Process optimization for the manufacture of lemon based beverage from hydrolyzed whey

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Abstract Whey obtained during the manufacture of *Cheddar cheese* and *paneer* was lactose hydrolyzed to develop lemon based whey beverage. The lactose present in whey was hydrolyzed by Maxilact L-2000 lactase enzyme. Maximum (85–90%) hydrolysis in *cheese* and *paneer* whey was optimized with enzyme concentration of 0.4% at pH 6.75 after incubation at 40 °C for 3 h. The sweetness level in hydrolyzed whey was equivalent to 2.5% sucrose solution. Response surface methodology was used to optimize the levels of sugar, lemon juice, lemon flavor and stabilizer i.e. carboxyl methyl cellulose (CMC). The most acceptable lemon based beverage contained 8, 4, 0.1 and 0.05% of sugar, lemon juice, lemon flavor and CMC, respectively. The beverage had greater acceptability to judges after heat treatment at 90 °C for 2 min than the heat treatment of 5 psi for 5 min.

Keywords Whey · Lactose hydrolysis · Lemon based beverage · Response surface methodology

Utilization of whey produced during the manufactures of *cheese*, *paneer*, *channa* and *shrikhand* has been of great concern. Whey, a valuable dairy by product contains half of the milk solids and is a rich source of lactose, water soluble vitamins, minerals, and immunologically active proteins (Durham et al. 1997). It contains about 50–55% total milk solids, 70% of milk sugar, 20% of milk proteins and 70–90% of minerals and almost all water soluble vitamins especially vitamin B complex and vitamin C (Sinha et al. 2007). Whey proteins consist of lactoferrin, lactoperoxidase, β -lactoglobulin, α -lactalbumin, bovine serum albumin, thermostable fractions of proteose peptones, immunoglobulins and bioactive peptides. Presence of essential amino acids such as lysine, cysteine, methionine and cystin imparts anticarcinogenic properties to these proteins (Durham et al. 1997; Jelacic et al. 2008). However, large quantities of whey are drained off as waste. There is an increased awareness all over the world on the potential for utilization of whey, primarily because of stringent pollution prevention regulations and secondly on salvaging the unique components of whey nutrients to improve the functional quality of formulated foods (Jayaprakasha and Brueckner 1999).

Whey protein enriched products carry very good foaming characteristics and hence are widely used in foaming applications in foods. Foaming and foam stability depend on parameters such as extent of protein denaturation, fat and carbohydrate concentration, whipping method, protein concentration, pH, presence of calcium and other ions (Morr and Ha 1993). Whey proteins possess very good functional properties such as solubility, foaming, emulsifying, gelling and water binding (Patel and Kailara 1990; Morr and Foegeding 1990; De Wit and Kessel 1996).

Though whey has been successfully utilized in fruit based drinks and vegetable soups (Singh et al. 1994a, b). Its

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use is limited as lactose has low sweetness, low solubility and difficulty in digestibility in lactose intolerant persons (Rexroat and Bradley 1986; Ogunrinola et al. 1988). Hydrolysis of lactose generally improves desirability by increased flavour enhancement, increased osmotic pressure, easier digestibility, increased solubility, increased sweetness and easier fermentability (Coton 1980; Arndt and Wehling 1989; Geilman 1993). The sweetness of whey due to lactose hydrolysis helps its utilization in dairy products such as flavoured milk and fermented milks. Further, it is light, refreshing, healthful, nutritious and less acidic than fruit juices which offer good scope (Jelen 1992; Mann 1994).

In view of growing importance and health benefits of lactose hydrolyzed whey, the present investigation was undertaken to develop a lemon beverage utilizing lactose hydrolyzed *paneer* whey.

Materials and methods

Whey Fresh whey was obtained during the manufacture of *paneer* and *Cheddar cheese* collected from Experimental Dairy of National Dairy Research Institute, Karnal (Haryana). It was immediately subjected to pasteurization at 63 °C for 30 min followed by cooling at 4–5 °C.

