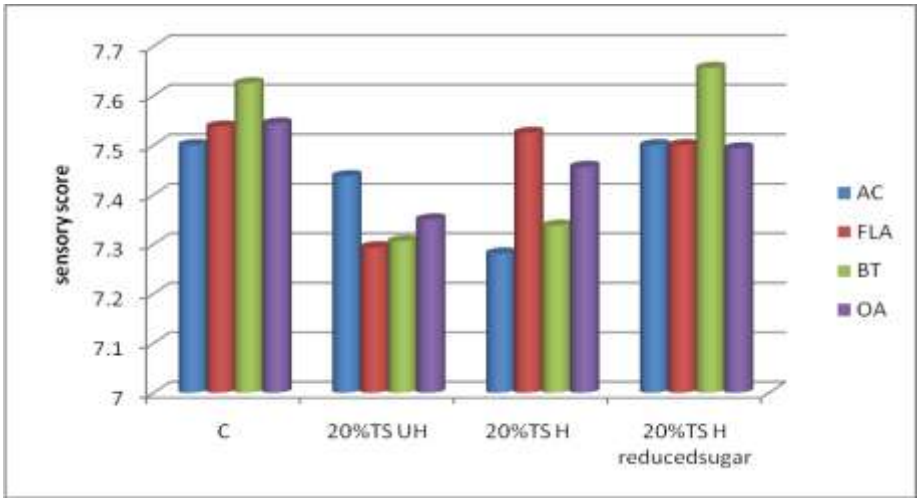


Fig. 4.6: Effect of sugar level on sensory quality of buns.

4.6. Optimization of proofing time for buns prepared utilizing concentrated paneer whey

It was observed during the course of optimization of the production of buns that the use of concentrated whey resulted in enhanced proofing time (the time required to double the volume of dough by fermentation before baking). The time required for control was observed to be around 50 minutes compared to 150 and 180 minutes required for the dough prepared by using concentrated whey with 20% and 30% TS respectively as the diluent (Table 4.10). The increased proofing time due to the addition of concentrated whey in a production unit would affect the production cycle, which in turn will affect the productivity defeating the basic objective of increased profitability. The increased total solids content might be increasing the proofing time due to decreased availability of water compared to that of control samples. In order to address this problem, extra amount of water (8 and 12 ml of water per 100 ml whey containing 20% and 30% TS respectively) was added. This reduced the proofing time to 65 and 75 minutes for dough prepared using whey with 20 and 30% TS respectively. The microbial activity largely depends on free water available in any medium. The added pure water has increased the availability of free water for yeast in dough which has resulted in increased carbon dioxide production required for proofing. Availability of free water is an important physico-chemical property affecting the growth of yeast which in turn affects proofing time (Srilakshmi, 2003). Addition of extra amount of water reduced the level of whey solids, for a batch of dough made with 500 g of flour, by about 0.2%. Meena (2007) also reported that addition of extra water was required for reducing the proofing time when concentrated whey was utilized for the preparation of buns. Mallik (2007) reported that addition of ammonium persulphate reduced the proofing time in the dough meant for the

preparation of rusks and soup sticks. However, in the present investigation addition of ammonium persulphate to reduce the proofing time did not have any significant effect.

Table 4.10: Effect of level of solids in whey on proofing time.

Control	20% TS whey	30% TS whey
Proofing time (min)		
50	150*	180*
50	65**	75**

* No addition of water

** Amount of extra water added

20% TS whey - 8.0 ml water /100 ml whey

30% TS whey - 12 ml water /100 ml whey

4.7. Optimization of baking temperature for manufacture of buns using concentrated paneer whey

In order to optimise the baking temperature required for attaining a desired crust colour and proper cooking of the crumb, the dough balls were baked at 180^0, 200^0 and 210^0C for 10-12 min. The buns thus obtained were subjected to sensory evaluation and the sensory scores are presented in Table 4.11 and Fig 4.7. It was observed that baking at 180^0C for 10- 12 min yielded buns of desired quality with respect to all the sensory parameters. Sensory scores for flavour, body and texture and overall acceptability differed significantly for the buns baked at 180^0C when compared to those baked at 200^0 and 210^0C. Meena (2007) reported baking at 200^0C for 17 min for buns prepared using concentrated whey with 15% TS.

Table 4.11: Effect of baking temperature on sensory quality of buns

Parameters	180°C	200°C	210°C	F-value	Critical difference
C & A	7.7± 0.51	7.6± 0.32	7.4 ±0.42	3.5^{NS}	
FLA	7.6±0.46 ^{b}	7.4± 0.56^a	7.2± 0.79^a	9.1*	0.20
B & T	7.7± 0.58^b	7.4± 0.61^a	7.3± 0.68^a	12*	0.20
OA	7.6± 0.36^b	7.4±0.81 ^{a}	7.2± 0.85^a	19.9*	0.14

*: Significant difference, NS: Not Significant difference (P<0.05)

* Figures with different alphabets differ significantly

- Mean of three trials
- Scores based on 9 point hedonic scale

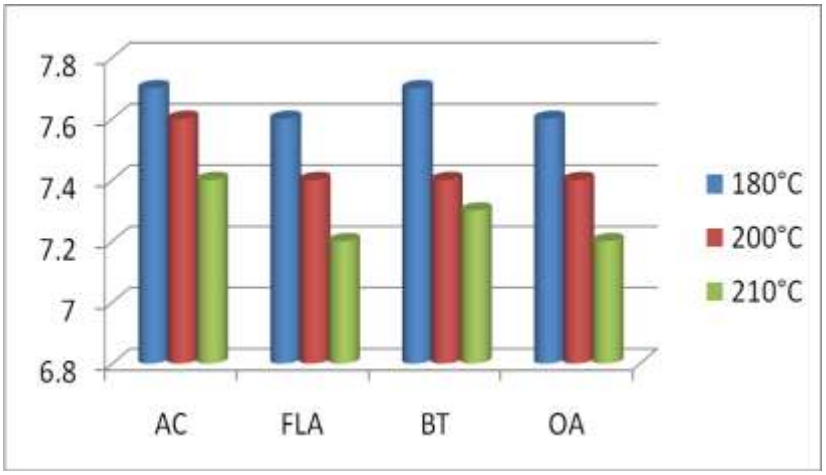


Fig. 4.7: Effect of baking temperature on sensory quality of buns.

