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Effect of coagulation temperature, pressure and coagulant on the quality of cow milk paneer

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Abstract
A study was conducted to determine the influence of coagulation temperature *viz.*, 70, 80 & 90 °C, pressure *viz.*, 3, 4, 5 & 6 bar and coagulant (citric acid & vinegar) on the yield, moisture content and sensory characteristics of cow milk paneer. Study revealed that increase in the pressure brought about a highly significant ($P \leq 0.01$) difference in yield of paneer coagulated with vinegar and citric acid separately at 80 °C of coagulation temperature whereas there was insignificant change found in yield of paneer coagulated with vinegar at 90 °C and citric acid at 70 °C & 90 °C, respectively. On contrary, moisture content of paneer decreased with increase in the pressure values at all coagulation temperatures when coagulated with both vinegar and citric acid. Paneer samples prepared by vinegar and citric acid at various coagulation temperatures (70, 80 and 90 °C) showed highly significant ($P \leq 0.01$) difference in sensory attributes on applying pneumatic pressure (3, 4, 5 and 6 bar). Based on significantly ($P \leq 0.01$) higher yield and sensory scores, paneer made from 5 bar pressure coagulated with vinegar at the coagulation temperature of 80 °C was found to be good for the preparation of cow milk paneer.

Keywords: Vinegar, paneer, cow milk, pressure, yield, moisture content

1. Introduction
India has witnessed to be one of the largest milk producers across the world during the last few decades (NCEAR, 2012) [1]. In contrast to this, there are lots of factors leading to spoilage of milk such as excess of microbial count, improper refrigeration facilities and handling loss during transportation. Therefore, to prevent the spoilage of milk and decrease in the economic value due to wastage, it can be converted in to various value added dairy products such as khoa, paneer, cheese, ice cream, yoghurt, butter, ghee etc., One such value added product manufactured from milk is paneer which is widely consumed throughout the world. India a leading country in the world with 132.4 million metric tonne milk production in 2012-2013 accounts 15% of world's total milk production. An estimated 7% of milk produced in India is converted into paneer (NCEAR, 2012) [1].

Paneer is an important indigenous product categorized under cheese family which is obtained by heat treating the milk followed by acid coagulation. Paneer is a rich source of animal protein available at a comparatively lower cost. In addition, paneer is also a valuable source of fat, vitamins and minerals like calcium and phosphorus. The biological value of protein in paneer is in the range of 80 to 86 reported by Srivastava and Goyal, (2007) [2]. Paneer can be made from buffalo milk, cow milk and mixed milk but traditionally paneer is prepared from buffalo milk because it is reported to have higher amounts of bigger size fat globules and casein micelles. Paneer is used for making culinary dishes such as wrapped in dough and deep-fried or served with either spinach or peas. It has been defined that paneer means the product obtained from cow or buffalo milk or a combination thereof by precipitation with sour milk, lactic acid or citric acid. It shall not contain more than 70.0% moisture and milk fat content shall not be less than 50.0% of dry matter. The milk fat content of skim milk paneer shall not exceed 13.0% of dry matter (PFA, 2010) [3].

Paneer production involves the unit operations of heating of milk, coagulation, draining of whey, separation of chhana, pressing of chhana and cooling the paneer in cold water. Coagulation of milk can be achieved by admixing with acids during which fat with serum proteins get entrapped along with some whey which is called "chhana". It is then pressed into blocks and cooled. These blocks are cut into convenient retail sizes. The shelf life of paneer is only one day at room temperature and the spoilage is mainly attributed to the growth of surface

tainting and off-flavour producing microbes. The shelf life of paneer can be enhanced by vacuum packaging. Though there are improved methods of paneer production available for obtaining better yield, optimization of process parameters is still needed to enhance sensory and textural properties of paneer. Hence, the following work was undertaken to optimize the coagulation temperature, pressure and coagulant for production of paneer with higher yield and good sensory profile.