Enzyme Maxilact L-2000, a purified food grade lactase preparation was isolated from selected strain of yeast, *Kluyveromyces marxianus* var. *lactis* was obtained from M/s Duke Thomson's International Sukhila, Indore (Madhya Pradesh). The enzyme had 2,000 neutral lactase units per gram and one neutral lactase unit is the quantity of enzyme having 1.30 nmol orthonitrophenol from an orthonitrophenol galactosidase substrate.

Ingredients and chemicals Analytical grade sodium bicarbonate 20% (w/v) and citric acid 20% (w/v) were used to adjust the pH of *paneer* and *cheese* whey prior to lactose hydrolysis by Maxilact L-2000. Lemon juice was procured from M/s Solar Sales (India), New Delhi. Lemon flavour was obtained from M/s International Flavour and Fragrance, India Ltd. Chennai. CMC was purchased from Himedia Pvt. Ltd. India. All other reagents used in the investigations were of analytical grade.

Enzymatic hydrolysis Different parameters such as time, temperature, pH and the enzyme levels were optimized to obtain lactose hydrolysis in *paneer* and *cheese* whey. A known quantity (250 ml) of whey was adjusted to pH 6.75 by 20% (w/v) sodium bicarbonate solution. The enzyme was added to this solution at the rate of 0.4% (v/v)

and mixed thoroughly. The whey was incubated at 40 °C from 30 min to 4 h. The hydrolyzed whey was taken out after definite time intervals and enzyme activity was arrested by heating at 60 °C for 2 min in water bath. The heated whey was immediately cooled to room temperature and the degree of lactose hydrolysis of whey incubated for definite time interval was estimated. The optimum time for maximum hydrolysis of whey was estimated. After standardizing the optimum time for lactose hydrolysis, the temperature of whey was adjusted to different temperatures of 20, 30, 40, 50, and 60 °C. The pH of whey was adjusted to 6.75. The whey was incubated for 4 h after addition of 0.4% (v/v) Maxilact L-2000 enzyme at varying temperatures. The hydrolysis of whey was estimated and optimum temperature for maximum hydrolysis of whey was carried out. In another experiment, the pH of whey was adjusted to 6.0, 6.5, 6.75, 7.0, and 7.5 with the help of 20% citric acid and 20% sodium bicarbonate solutions. The enzyme Maxilact L-2000 at 0.4% (v/v) was added to the whey samples and whey samples were incubated for 4 h. The optimum pH for maximum hydrolysis of whey was estimated. In another experiment, the pH of whey was adjusted to 6.75 and separately added with enzyme concentration of 0.1, 0.2, 0.3, 0.4, and 0.5% (w/v) and incubated at 40 °C for 4 h. After 4 h of incubation, the extent of hydrolysis and optimum level of enzyme concentration were measured.

Comparison of sweetness level in hydrolyzed whey The sweetness level in hydrolyzed whey with different levels of sucrose (1–2.5%, w/v) solution was carried out by triangle testing (Wardip 1978).

Standardization of levels of sugar, lemon juice, lemon flavour and CMC for beverage preparation Different levels of sugar, lemon juice, lemon flavour and stabilizer were standardized and their influence was assessed on the basis of sensory and physico-chemical properties of the product. The flow diagram for the manufacture of lactose hydrolyzed *paneer* whey lemon beverage is presented in Fig. 1. The experiment was carried out in D6 Hoke's Response Surface Design (Thompson 1982) for four independent variables as shown in Table 1. Sugar and CMC mixed together and were added to a definite amount of hydrolyzed *paneer* whey. The whey was heated to 40–45 °C to solubilize the stabilizer. It was then filtered through muslin cloth. After the addition of desired amount of lemon juice and lemon flavour, the pH of the beverage was adjusted to 3.8 with 25% (w/v) citric acid. Lemon based hydrolyzed whey beverage was filled into 200 ml clean, sterilized glass bottles which were crown corked. The bottles were heat treated at 90 °C for 2 min or at 5 psi for 5 min

Fig. 1 Flow diagram for the manufacture of 10 L lactose hydrolyzed paneer whey

Sensory evaluation The hydrolyzed paneer whey beverage was served in chilled condition to a panel of trained judges. The beverage was evaluated for flavour, consistency, colour and appearance and overall acceptability (OAA) score on 9-point Hedonic scale.