4.8. Optimised procedure for the preparation of buns utilizing concentrated and lactose hydrolysed paneer whey

A method of preparation of buns utilizing concentrated (20% TS) and lactose hydrolysed (DH ≈60%) *paneer* whey and wheat flour was optimised based on trials carried out in the present investigation. The process for the production of buns as flow diagram is given in Fig 4.8. The procedure is essentially the same used for conventional bun making with a few modifications. One-fourth of maida was replaced with wheat flour and water used for dough making was replaced with concentrated *paneer* whey. For every 100 ml whey used additional 8 ml of water was used to reduce proofing time. The pictures of dough before and after proofing with this modification are shown in Fig 4.9. Skim milk powder used for the preparation of control buns was not used for the buns preparing using concentrated *paneer* whey. Sugar level was adjusted to 8, 10 and 7% in control buns and products prepared using concentrated unhydrolysed and lactose hydrolysed *paneer* whey respectively. Buns were baked at 180^0C for 10-12 min.

Maida (400 g) and wheat flour (100 g)

⇩

Addition of water/ whey*

⇩

Addition of sugar (30 g) and salt (10 g)

Activation of yeast
Yeast : 15 g
Sugar : 5 g
Water/whey : 100 ml
Mix and set for 10 min

⇒ ⇩

Mixing

⇩

Kneading with increments of oil (60 g)

⇩

Fermentation and intermediate proofing (30 min)

⇩

Portioning (60 g)

⇩

Rounding

⇩

Final proofing (control- 50 min, whey-65 min)

⇩

Baking at 180^0C/10-12 min

⇩

Cooling

⇩

Packing

(LDPE pouches)

*****Control: water of 200 ml

Experimental bun: concentrated *paneer* whey (20% TS) of 200 ml + water (24 ml).

Fig. 4.8: Flow chart for the preparation of buns utilizing concentrated and lactose hydrolysed paneer whey.

Fig. 4.9: Photograph of dough prepared using concentrated paneer whey before (top) and after proofing (bottom).

4.8.1. Sensory evaluation of buns

Buns prepared utilising concentrated *paneer* whey (20% TS) with and without lactose hydrolysis and the control product made using water were subjected to sensory analysis. The data given in the Table 4.12 showed that sensory properties of buns produced using both types of whey i.e. with and without lactose hydrolysis, were comparable to those of the control product. The pictures of control buns and whey (hydrolyzed for lactose) are shown in Fig 4.10. The statistical analysis of the sensory scores also showed no significant difference among the three varieties of buns. Based on the sensory evaluation (Table 4.12), it was observed that concentrated (20%TS) and lactose hydrolyzed (DH ≈60%) *paneer* whey with partial replacement of maida at the rate of 25% could be used for production of buns with sensory quality comparable to that of control product.

Table 4.12: Sensory scores of buns prepared utilizing concentrated and lactose hydrolysed paneer whey.

Parameters	Control	20% TS UH	20% TS H	F-value
C & A	7.41±0.51	7.46±0.51	7.58±0.56	0.39 NS
FLA	7.48±0.40	7.18±0.94	7.23±0.97	0.61 NS
B & T	7.44±0.47	7.49±0.44	7.76±0.42	2.44 NS
OA	7.42±0.42	7.40±0.52	7.43±0.72	0.01 NS

NS: Not significant (P<0.05%)

