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ORIGINAL ARTICLE

Effect of modified atmospheric packaging on the shelf stability of paneer prepared by adopting hurdle technology

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Abstract Paneer was prepared by application of hurdle technology (HT) and its shelf stability studied by modified atmospheric packaging (MAP). The hurdles adopted comprised of water activity (a_w), pH, preservative and MAP. The a_w was reduced by using NaCl (1–3%), citric acid (CA, 0.01–0.1%) and potassium sorbate (0.1%). NaCl and CA at 3 and 0.1% reduced a_w from 0.994 to 0.970 and pH from 5.6 to 5.1, respectively. Sensory scores of all samples decreased ($p \leq 0.05$) from control during storage at different temperatures, but these scores at the end of 20 days were still under acceptable limit of 6 and above (liked moderately). MAP was carried out by using a mixture of CO_2 to N_2 in the ratio of 50:50. The HT adopted paneer with MAP had extended the shelf-life from 1 to 12 days at room temperature (30±1°C) and 6 to 20 days at refrigeration (7±1°C) temperatures.

Keywords Paneer · Hurdle technology · Citric acid · Modified atmospheric packaging · Potassium sorbate

Introduction

Dairy industry in India has witnessed rapid growth in the last 3 decades. The milk production during 2009 was estimated to be 104.8 million tonnes (NSI 2009) of which 45–50% were converted into variety of traditional milk products (Venkateshaiah 2003). Paneer is one of the important Indian traditional heat and acid coagulated dairy product, which is being widely used in varieties of culinary dishes. The annual paneer production is about 150,000 tonnes (Aneja et al. 2002). The higher moisture content of this product (50–60%) makes it more prone to faster spoilage resulting in limited shelf life. The shelf-life of paneer is only 1 day at room temperature (30±1°C) and the spoilage is mainly attributed to the growth of surface tainting and off-flavour producing microbes. In order to enhance the shelf life of paneer several attempts have been made in the past, which included addition of preservatives (Kaur et al. 2003), vacuum packaging, low temperature storage, dehydration and heat sterilization (Rao and Patil 2001), treatment with brine, chlorinated water, H_2O_2, delvocid, sorbic acid, potassium sorbate and antioxidants (Rao 2000). However, these methods could not improve the shelf-life and fully also led to jeopardize the flavour and texture of the product. Hurdle technology (HT) concept may enhance the shelf stability of paneer. Each hurdle like a_w, pH, redox-potential (Eh) and modified atmospheric packaging (MAP), which are either bacteriostatic or bactericidal in nature, may help to extend shelf life. When used in combination at an optimum level without affecting the product quality, HT enhances shelf-life of the product (Leistner 1994). MAP is known to bring about changes in respiration rate, microbial growth, oxidation reactions and by changing the levels of gases that surround the product and thus increase the keeping quality (Mangarj and Goswami 2009). Present study was undertaken to study the effect of HT and MAP on shelf-life enhancement of paneer.

Materials and methods

Preparation of paneer Fresh cow's milk, cream and skim milk were procured from Students Experimental Dairy

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Table 1 Water activity (a_w) and pH of paneer after diffusion for about 12 h in NaCl and citric acid (CA) solutions of various concentrations at 7 C

NaCl solution,%	a_w	CA solution,%	pH
0	0.994	0	5.6
1	0.99	0.01	5.5
2	0.98	0.05	5.3
3	0.97	0.1	5.1

(n=3)

Plant of the University. Cow milk was filtered and standardized to fat: solids not fat ratio of 1:1.65 using cream and skim milk. The standardized milk was transferred into a double jacketed insulated stainless steel vat. $CaCl_2$ (@ 0.08% of milk) was added to milk. The milk was heated to 90 C (no hold) and cooled to 80 C. Coagulation of milk was done by adding 1% citric acid (CA) solution at 80 C (2 g CA/l) and the coagulated mass was allowed to settle for 5 min. After the drainage of whey, curd was collected and filled in muslin cloth lined circular stainless steel hoops (10 cm diameter and 25 cm height) with holes on its side to facilitate the expulsion of whey. The hooped curd was pressed at 2-3 kg/cm^2 for 10–15 min. The pressed curd was immersed in chilled water (4 C/1-2 h) followed by cutting into pieces of 1 cm cubes for further studies.

Water activity and pH a_w and pH of paneer were reduced by dipping paneer cubes of 1 cm (100 g) each in stainless steel vessels containing 1 l of 1, 2 and 3% NaCl and 0.01, 0.05 and 0.1% CA solutions for diffusion at refrigeration (7± 1°C) temperature for 12 h, respectively. After diffusion, paneer cubes were taken out and kept on wire gauze in refrigerator for approximately 30 min to facilitate drainage. Paneer was then subjected to sensory evaluation by a panel of 5 judges. Potassium sorbate (01%) was used as a preservative (Thakral et al. 1990).

MAP Paneer was packed in 64 μm thick, 20 cm×14 cm size, two layered heat sealable pouch packaging material (PET/PE) procured from Shakthi Packaging, Bangalore. MAP was carried out by employing Reepack® and MAP mix 9000 Gas mixer manufactured by PBI DANSENSOR A/S, Denmark, by a combination of N_2 and CO_2 at a ratio of 50:50.

Shelf- life studies For enhancing the shelf-life, a_w and pH of paneer was reduced, packed in the packaging material (PET/PE) and subjected to MAP (CO_2:N_2=50:50) followed by storage at ambient (30°±1 C) and refrigeration (7±1 C) temperatures. Samples were drawn at regular intervals and evaluated for physico-chemical and sensory qualities.