Table 1 Coded and uncoded values of variables and their level

Independent variable	Coded levels	−1	0	+1
Sugar, % (w/v)	A	6	8	10
Lemon juice, %(v/v)	B	2	4	6
Lemon flavor, %(v/v)	C	0.05	0.10	0.15
Carboxyl methyl cellulose, % (w/v)	D	0.03	0.05	0.07

Analytical techniques The moisture content of the beverage was estimated by oven drying method (ISI 1981). Ash content was estimated by incinerating the samples at 550 °C in a muffle furnace as per ISI (1981). Total soluble solids were estimated by hand refractometer and the values were expressed as °Brix at 20 °C. The pH values of the samples were measured using a microprocessor digital pH meter. The acidity of the beverage was estimated by titrating with 0.1 N NaOH solution using phenolphthalein indicator and was expressed in terms of % citric acid as per the method described in ISI (1960). The viscosity of the sample was measured using a falling ball viscometer (Gilmont Instruments) at 20 °C. The lactose content in whey was determined by the method of Perry and Doan (1950). The total sugar, reducing sugar and sucrose content in the beverage were estimated as per the method described by Ranganna (1995). Lactose content in cheese and paneer whey and residual lactose after hydrolysis were determined colorimetrically by the method of Nickerson et al. (1976). The per cent hydrolysis was calculated by the formula:

$$\frac{x - y}{x} \times 100$$

Where X = amount of lactose present in whey before hydrolysis and y = amount of lactose present in whey after hydrolysis.

Results and discussion

Composition of whey The total solids content in paneer and cheese whey varied from 6.35 to 6.78%. Lactose content was in the range of 5.03–5.04% in both the wheys. The protein and ash content ranged from 0.49–0.82% and 0.62–0.65% in paneer and cheese wheys, respectively. Balasubramanyam et al. (1989) had reported similar values for protein and ash content in paneer and cheese whey.

Lactose hydrolysis Lactose hydrolysis in cheese and paneer whey increased with increase the incubation time

from 30 min to 240 min. The degree of hydrolysis in *paneer* and *cheese* whey ranged from 70.7–89.7% and 79.8–89.2%, respectively after 30–180 min of incubation (Fig. 2). The sweetness level in hydrolyzed whey after 30 min hydrolysis time was equivalent to 1–2% sucrose solution, whereas sweetness level was equivalent to 2.5% sucrose solution after 180 min of incubation (Table 2). Both the whey systems and periods of incubation had significant effect ($p < 0.01$) on the hydrolysis of whey. Among the various temperatures (20–60 °C) and at a pH of 6.75 and enzyme concentration of 0.4% (v/v), it was noted that degree of hydrolysis of lactose was maximum (89.2–91.3%) was obtained at 40 °C while it was minimum (41.9–42.0%) at 20 °C (Fig. 2). The sweetness level in hydrolyzed whey at 30 and 40 °C of incubation was equivalent to 2.5% sucrose solution whereas, the sweetness level was judged as less than 1.0% after incubation at 20 °C (Table 2). Suresh and Jayaprakasha (2004) also obtained maximum hydrolysis of lactose in whey permeates at a temperature of 37 °C. Minimum (42%) hydrolysis of lactose attained at 20 °C was in close agreement with the findings of Suresh and Jayaprakasha (2004). Maximum (84.3–88.9%) hydrolysis in whey was obtained at pH 6.75 while minimum (55.8–66.5%) hydrolysis was observed at pH 6.0 (Fig. 2). The optimization of pH plays an important role in obtaining lactose hydrolysis in whey (Jelen 1993; Geilman 1993). However, Suresh and Jayaprakasha (2004) obtained maximum hydrolysis of lactose in whey permeate at pH 6.5. The sweetness level in hydrolyzed whey increased with increase the pH from 6.0 to 6.75. Maximum (2.5% sucrose solution) sweetness level in hydrolyzed whey occurred at pH 6.75 while minimum (1–1.5% sucrose