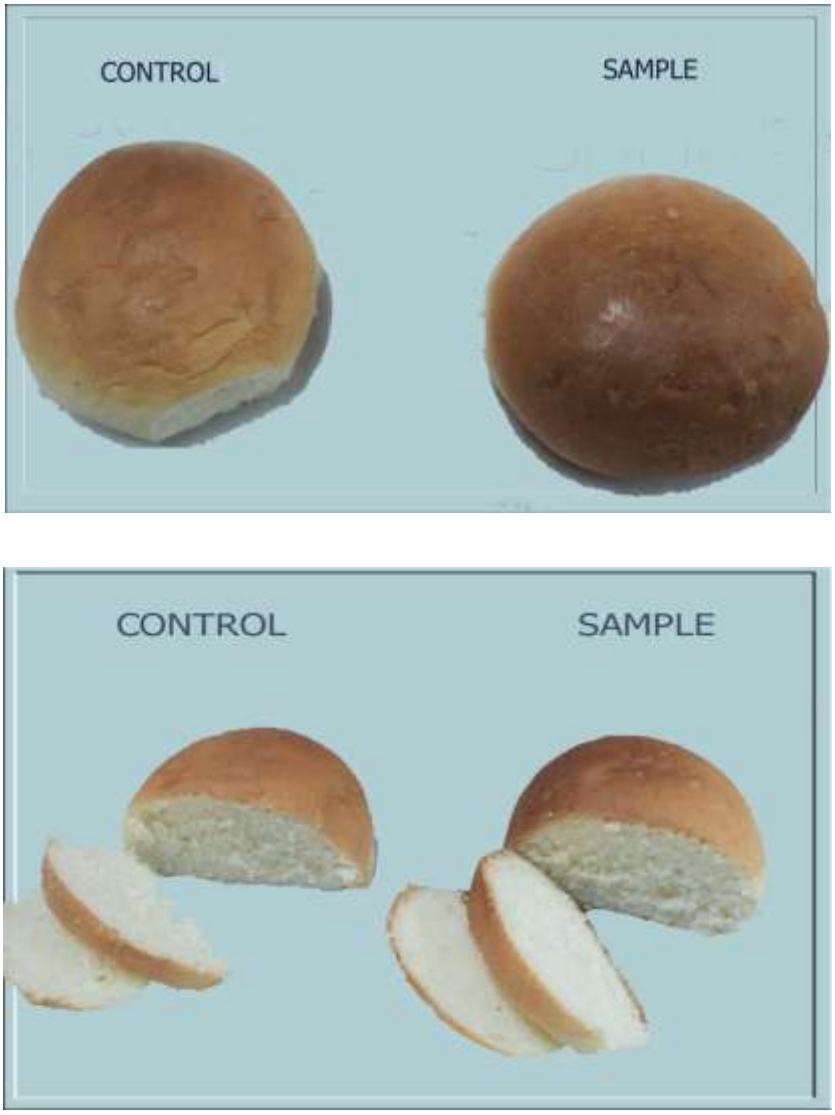


Fig. 4.10: Photograph of buns.

4.8.2. Yield of buns

The mass balance for the production of buns from 500 g of flour is presented in Table 4.13. In the buns prepared with concentrated, lactose hydrolyzed whey, sugar level was reduced from 10% to 7%. In order to reduce the proofing time, additional quantity of water was added at the rate of 8 ml per 100 ml of whey used. Skim milk powder was used for the preparation of control product and in experimental buns due to the presence of whey solids, powder was not added. The yield of buns was calculated based on the mass balance of the ingredients used in the preparation. The mass balance (Table 4.13) in the production of buns indicated that 935, 960 and 945 g of dough in control and buns prepared using unhydrolysed and hydrolyzed concentrated *paneer* whey resulted in 687.2, 740.16 and 726.32 g of the end product respectively. The yield of the buns in control and buns prepared using unhydrolyzed and hydrolyzed concentrated *paneer* whey was 73.5, 77.10 and 76.86% respectively. This

difference in yield could be ascribed to the increased solids content in experimental dough due to the use of concentrated whey as diluent in the production buns. Meena (2007) reported that yield of buns was 80.94 and 76.67% for 15% TS the product made using whey and the control sample respectively.

Table 4.13: Ingredient balance for production of buns.

Ingredients	Control	20% TS UH	20% TS H
Maida (g)	400	400	400
Wheat flour (g)	100	100	100
Fat (g)	60	60	60
Sugar (g)	40	50	35
Salt (g)	10	10	10
SMP (g)	10	-	-
Yeast(g)	15	15	15
Water/whey* (ml)	300	324(55 g TS)	324*(55 g TS)
Total (g)	935	960	945
Total wt of buns (g)	687.2	740.16	726.32
Yield (%)	73.5	77.10	76.86

*Concentrated lactose hydrolyzed *paneer* whey (DH: ≈60%)

4.9. Physico-chemical characteristics of buns

The physicochemical characteristics of buns (Table 4.14) indicated that the moisture content of the experimental samples prepared using concentrated *paneer* whey with and without lactose hydrolysis was lower compared to the control samples. The moisture content was observed to be 30.46% in control as compared to 26.42 and 28.90% in the case of unhydrolyzed (UH) and hydrolyzed (H) whey buns respectively. The lower moisture content in buns prepared using concentrated *paneer* whey could be ascribed to the higher solids content in the dough. The higher moisture content in buns prepared using hydrolyzed whey in comparison to their prepared using unhydrolyzed whey may be due to humactant property of hydrolyzed lactose i.e. absorption of moisture from the atmosphere (Shah et al, 1978). The fat content in control buns was observed to be 9.64% while in experimental buns UH and H, have marginally higher fat content of 10.3 and 9.95% respectively. The protein content in buns was observed to be 11.81, 12.72 and 12.3% for control, UH and H samples respectively. The higher protein content in experimental samples of buns could be due to the addition of concentrated whey which contributed for the increased protein content. Similar observation has been made with respect to the production of bread (Mann, 1982). The ash content increased markedly due to the use of concentrated whey as diluent. The ash content was 1.3, 1.47 and 1.42% for control, unhydrolyzed and hydrolyzed samples respectively. The higher

ash content in concentrated whey of 2.75% (Table 4.2) contributed for the increased ash content in the baked products. The water activity was observed to decrease due to the use of concentrated whey as diluent in buns. The values were 0.880, 0.852 and 0.872 for control, UH and H samples respectively. The use of whey as a diluent resulted in higher solids level and increased soluble solids in the dough, which perhaps contributed for the decreased water activity. The effect of increased soluble solids on the reduction of water activity was reported earlier by Rockland and Stewart (1981). The pH of the buns was observed to be 5.1, 5.3 and 5.43 for control, unhydrolyzed and hydrolyzed samples. The acidity expressed in ml of 0.1N NaOH/100 g TS was 28.57, 27.84 and 24.28 for control, UH and H samples respectively. The energy contributed by control, UH and H samples were calculated to be 321.20, 339.94 and 328.47 kcal/100 g respectively. The differences in energy levels are due to differences in the composition of the buns.

Table 4.14: Physico-chemical characteristics of buns.