2. Materials and Methods

2.1 Milk Source

The milk samples were purchased from local market. Platform test such as clot on boiling and sensory analysis were done initially to check the quality of the milk. The fat and SNF of the raw milk samples were electronically measured using EKOMILK ULTRA PRO (make: Everest instrument Pvt. Ltd, chennai). The fat, SNF and acidity of cow milk were 3.80%, 7.50% and 0.14%. For each trial, 5L of milk samples were used for paneer preparation.

2.2 Preparation of Paneer

Cow milk (fat 3.80% and SNF 7.50%) was filtered and heated in a stainless steel vessel at various coagulation temperatures viz., 70, 80 and 90 °C. The coagulant such as citric acid or vinegar was added with the coagulum period of 5 minutes. Constant stirring was done during the addition of coagulant to attain complete coagulation and to reduce the loss in yield. Then the coagulum was dropped in the pressing unit. Pressure was applied at the top of the pneumatic press at various levels ranging from 3-6 bar at an interval of 1 bar pressure (P_1 - P_4). Whey was drained and the pressed paneer was removed from the press. It was immersed in chill water and it was weighed in weighing balance (make: Cibi, giritronics; 20g-10000g; e =1g) to measure the weight of the paneer samples. The paneer was cut into required size and packed in metalized pouch. The packed paneer sample was kept in deep freezer (make: Voltas, Mangaldeep Engineering Company, Ahmadabad) for freezing of the paneer samples for further studies.

2.3 Physico-Chemical Properties of Paneer

Yield was calculated based on the quantity of the paneer obtained from the milk. It was calculated as Kg / Kg of milk (Kalab *et al.*, 1988 and Agnihotri & Pal, 1996) [4, 5]. The moisture content of the paneer was determined by hot air oven method (BIS, 1983: IS 10484) [6]. A sample size of 2g was kept at 102 ± 1 °C for about 4 hours to constant weight.

2.4 Sensory Evaluation of Paneer

The sensory properties of paneer samples were judged by a panel of 10 semi-trained judges drawn from the College of Food and Dairy Technology, Chennai. Each panelist was served with a standard score card ('9' point hedonic scale) for recording score for sensory attributes such as colour & appearance, flavour, body & texture and overall acceptability of the product (Thippeswamy, *et al.*, 2011 and Kumar *et al.*, 2008) [7, 8].

2.5 Statistical analysis

Data obtained during the present study was analysed using IBM SPSS® 20.0 for Windows® software as per the standard procedure of Snedecor and Cochran (1968) [9]. Results were expressed as mean ± standard error.

3. Results and Discussion

3.1 Physico-Chemical Properties of Paneer

It was observed from table. 1 that the yield of the cow milk paneer ranged from 13.17 to 15.51%. The mean values on the yield of cow milk paneer prepared from vinegar were increased with increase in pressure values at the coagulation temperature of 70 ºC. The yield of cow milk paneer showed highly significant ($P \leq 0.01$) difference at all pressure levels (3, 4, 5 and 6 bar) at the coagulation temperature of 80 ºC. The yield of paneer was increased with increase in pressure till 5 bar and decreased with further increase in pressure at the coagulation temperature of 80 ºC when vinegar was used as a coagulant. An unsteady trend of yield was observed with respect to applied pressures at the coagulation temperature of 90 ºC. Although there were changes in the mean values of yield of cow milk paneer, the changes were insignificant at 90 ºC when the vinegar was used as a coagulant. The mean values on the yield of cow milk paneer coagulated with vinegar on applying various pressures (3, 4, 5 and 6 bar) at the coagulation temperature of 70, 80 and 90 ºC is shown in fig 1. The mean values on yield of cow milk paneer prepared from citric acid were increased with increase in pressure values. The yield of paneer increased at the pressure levels 3, 4 and 5 whereas at 6 bar pressure the yield of paneer decreased at the coagulation temperature of 70, 80 and 90 ºC. Although there were changes in the mean values on the yield of cow milk paneer coagulated at 70 and 90 ºC, the changes were found to be insignificant. The yield of cow milk paneer coagulated with citric acid on applying various pressures (3, 4, 5 and 6 bar) at the coagulation temperature of 70, 80 and 90 ºC is shown in fig 2.