solution) sweetness level was obtained at pH 6.0 and 7.5 (Table 2). The maximum (88.2–89.2%) hydrolysis of lactose was obtained with Maxilact L-2000 enzyme concentration of 0.4% while, minimum (59.2–63%) hydrolysis was attained at the enzyme concentration of 0.1% in both *paneer* and *cheese* whey (Fig. 2). The sweetness level at minimum (0.1% enzyme concentration) hydrolysis level was equivalent to 1.5% sucrose solution, while sweetness level was 2.5% sucrose solution at maximum hydrolysis of 0.4–0.5% enzyme concentration (Table 2). Different enzyme concentrations had significant ($p < 0.01$, CD-2.139) effect on hydrolysis of lactose in whey. The results had shown that a pH of 6.75 and temperature of 40 °C, maximum hydrolysis in *cheese* and *paneer* whey was obtained with enzyme concentration of 0.4% of Maxilact L-2000 enzyme after incubation for 180 min. However, Veerapandian et al. (1998) reported that the hydrolysis of whey increased with increase the enzyme concentration from 1.0 to 2.0%.

Process optimization for manufacture beverage Judges had preferred the lemon based beverage after heat treatment at 90 °C for 2 min with overall acceptability score of 8 as compared to heat treated beverage at 5 psi for 5 min having overall acceptability score of 7.0. The heat treated beverage at 5 psi for 5 min was not acceptable due to the development of cooked flavour.

The effect of sugar, lemon juice, lemon flavour and CMC on sensory score of lemon based lactose hydrolyzed *paneer* whey is described in Table 3. The second order polynomial models were regressed for all the responses for the manufacture of lemon based lactose hydrolyzed *paneer* whey beverage. The flavour score in

Fig. 2 Effect of time, temperature, pH and enzyme concentration on lactose hydrolysis of *cheese* and *paneer* whey. Each observation is the mean of five replicates

Table 2 Optimization for hydrolysis of whey

	% degree of hydrolysis		Sweetness level (% sucrose solution)	
	Paneer	Cheese	Paneer	Cheese
Time (min)				
30	70.7	79.8	1	2
60	74.2	81.7	1.5	2
120	81.1	82.9	2	2
180	89.7	89.2	2.5	2.5
240	90.4	91.0	2.5	2.5
CD ($p<0.01$) whey 2.79; time 4.41 ($n=5$)				
Temperature (°C)				
20	41.9	42.0	<1.0	<1.0
30	86.2	87.2	2.5	2.5
40	91.3	89.2	2.5	2.5
50	82.8	62.7	2	1
60	56.9	49.5	<1	<1
CD ($p<0.01$) whey 1.18; temperature 1.87; whey x temperature 2.65 ($n=5$)				
pH				
6	55.8	66.5	1	1.5
6.5	86.7	81.0	2	2
6.75	88.9	84.3	2.5	2.5
7	79.5	78.9	1.5	1.5
7.5	75.9	78.0	1	1.5
CD ($p<0.01$) whey 1.26; pH 2; whey x pH 2.83 ($n=5$)				
Enzyme concentration (%)				
0.1	59.2	63.0	1.5	1.5
0.2	83.6	82.2	2	2
0.3	87.0	84.0	2.5	2.5
0.4	88.2	89.2	2.5	2.5
0.5	89.6	90.1	2.5	2.5
CD ($p<0.01$) enzyme concentration 2.14 ($n=5$)				

lactose hydrolyzed *paneer* whey beverage varied from 6.2 to 7.75. Maximum flavour score (7.75) was attained for formulation 5, 6 and 22 and minimum flavour score (6.2) was obtained for formulation 4 which had 6% sugar, 2% lemon juice, 0.05% lemon flavour and 0.03% CMC. Maximum consistency score (7.83) was obtained for formulation 5 and 7 and minimum consistency score (7.0) was reflected in formulation 4, 12 and 23. Judges had maximum preference for colour and appearance score (7.83) for formulation 5 and 15 of lactose hydrolyzed *paneer* whey beverage while minimum sensory score (6.5) for formulation 12 having 6% sugar, 6% lemon juice, 0.15% lemon flavour and 0.03% CMC. The sweetness profile in lemon based lactose hydrolyzed beverage ranged from 4 to 8%. Maximum sweetness score (8.0) in lactose hydrolyzed *paneer* whey beverage was reflected in formulation 1, 5, 6, 7, 8, 10, 15, 18, 19, 20, 22, 25, 27, 28 and 29 and minimum sweetness score (4.0) was observed in formulation 3 and 23. Maximum