Constituents	Control	Unhydrolysed whey bun (20% TS)	Hydrolysed whey bun (20% TS)
Moisture (%)	30.46±0.37	26.42±.033	28.90±0.32
Total solids (%)	69.54±.037	73.58±0.26	71.10±0.24
Fat (%)	9.64±0.14	10.30±.30	9.95±0.35
Protein (%)	11.81±0.1	12.72±0.2	12.30±0.05
Total carbohydrates (%)	46.8±0.25	49.09±0.12	47.43±0.21
Ash (%)	1.3±0.04	1.47±0.05	1.42±0.01
pH	5.1±0.02	5.3±0.05	5.43±0.04
Acidity (ml of 0.1N NaOH/100 g TS)	28.57±0.52	27.14±0.83	24.28±0.84
Water activity	0.88±0.001	0.852±0.002	0.872±0.001
Energy (kcal/100 g)	321.20	339.94	328.47

The lactose content in buns was calculated and is shown in the Table 4.15. The lactose content in control, unhydrolysed and hydrolyzed samples was 0.75, 2.86 and 1.72%. Thus it may be seen that lactose level decreased substantially in buns prepared using concentrated (20%TS) and lactose hydrolysed (DH ≈ 60%) *paneer* whey.

Table 4.15: Lactose content* in bun

Expression	Control	Unhydrolyzed whey	Hydrolyzed whey
	Lactose content (%)		
Per bun (avg. wt of bun-46g)	0.346	1.32	0.792
Per serving (2 buns)	0.692	2.64	1.584
Per 100 g	0.75	2.86	1.72

* By calculation

4.10. Textural profile of buns

The samples viz. control, 20% TS unhydrolyzed (UH) and hydrolyzed (H) *paneer* whey buns were analysed for their texture profile characteristics as measured by Texture Analyser. The values for the same are given in Table 4.16 and Fig 4.11.

It may be observed from the data in the Table that the hardness values for the control and the experimental samples with UH and H whey were 0.681, 0.342 and 0.152 kg, respectively. The experimental sample prepared using lactose hydrolysed whey showed the lowest hardness value indicating that it was softer than the other samples. When whey solids are incorporated, the sugars present in whey, more so in hydrolysed whey, are expected to get solubilised in the moisture present in dough. In the process, moisture bound by the 'dough' may also get extracted giving a liquefying effect. Thus the dough viscosity is reduced imparting softness to the final product. Statistical analysis indicated a significant difference between the mean value of the control sample and experimental samples made using 20 % TS whey. The cohesiveness scores ranged from 0.387 to 0.565 with the experimental sample (20% TS UH) securing the lowest value of 0.387 indicating that it was the least cohesive of all samples. Statistical analysis of the data also showed a significant difference between the control and 20% TS UH product, but no difference between the control and 20% TS H buns. Similarly the springiness values were 0.831, 0.759 and 0.794 for the samples of control and the experimental samples with 20 % TS UH and H respectively; with the control sample showing the highest score. The gumminess and chewiness for control and 20% TS UH and H samples were 0.371, 0.132 and 0.085 kg and 0.309, 0.10 and 0.068 kg/sec respectively. Statistical analysis of the data, in this case also, revealed a significant difference between the values of the control and the experimental samples.

Changes in rheological characteristics of bun after incorporation of whey were on expected lines. Use of concentrated whey imparted softness to the product as indicated by low hardness values. This could be attributed to sugars present in whey, which has good water binding characteristics. Bun being foam in structure, its firmness depends on the viscosity of the lamellar liquid. The surface viscosity of lamellar liquid imparts firmness to the structure and provides stability to the structure (Walstra et al., 1999). Thus it was noted that the water binding increased the softness of bun, but at the same time decreased the cohesiveness implying that the product was becoming crumbly in body and texture. This was also reflected in increasing body and texture scores. Springiness values though showed statistically

significant difference, there was no much difference in the actual values. These results show that incorporation of whey solids has to be limited only to a certain level, which in this study was observed as 20% TS level in whey.

Table 4.16: Textural profile analysis of buns

Parameters	Control	20% U H	20%H
Hardness (kg)	0.681[c]	0.342[b]	0.152[a]
Cohesiveness	0.545[b]	0.387[a]	0.565[b]
Sponginess	0.831[b]	0.759[a]	0.794[b]
Gumminess (kg)	0.371[b]	0.132[a]	0.085[a]
Chewiness (kg/ sec)	0.309[b]	0.100[a]	0.068[a]

Mean of four trials

Note: Values with different superscripts in a row are significantly different at P<0.05.

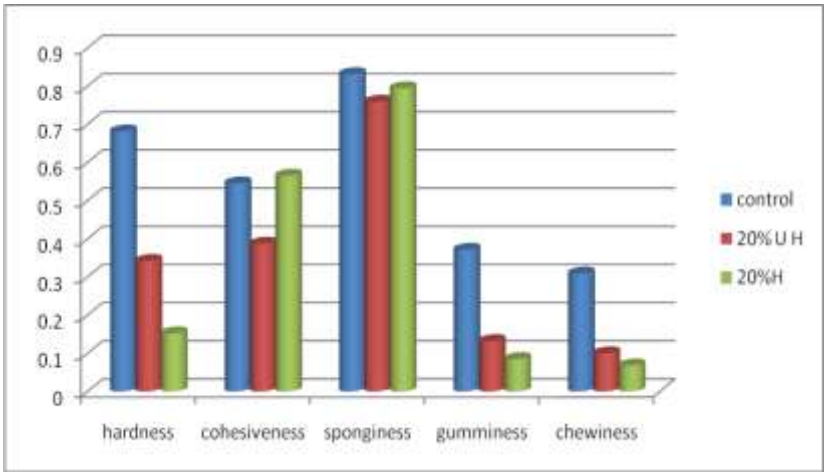


Fig. 4.11: Textural profile analysis of buns

4.11. Shelf-life of buns

The bun samples were packed in LDPE pouches of thickness 55 microns and stored at temperatures of 30° and 37^{0}C and analyzed at regular intervals of 2 days for their sensory, rheological, chemical and microbiological changes. The preliminary trials showed that storage at 37^{0}C was not suitable because of release of moisture from buns and appearance of water vapor (gas) and condensate within the pack. Hence, further studies on storage of buns were carried out at 30^{0}C. The basic mechanism of bread and bun staling involves changes in analogous to crystallization of starch component of the crumb (Zobel, 1973).