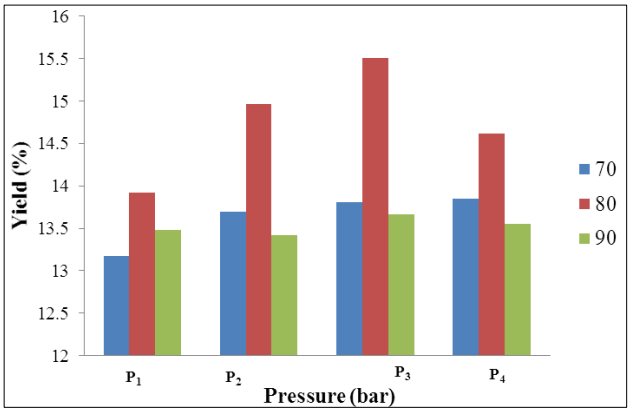

Fig 1: Yield (%) of cow milk paneer at various coagulation temperatures and pressure levels when coagulated with vinegar

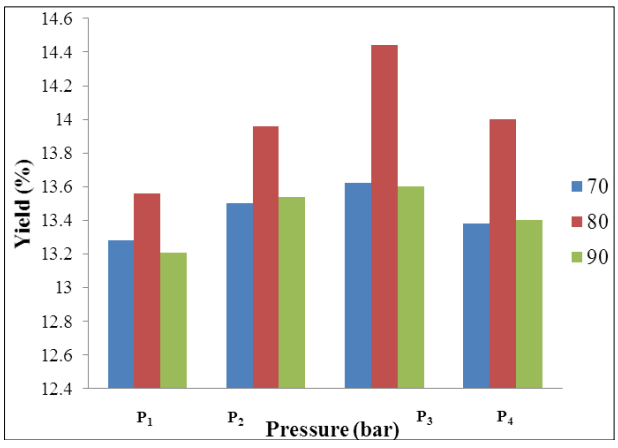

Fig 2: Yield (%) of cow milk paneer at various coagulation temperatures and pressure levels when coagulated with citric acid

Paneer developed with vinegar resulted on a higher yield than citric acid. The highest yield (15.51%) was obtained when cow milk was coagulated with vinegar by applying 5 bar pressure at coagulation temperature of 80 °C. The observed differences in yield might be due to type and strength of coagulant used in this study. These findings were similar to the observations of Shanaziya *et al.*, (2018) [10] who reported that yield of paneer using citric acid and vinegar was 120 and 134 g/kg of milk, respectively.

Table 1: Yield (%) of cow milk paneer (Mean±SE) @ at various temperature and pressure levels when coagulated with vinegar and citric acid

P (bar)	Vinegar			Citric acid		
	70 °C	80 °C	90 °C	70 °C	80 °C	90 °C
3	13.17^{a}±0.11	13.92^{a}±0.10	13.48^{a}±0.15	13.28^{a}±0.11	13.56^{a}±0.08	13.21^{a}±0.09
4	13.70^{b}±0.15	14.97^{c}±0.11	13.42^{a}±0.12	13.50^{a}±0.13	13.96^{b}±0.09	13.54^{a}±0.10
5	13.81^{b}±0.16	15.51^{d}±0.08	13.66^{a}±0.13	13.62^{a}±0.10	14.44^{c}±0.11	13.60^{a}±0.14
6	13.85^{b}±0.20	14.62^{b}±0.09	13.55^{a}±0.10	13.38^{a}±0.13	14.00^{b}±0.11	13.40^{a}±0.18
F-value	3.914*	48.671**	0.651^{NS}	1.522^{NS}	13.296**	1.674^{NS}

P – Pressure (bar), @ - Average of six trials

**- Highly significant ($P \leq 0.01$) at intervals,*- Significant ($0.05 < P \leq 0.01$) at intervals, NS - Non significant

a, b, c and d- Superscripts with same letter indicates that the treatments are on par

It was observed that from table 2, moisture content of the cow milk paneer ranged from 49.83% to 58.41% on wet basis. The mean values on the moisture content of cow milk paneer prepared from citric acid and vinegar were decreased with increase in pressure values at the coagulation temperature of 70, 80 and 90 °C. As discussed in above section, the yield of the cow milk paneer (15.51%) was highest when coagulated with vinegar at the coagulation temperature of 80 °C by applying 5 bar pressure and the corresponding moisture content was 51.81%.