OAA score (7.85) in hydrolyzed beverage was obtained in formulation 5 having 8% sugar, 4% lemon juice, 0.10% lemon flavour and 0.05% CMC and minimum OAA score (6.09) for formulation 23 which contained 4% sugar, 4% lemon juice, 0.10% lemon flavour and 0.05% CMC (Table 3). ANOVA studies had shown that sugar content in hydrolyzed lactose whey beverage had significant ($p<0.05$) effect for flavour, consistency and colour and appearance score. The sugar level had negative response on OAA score in lactose hydrolyzed whey beverage. Similarly the interaction of lemon juice and lemon flavour also exhibited negative response on flavour, consistency, colour and appearance score in whey beverage. The calculated adequate precision value was 6.46, 6.35, 6.03, 9.23 and 5.68 for flavour, consistency, colour and appearance, sweetness and OAA score in whey beverage which was greater than 4.0. A ratio greater than 4 is desirable which indicates that the model can be used to navigate the design space.

Table 3 Central composite rotatable design matrix and observed sensory values of response variables in lactose hydrolyzed whey beverage

Formulation	Sugar, %	Lemon juice, %	Lemon flavour, %	CMC, %	Flavour	Consistency	Colour and appearance	Sweetness	OAA
1	8	8	0.1	0.05	7.5	7.6	7.6	8	7.67
2	6	6	0.05	0.03	6.3	7.2	7.2	7	6.9
3	12	4	0.10	0.05	6.8	7.6	7.6	4	6.5
4	6	2	0.05	0.03	6.2	7	7.2	6	6.6
5	8	4	0.10	0.05	7.75	7.83	7.83	8	7.85
6	8	4	0.10	0.05	7.75	7.8	7.8	8	7.83
7	8	4	0.10	0.05	7.72	7.83	7.8	8	7.84
8	8	4	0.10	0.00	7.66	7.66	7.66	8	7.74
9	10	2	0.05	0.03	7.7	7.8	7.8	5	7.77
10	10	6	0.05	0.03	7.71	7.71	7.71	8	7.78
11	6	2	0.05	0.07	6.64	7.1	7.25	6.5	6.87
12	6	6	0.15	0.03	6.42	7	6.5	6.25	6.54
13	8	4	0.10	0.05	7.35	7.42	7.58	7	7.33
14	6	2	0.15	0.03	6.3	7.6	7.6	6.5	7
15	10	6	0.15	0.07	7.42	7.67	7.83	8	7.73
16	8	0	0.10	0.05	7	7.5	7.5	7	7.25
17	8	4	0.10	0.05	6.92	7.6	7.6	7	7.28
18	10	6	0.15	0.03	7.7	7.8	7.8	8	7.82
19	10	2	0.05	0.07	7.7	7.8	7.8	8	7.82
20	10	2	0.15	0.03	7.7	7.5	7.75	8	7.73
21	6	6	0.15	0.07	6.8	7.4	7.5	7	7.17
22	8	4	0.10	0.10	7.75	7.5	7.25	8	7.62
23	4	4	0.10	0.05	6.63	7	6.75	4	6.09
24	10	2	0.15	0.07	7.13	7.25	7	5	6.59
25	10	6	0.05	0.07	7.38	7.25	7	8	7.4
26	6	2	0.15	0.07	7	7.2	7	6	6.8
27	8	4	0.0	0.05	7.4	7.4	7.4	8	7.55
28	8	4	0.10	0.05	7.7	7.7	7.8	8	7.8
29	8	4	0.20	0.05	7.63	7.4	7.4	8	7.6
30	6	6	0.05	0.07	7.25	7.3	7.4	7	7.23