4.11.1. Changes in sensory characteristics of buns during storage

The sensory scores of the control and the experimental samples of buns stored at 30° are presented in the Table 4.17 and Fig 4.12.

Table 4.17: Effect of storage (30^{0}C) on sensory scores of buns

Para meters	0 day			2nd day			4th day			6th day
	Control	UH	H	Control	UH	H	Control	UH	H	
C & A	7.70	7.69	7.81	7.57	7.53	7.73	7.28	7.25	7.33	Visible yeast and mold growth is observed
FLA	7.53	7.58	7.94	7.44	7.40	7.60	6.42	6.52	6.53	
B & T	7.56	7.63	7.86	7.39	7.29	7.47	6.67	6.75	6.73	
OA	7.49	7.59	7.88	7.57	7.36	7.64	6.45	6.60	6.49	

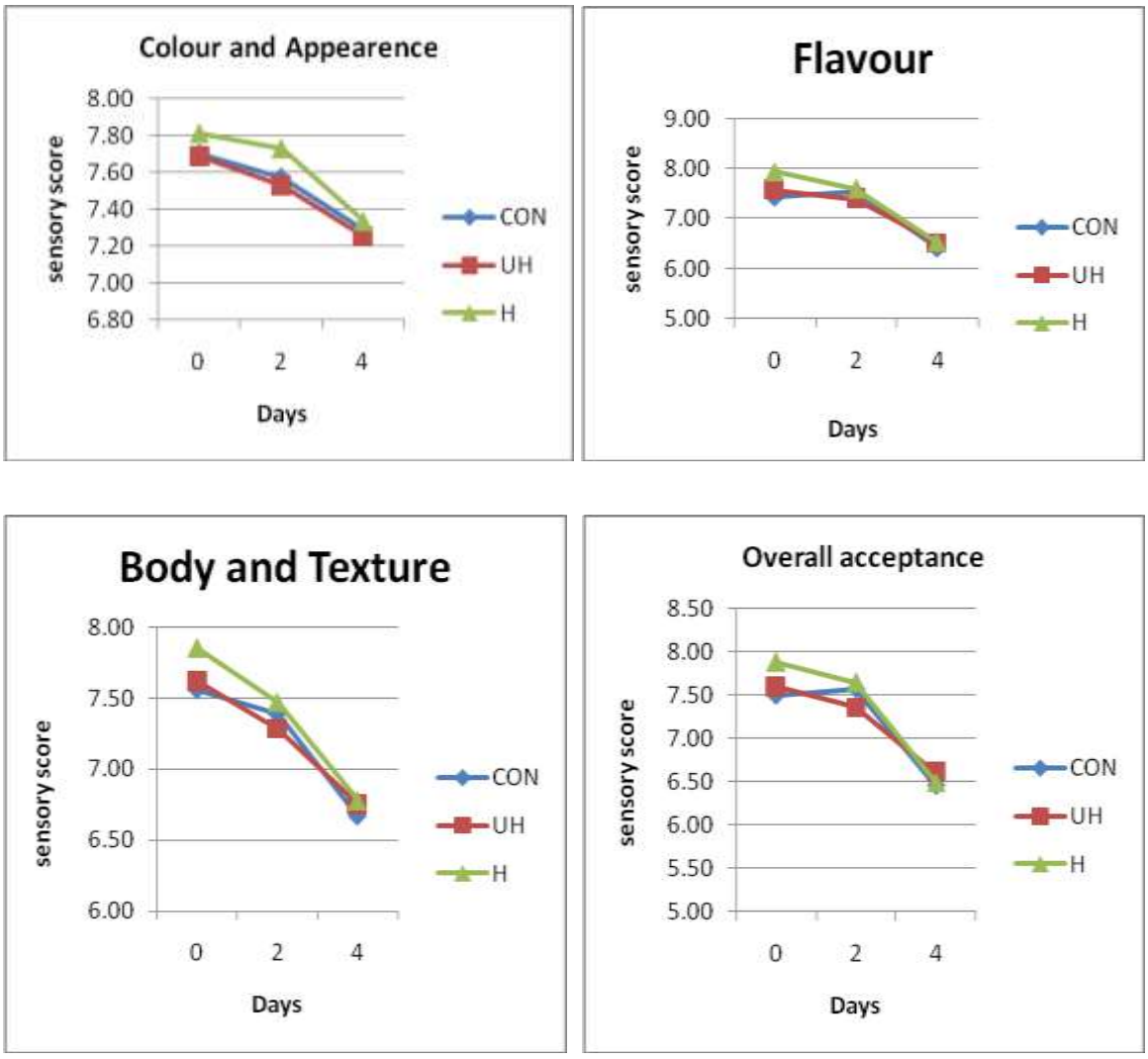


Fig. 4.12: Effect of storage (30^{0}C) on sensory scores of buns

As can be seen from the data, there was a distinct effect of the storage on the scores for colour and appearance, flavour, body and texture and overall acceptability of all the products. The scores decreased with storage period. All the buns, i.e. control and experimental, showed a similar trend. At the end of the 6th day visible appearance of molds was observed in all the products. The experimental samples had a shelf life of 4 days at 30^{0}C similar to that of

control. However, Meena (2007) reported that buns prepared using whey (15% TS) showed better shelf life than control buns.