Table 2: Moisture content (%) of cow milk paneer (Mean±SE) @ on wet basis

P (bar)	Vinegar			F-value	Citric acid			F-value
	70 °C	80 °C	90 °C		70 °C	80 °C	90 °C	
3	58.41^{bB} ±0.52	57.33^{cB} ±0.26	56.11^{cA} ±0.48	13.13**	55.23^{cA}±0.42	56.11^{bAB} ±0.30	57.49^{cB} ±0.36	7.282*
4	58.17^{bB} ±0.35	54.28^{bA} ±0.26	55.36^{bcA} ±0.37	43.65**	53.63^{bA}±0.30	55.36^{bB} ±0.35	56.38^{bB} ±0.32	17.484**
5	54.14^{aB} ±0.38	51.81^{aA} ±0.37	53.74^{bB} ±0.49	14.231**	50.73^{aA}±0.30	53.74^{aB} ±0.30	55.30^{aC} ±0.34	36.535**
6	53.81^{aB} ±0.38	51.21^{aA} ±0.43	52.49^{aB} ±0.36	9.770*	49.83^{aA}±0.33	52.49^{aB} ±0.45	55.14^{aC} ±0.26	68.459**
F-value	36.560**	68.230**	10.501**		53.496**	14.391**	11.486**	

P – Pressure (bar), @ - Average of six trials

**-Highly significant ($P \leq 0.01$) at intervals,*- Significant ($0.05 < P \leq 0.01$) at intervals, NS- Non significant

a, b, c and A, B, C - Superscripts with same letter indicates that the treatments are on par

This is in concordance with the observations made by chitranayak *et al.*, (2017) [11] that increase in the pressure applied (2.5 – 3.5 kg/cm^2) resulted in a reduction in the moisture content of paneer from 54.73 to 45.65%.

3.2 Sensory Evaluation of Paneer

It was observed from table 3, that paneer prepared from cow milk coagulated with citric acid and vinegar separately at coagulation temperatures of 70, 80 and 90 °C showed highly significant ($P \leq 0.01$) changes in color & appearance, body & texture, flavor and overall acceptability among the samples on applying the pneumatic pressures of 3, 4, 5 and 6 bar.

The average color & appearance scores of paneer ranged from 5.20 to 7.60. The average flavor scores of paneer ranged from 5.20 to 7.80. The average body & texture scores of paneer ranged from 3.20 to 8.60. The average overall acceptability scores of paneer ranged from 5.13 to 7.60.

Table 3: Mean scores of **s**ensory evaluation on paneer prepared from cow milk by applying various pressures, coagulation temperature and coagulants (Mean±SE) @