The model thus developed with coded variables are follows:

$$\text{Flavour} = 7.52 + 0.31*A + 0.11*B + 0.05*C + 0.01*D - 0.11*A*B - 0.11*A*C - 0.16*A*D + 0.01*B*C - 0.02*B*D - 0.08*C*D$$

$$- 0.23*A^2 - 0.10*B^2 - 0.03*C^2 + 0.01*D^2$$

$$\text{Consistency} = 7.69 + 0.14*A + 0.05*B + 0.05*C - 0.07*D - 0.03*A*B - 0.09*A*C - 0.03*A*D + 0.05*B*C + 0.01*B*D - 0.03*C*D$$

$$- 0.10*A^2 - 0.04*B^2 - 0.08*C^2 - 0.02*D^2$$

$$\text{Colour and appearance} = 7.73 + 0.16*A + 0.06*B + 0.06*C - 0.12*D - 0.06*A*B - 0.05*A*C - 0.04*A*D + 0.09*B*C + 0.09*B*D$$

$$- 0.02*C*D - 0.14*A^2 - 0.04*B^2 - 0.08*C^2 - 0.04D^2$$

$$\text{Sweetness} = 7.68 + 0.18*A + 0.51*B + 0.06*C - 0.05 + 0.10*A*B - 0.08*A*C + 0.08*A*D + 0.04*B*C - 0.04*B*D - 0.47*C*D$$

$$- 0.89*A^2 - 0.02*B^2 + 0.10*C^2 + 0.06*D^2$$

$$\text{Overall acceptability} = -0.89 + 5.16*A - 59.57*B + 0.11*C - 0.15*D - 0.20*A*B - 0.26*A*C + 0.05*A*D - 7.30*B*C + 7.45*B*D$$

$$+ 7.29*C*D - 16.01*A^2 + 74.0*B^2 - 15.69*C^2 - 5.92*D^2$$

The flavour score in whey beverage had decreasing trend with increase the lemon juice (2–6%) and sugar content from 6 to 10% (Fig. 3a). The flavour score in whey hydrolyzed beverage also declined with increase (0.03–0.07%) the CMC content. However, flavour score had increasing trend with increase (6–10%) in sugar content in

hydrolyzed beverage (Fig. 3a). However, as the content of lemon flavour (0.05–0.15%) and lemon juice (2–6%) increased, the flavour score in lemon based beverage decreased (Fig. 3a). The consistency score in hydrolyzed beverage decreased with increase the content of lemon juice and sugar (Fig. 3b). The consistency score in hydrolyzed

Fig. 3 Response surface plots on effect of processing variable on sensory scores **a** flavour, **b** consistency, **c** colour and appearance and **d** sweetness

beverage decreased with increase the level of CMC (0.03–0.07%). However, consistency score had increasing trend with increase the sugar content from 6 to 10% in hydrolyzed beverage (Fig. 3b). However, as the content of lemon flavour (0.05–0.15%) and lemon juice (2–6%) in beverage increased, the consistency score decreased (Fig. 3b). Judges had less preference to the hydrolyzed beverage with increase the lemon juice and sugar content during the manufacturing process. As the level of CMC and sugar content increased, the colour and appearance score decreased in hydrolyzed whey beverage. There had been sharp decrease in colour and appearance score in beverage with increase in lemon flavour and lemon juice (Fig. 3c). The sweetness level in beverage affects the acceptability to the consumers. As the content of lemon juice, lemon flavour and sugar increased the sweetness level at initial stage increased in hydrolyzed beverage. However, the

sweetness level decreased with further increase the lemon juice, lemon flavour and sugar content (Fig. 3d). However, as the level of CMC and sugar content increased the sweetness level in hydrolyzed beverage decreased. Similarly the sweetness level in hydrolyzed beverage decreased with increase in CMC and lemon flavour (Fig. 3d).