4.11.2. Changes in physico-chemical characteristics of buns during storage

4.11.2.1. Moisture and water activity

The changes in moisture and water activity (Aw) during storage of buns (Table 4.18 and Fig4.13) were marginal and did not follow a particular trend. Control buns gained a moisture of 1.15% while experimental buns, UH and H, lost moisture at the rate of 3.86 and 2.62% respectively at the end of 6 days of storage. A marginal increase in water activity was observed in all the products at the end of 6 days of storage. Meena (2007) also reported that similar type of results for buns prepared using concentrated whey and concluded that the variation in moisture content could be due to the hygroscopic nature of whey proteins or might be due to inadequate moisture barrier properties of packing material (LDPE).

Table 4.18: Effect of storage on moisture (%) and water activity of buns

Storage period (days)	Control		Unhydrolyzed whey		Hydrolyzed whey	
	Moisture	Aw	Moisture	Aw	Moisture	Aw
0	31.09	0.867	26.42	0.865	28.92	0.871
2	31.44	0.872	27.26	0.869	26.41	0.875
4	31.16	0.87	27.37	0.872	28.48	0.869
6	31.45 (+1.15%)	0.874	25.39 (-3.86%)	0.875	28.16 (-2.62%)	0.872

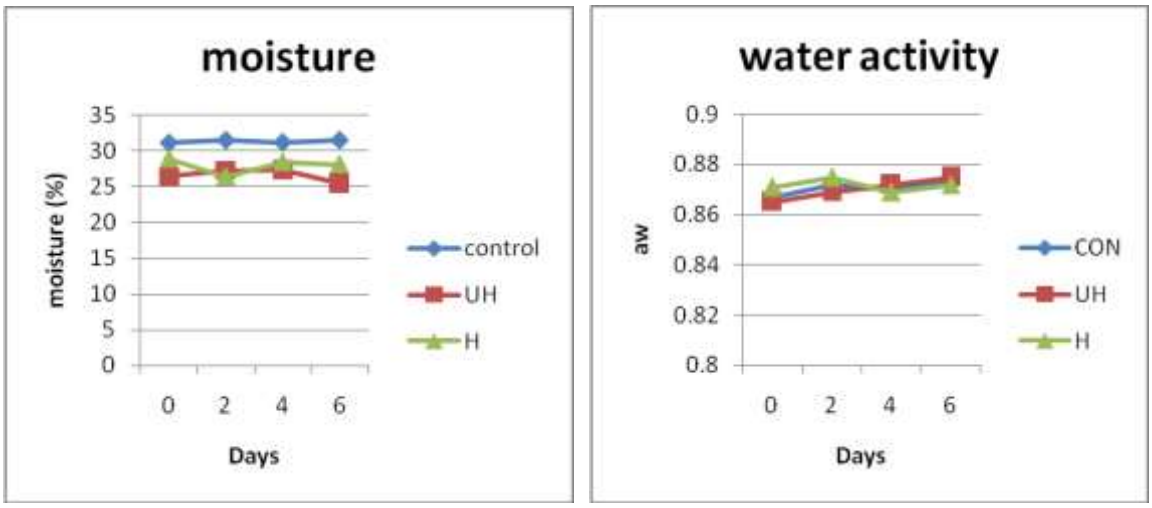


Fig. 4.13: Effect of storage on moisture (%) and water activity of buns.

4.11.2.2: pH and acidity

It was observed from the results that the pH of the products stored at 30^0C showed a downward trend in the pH and upward trend in acidity (expressed in ml of 0.1N NaOH/ 100 g

TS). On the 4th day of analysis, i.e., the control sample showed a pH of 4.54 while the UH and H samples showed a pH of 5 and 4.99 respectively. The buffering effect of the whey proteins in experimental samples could be responsible for a higher pH. Faster decline in pH being is an indication of accelerated spoilage. The acidity values on the 4th day of analysis were 38.57, 37.14 and 37.84 for control and experimental samples. (Table 4.19 and Fig 4.14)

Table 4.19: Effect of storage on pH and acidity of buns

Storage period (days)	Control		Unhydrolyzed whey		Hydrolyzed whey	
	pH	Acidity*	pH	Acidity	pH	Acidity
0	5.14	28.57	5.3	27.14	5.43	24.28
2	5.1	31.42	5.14	31.42	5.26	28.57
4	4.81	35.71	5.05	34.28	5.17	31.42
6	4.54	38.57	5	37.14	4.99	37.84