Treatments			Colour and appearance	Body and texture	Flavour	Overall acceptability
C	T	P				
		3	6.00 ^{abcd}±0.32	4.60 ^{bc}±0.24	6.40 ^{bcdef}±0.24	5.67 ^{abcd}±0.18
Vinegar	70 °C	4	6.20 ^{bcde}±0.20	4.60 ^{bc}±0.24	6.20 ^{bcde}±0.20	5.67 ^{abcd}±0.15
		5	6.20 ^{bcde}±0.20	7.40 ^{gh}±0.24	6.60 ^{cdef}±0.24	6.73 ^{ghij}±0.07
		6	7.20 ^{fg}±0.20	7.60 ^{h}±0.24	7.20 ^{fghi}±0.20	7.33 ^{kl}±0.18
	80 °C	3	5.80 ^{abc}±0.20	5.20 ^{cd}±0.20	5.20 ^{a}±0.37	5.40 ^{ab}±0.07
		4	5.80 ^{abc}±0.37	6.20 ^{ef}±0.20	6.20 ^{bcde}±0.20	6.07 ^{cdef}±0.12
		5	6.60 ^{cdef}±0.24	8.60 ^{i}±0.24	7.60 ^{hi}±0.51	7.60 ^{l}±0.27
		6	7.60^{g}±0.24	6.60 ^{fg}±0.40	6.20 ^{bcde}±0.20	6.80 ^{hijk}±0.13
	90 °C	3	6.80 ^{defg}±0.37	4.80 ^{cd}±0.20	6.00 ^{abcd}±0.32	5.87 ^{bcde}±0.08
		4	7.00 ^{efg}±0.32	5.00 ^{cd}±0.32	6.00 ^{abcd}±0.32	6.00 ^{cdef}±0.28
		5	6.80 ^{defg}±0.20	6.60 ^{fg}±0.40	5.60 ^{ab}±0.24	6.33 ^{efgh}±0.24
		6	7.20 ^{fg}±0.37	7.40 ^{gh}±0.24	7.40 ^{ghi}±0.24	7.33 ^{kl}±0.18
citri	70 °C	3	5.20 ^{a}±0.20	3.80 ^{ab}±0.37	6.40 ^{bcdef}±0.24	5.13 ^{a}±0.17
		4	5.20 ^{a}±0.20	4.60 ^{abc}±0.24	6.80 ^{defgh}±0.20	5.53 ^{abc}±0.08
		5	5.80 ^{abc}±0.20	6.20 ^{ef}±0.20	7.60 ^{hi}±0.24	6.53 ^{fghi}±0.13
		6	7.00 ^{efg}±0.32	7.00 ^{fgh}±0.32	7.80 ^{i}±0.20	7.27 ^{jkl}±0.22
	80 °C	3	5.60 ^{ab}±0.40	5.60 ^{de}±0.24	5.80 ^{abc}±0.20	5.67 ^{abcd}±0.15

c a c i d		4	5.40 ^{ab}±0.24	5.20 ^{cd}±0.20	6.40 ^{bcdef}±0.24	5.67 ^{abcd}±0.11
		5	6.20 ^{bcde}±0.20	5.60 ^{de}±0.40	6.20 ^{bcde}±0.20	6.00 ^{bcd}±0.11
		6	7.40 ^{fg}±0.24	6.20 ^{ef}±0.20	6.80 ^{defgh}±0.20	6.80 ^{hijk}±0.13
	90 °C	3	6.60 ^{cdef}±0.40	3.20 ^{a}±0.37	6.80 ^{defgh}±0.37	5.53 ^{abc}±0.27
		4	6.80 ^{defg}±0.37	5.00 ^{cd}±0.32	6.80 ^{defgh}±0.37	6.20 ^{defg}±0.08
		5	6.80 ^{defg}±0.37	5.40 ^{cde}±0.40	6.80 ^{defgh}±0.20	6.33 ^{efgh}±0.24
		6	7.20 ^{fg}±0.37	6.80 ^{fgh}±0.37	7.00 ^{efgh}±0.45	7.00 ^{ijk}±0.18
F-Value			5.90**	19.43**	5.42**	16.72**

C – Coagulant, T – Temperature (°C), P – Pressure (bar), @ - Average of six trials

**-Highly significant ($P \leq 0.01$) at intervals $^{a-l}$ - Superscripts with same letter indicates that the treatments are on par

The overall acceptability scores of paneer produced by coagulating with vinegar at 80 °C of coagulation temperature at 5 bar was resulted in the maximum overall acceptability values of 7.60 and the yield was also found to be maximum at the same treatment which was observed from table 4.2.

The results found were on par with the observations made by Vishweshwaraiah & Anantakrishnan (1985) [12] and Arya & Bhaik (1992) [13] who produced good quality paneer from cow milk at coagulation temperature of 80-85 °C.

4. Conclusion

Hence on the basis of above findings we can conclude that the treatment which resulted in the yield of 15.51%, moisture content of 51.81% and overall acceptability of 7.60 when it was coagulated with vinegar at the coagulation temperature of 80 °C was found superior to others on applying pneumatic pressure of 5 bar.

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