Physico-chemical properties The effect of sugar, lemon juice, lemon flavour and CMC levels on physico-chemical properties in hydrolyzed whey beverage is described in Table 4. The total solids level in hydrolyzed whey beverage varied from 10.2 to 17.2%. The acidity in lactose hydrolyzed whey beverage varied from 0.31 to 0.60% as citric acid. The viscosity level in hydrolyzed whey beverage was in the range of 1.48–2.58 Cp. In linear terms, sugar concentration had significant model term for total solids, total soluble solids, acidity and viscosity. Similar compo-

Table 4 Effect of sugar, lemon juice, lemon flavour and CMC levels on physico-chemical properties in lactose hydrolyzed whey beverage

Formulation	Sugar, %	Lemon juice, %	Lemon flavor, %	CMC, %	Total solids, %	Total soluble solids, %	Acidity, % citric acid	Viscosity (Cp)
1	8	8	0.1	0.05	13.40	13.40	0.60	1.94
2	6	6	0.05	0.03	10.20	10.40	0.50	1.64
3	12	4	0.10	0.05	16.80	17.0	0.31	2.09
4	6	2	0.05	0.03	11.0	11.60	0.41	1.48
5	8	4	0.10	0.05	11.90	14.0	0.42	1.79
6	8	4	0.10	0.05	12.0	14.20	0.42	1.72
7	8	4	0.10	0.05	11.80	14.0	0.41	1.76
8	8	4	0.10	0.00	12.70	14.0	0.42	1.51
9	10	2	0.05	0.03	15.80	16.0	0.46	1.70
10	10	6	0.05	0.03	15.80	16.0	0.46	1.70
11	6	2	0.05	0.07	12.0	16.0	0.43	1.84
12	6	6	0.15	0.03	12.0	12.0	0.39	1.63
13	8	4	0.10	0.05	14.0	14.0	0.41	1.79
14	6	2	0.15	0.03	14.0	14.0	0.41	1.79
15	10	6	0.15	0.07	15.45	15.60	0.40	2.30
16	8	0	0.10	0.05	13.70	14.20	0.45	1.74
17	8	4	0.10	0.05	13.50	14.0	0.38	1.79
18	10	6	0.15	0.03	13.50	14.0	0.38	1.79
19	10	2	0.05	0.07	14.55	15.20	0.41	2.19
20	10	2	0.15	0.03	15.95	16.0	0.44	1.73
21	6	6	0.15	0.07	11.0	11.40	0.41	2.05
22	8	4	0.10	0.10	15.20	15.40	0.47	2.58
23	4	4	0.10	0.05	11.20	13.20	0.51	1.67
24	10	2	0.15	0.07	17.20	17.40	0.47	2.50
25	10	6	0.05	0.07	16.90	17.60	0.46	2.42
26	6	2	0.15	0.07	13.40	13.80	0.48	2.39
27	8	4	0.0	0.05	13.70	14.0	0.49	1.95
28	8	4	0.10	0.05	11.90	14.0	0.42	1.82
29	8	4	0.20	0.05	13.66	14.80	0.48	1.98
30	6	6	0.05	0.07	11.90	12.40	0.48	1.94

sition values of the beverage in terms of total solids, total soluble solids, acidity and viscosity was reported by Suresh and Jayaprakasha (2004) in the manufacture of lactose hydrolyzed whey permeate based beverage. The CMC level had also significant model term for total solids and viscosity except for TSS and acidity level in lactose hydrolyzed whey beverage.

The values on regression coefficient for physico-chemical properties in lactose hydrolyzed whey beverage reflected that lemon juice had negative effect on TS and TSS content in lactose hydrolyzed whey beverage. Similarly the interaction of sugar and lemon flavour had negative effect on TS, TSS and viscosity of lactose hydrolyzed whey beverage. The coefficient of determination R^2 was between 0.68 and 0.95 for TS, TSS, acidity and viscosity. The higher coefficient of regression (R^2) values signified the goodness of the fit of the model.

Optimization In order to optimize the process for the development of hydrolyzed whey lemon beverage from *paneer* whey, the process variable consisted of sugar 6–10%, lemon juice 2–6%, lemon flavour 0.05–0.15% and CMC 0.03–0.07% for good hydrolyzed whey based lemon beverage. The maximum desirability was obtained with 8.45% sugar, 5.64% lemon juice, 0.08% lemon flavour and 0.05% CMC.

Conclusion

It can be concluded that maximum (85–90%) hydrolysis in *cheese* and *paneer* whey was obtained with enzyme concentration of 0.4% at pH 6.75 after incubation at 40 °C for 3 h. The most acceptable lemon based beverage contained 8% sugar, 4% lemon juice, 0.1% lemon flavor and 0.05% CMC.

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