* Acidity is expressed in ml of 0.1N NaOH/100g TS

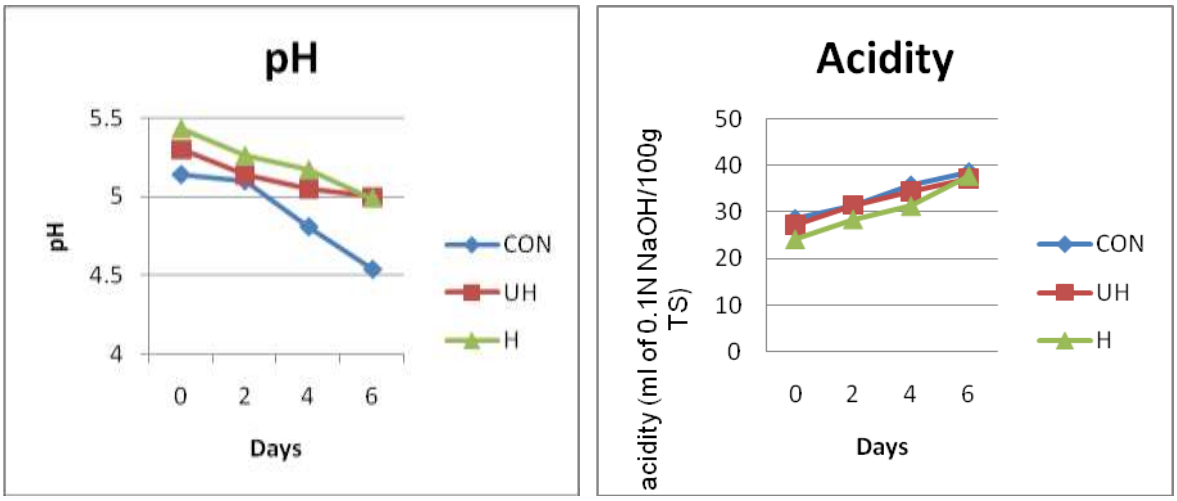


Fig. 4.14: Effect of storage on pH and acidity of buns

4.11.3. Effect of TPA during storage study

From the results presented in Table 4.20 and Fig 4.15, it was observed that for the products stored at 30^0C the hardness value increased from the first to the final day of storage indicating that the products became harder. This could be explained by the variation in moisture content of products upon storage. On the final day of analysis it was observed that the 20% TS UH sample was harder than the control with values of 0.890 and 0.635 kg respectively. The cohesiveness values also showed a decline with each day of storage, the experimental hydrolysed sample being less cohesive than the control. The springiness values were almost constant for all the samples. The gumminess and cohesiveness values showed that upward trend on storage. Divya (2007) and Meena (2007) also reported similar results on bread and

bun respectively prepared using concentrated whey. Staling of bread during storage is well known during which changes take place in the structural elements of the bread foam (Seiler, 1984).

Table 4.20: TPA during storage study

	zero day			2nd day			4th day		
Parameters	**control**	**UH**	**H**	**control**	**UH**	**H**	**control**	**UH**	**H**
Hardness	0.093	0.218	0.148	0.603	0.693	0.498	0.635	0.890	0.505
Cohesiveness	0.760	0.640	0.608	0.440	0.406	0.357	0.361	0.391	0.463
Sponginess	0.088	0.785	0.785	0.777	0.804	0.758	0.785	0.688	0.748
Gumminess	0.071	0.140	0.090	0.265	0.281	0.178	0.229	0.348	0.234
Chewiness	0.006	0.110	0.071	0.206	0.226	0.135	0.180	0.240	0.175

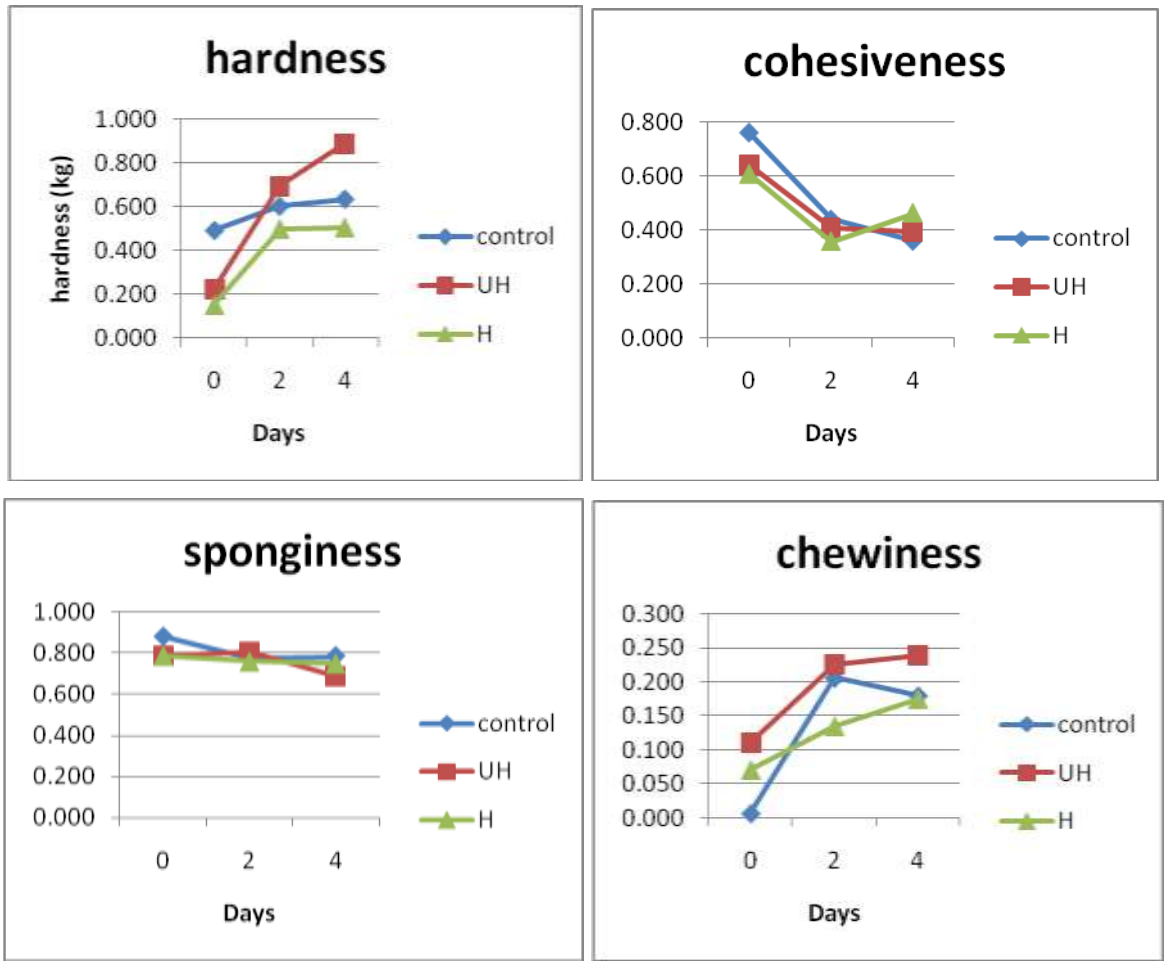


Fig. 4.15: TPA during storage study

4.11.4. Effect of Microbiological changes on bun

From the results obtained and presented in Table 4.21 and Fig 4.16, it was observed that the SPC and yeast and mold counts increased during storage up to the final day (4th day) of analysis. On the 6th day of storage there was a visible growth of yeast and molds and hence

the samples were rejected. Meena (2007) also reported a similar shelf life for buns prepared using concentrated whey. Incorporation of whey solids which include nutrients like proteins and sugars did not considerably alter the microbial growth in buns.

Table 4.21: Effect of microbiological changes on bun during storage

Parameters		Control	UH	H
		CFU/g		
0 day	SPC	55 X 10^2	125X 10^2	95 X 10^2
	Y & M	33X 10^1	28 X10^1	22X10^1
2nd day	SPC	196 X10^3	136 X10^3	112 X10^3
	Y & M	21 X 10^2	11 X 10^2	45 X 10^2
4th day	SPC	48 X10^4	252 X10^4	159 X10^4
	Y & M	3 X10^3	4 X10^3	6 X10^3
6th day	Visible yeast and mold growth was observed			

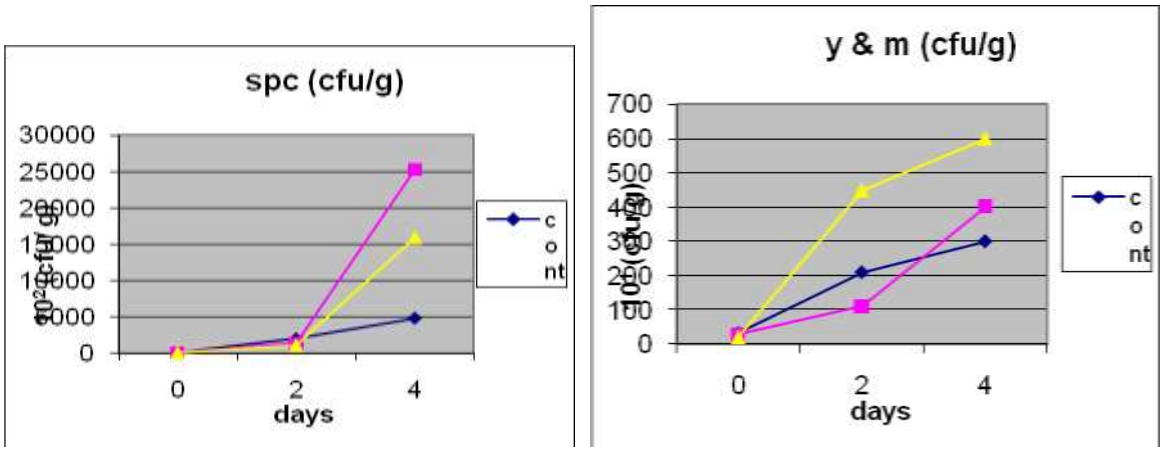


Fig. 4.16: Effect of microbiological changes on bun during storage

Based on the sensory, physico-chemical, textural and microbiological analysis, it was concluded that buns prepared using concentrated *paneer* whey with or without lactose hydrolysis and packed in LDPE pouches had a shelf life of 4 days at 30^0C like the control product.

It may be seen from the results and their interpretation as described above that lactose could be hydrolysed in concentrated *paneer* whey (30% TS) to 60% in 1 h under optimal conditions. Incorporation of concentrated (20% TS) and lactose hydrolyzed (DH ≈60%) *paneer* whey in place of water and partial replacement (25%) of maida with wheat flour yielded buns with quality comparable to control bun. Sugar level in buns could be reduced from 10 to 7% when concentrated and lactose hydrolyzed whey was used. Utilization of whey for bun making needed a few modifications to achieve optimal proofing time and

baking. The buns produced using concentrated lactose hydrolysed whey was characterized and it was observed that quality of these buns was equal or even better in some aspects as compared to that of the control product. The shelf life of all the varieties of buns was observed to be 4 days when packed in LDPE pouches and stored at 30^0C.

CONCLUSION

Paneer whey concentrated to 20% TS can effectively be used as diluent replacing water in the production of buns. This replacement not only improves the nutritional attributes of buns, but also contributes for the economy of operation of dairy plants reducing the cost of effluent treatment. Colorimetric methods for estimation of lactose and thereby evaluation of degree of hydrolysis (DH) of lactose in concentrated *paneer* whey were standardized. Lactose in concentrated *paneer* whey could be hydrolyzed up to ~60% in 60 min using lactozyme under optimal conditions of hydrolysis. Trials showed that replacement of maida with 25% wheat flour yielded buns with quality comparable to that of control product. Due to hydrolysis of lactose and release of sweeter monosaccharides, sucrose required in the bun preparation could be reduced from 10 to 7%. Utilization of concentrated lactose hydrolyzed whey (20% TS and 60% DH) and wheat flour (25% replacement of maida) required necessary modifications for achieving optimal proofing and baking. The yield of buns calculated on the basis mass balance of ingredients was 73.5 and 76.86% for control product prepared using water and experimental buns prepared using concentrated, lactose hydrolyzed *paneer* whey respectively. Sensory and textural quality of the experimental buns was observed to be better than that of the control product. The experimental buns had 28.90, 9.95, 12.30, 1.72, 47.43 and 1.42% respectively of moisture, fat, protein, lactose, total carbohydrates and ash. The corresponding values for the control were 30.46, 9.64, 11.81, 0.75, 46.9 and 1.3% respectively. Experimental and control samples packed in LDPE pouches had a shelf life of 4 days at 30^0C. This investigation showed that concentrated (20% TS) and lactose hydrolyzed (≈60% DH) *paneer* whey and wheat flour (25% replacement of maida) could be successfully utilized for the production of buns.

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