Analytical methods Milk, cream and skim milk were analyzed for fat, SNF and titratable acidity and paneer samples for moisture, fat, protein, free fatty acids and ash as per ISI (1981b). Paneer a_w was measured by using Rotronic probe type (AW-DIO) water activity meter (ROTRONIC® Instruments Corp., Switzerland). Paneer cubes were taken out after diffusion, and kept in refrigeration temperature for 30 min to remove excess moisture on surface of cubes. Paneer cubes were thoroughly ground by using pestle and mortar and the ground sample was taken into the sample container. After 5–10 min, a_w of the product shown by the display was recorded. The pH was determined by grinding 10 g of paneer with 10 ml of glass distilled water and dipping the electrode directly into the slurry by using digital pH meter (Elico Ltd., Hydarabad, India) as per the procedure followed for cheddar cheese ISI (1981b).

The paneer samples were analyzed for standard plate count (SPC), coliforms, yeast and moulds (ISI 1981a). Agar

Table 2 Sensory scores (max 9) of paneer diffused in NaCl and citric acid (CA) solution of different concentrations

NaCl solution,%	Colour and appearance	Flavour	Body and texture	Overall acceptability
0	7.7^a	7.5^a	7.9^a	7.8^a
1	7.5^b	7.5^a	7.5^b	7.4^b
2	7.4^b	7.4^a	7.2^c	7.4^b
3	7.4^b	7.0^b	7.0^d	7.0^c
4	7.0^c	5.5^c	6.0^e	6.0^d
$CD_{0.05}$	0.19	0.18	0.15	0.19
CA,%				
0	7.7^a	7.7^a	7.7^a	7.6^a
0.01	7.6^b	7.6^{ab}	7.6^{ab}	7.6^a
0.05	7.5^c	7.6^b	7.5^b	7.5^a
0.1	7.5^c	7.0^c	7.0^c	7.2^b
$CD_{0.05}$	0.076	0.17	0.13	0.12

Means with different superscripts in a column differ significantly at $p \leq 0.05$ (n=3)

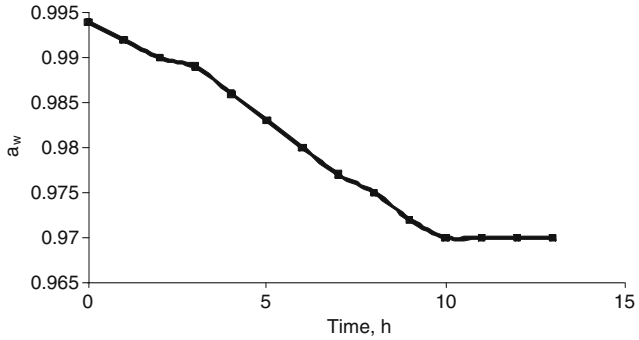

Fig. 1 Changes in a_w of paneer during diffusion in 3% sodium chloride solution at 5°C (n=3)

media were procured from Hi-media Laboratories Pvt. Ltd., Mumbai, India. The sensory analysis was carried out by a panel of 5 judges. The samples were examined for colour and appearance, body and texture, flavour and overall acceptability on 9-Hedonic scale score-card. All the results in triplicate were analyzed for significance at 5% level using Statistical packages for Social Sciences (SPSS Version 8.0).

Results and discussion

Reduction of a_w and pH of paneer by diffusion Preliminary trials indicated that paneer diffused with 4% NaCl had very high salty taste and hence was rejected by judges. Therefore, for further studies, only up to 3% NaCl was used for diffusion trials. As the concentration of NaCl increased from 1–3%, a_w decreased from 0.994 to 0.970 at the end of equilibration indicating that rate of diffusion increased with higher salt concentration (Table 1). This reduction in a_w may be due to the fact that NaCl is a good humectant as it binds free water in paneer (Singh et al. 1989, Jayaraj Rao and Patil 1999a, Sudhir Singh and Rai 2004). Similarly pH decreased from 5.6 to 5.1 (Table 1) when paneer was diffused in increasing concentrations (0.01–0.10%) of CA also observed by Jayaraj Rao and Patil (1999b).

Effect of NaCl diffusion on sensory quality of paneer Colour and appearance scores of salt diffused paneer were lower ($p \leq 0.05$) compared to control at all concentrations of salt due to turning of colour of paneer cubes to dull white, probably because the reflection or scattering of light was dimmed by the dispersion of moisture droplets on the surface, but the scores did not decrease ($p \leq 0.05$) with increase in salt concentration (Table 2). The flavour of paneer turned from pleasant nutty to more salty with increase in the salt concentration and these scores were similar to control up to 2% salt. This was expected as NaCl enhances the palatability up to certain level. The flavour scores decreased ($p \leq 0.05$) from 7.9 to 7.0 at 3% salt. This concentration may not be objectionable considering the fact that the product is later used for paneer curry making causing dilution of salt content.

The body and texture scores of NaCl diffused paneer decreased ($p \leq 0.05$) with increase in salt concentration (Table 2) possibly due to softening and dissolving effect of salt on proteins in paneer. Overall acceptability scores decreased ($p \leq 0.05$) with increased salt concentration, but these were within acceptable limit of 7 (liked moderately). Hence for all further studies 3% NaCl diffusion solution was used.

Effect of CA diffusion on sensory quality of paneer Colour and appearance scores of CA diffused paneer were lower ($p \leq 0.05$) than control at all concentrations of CA due to the presence of dispersed moisture droplets on the surface (Table 2). Similar trend was noticed with respect to flavour scores also, however it was non-significant up to 0.05% level. Probably at this level CA did not impart sour acidic taste. At 0.1% level the scores were different ($p \leq 0.05$) from control, which may be due to acidic sour taste imparted by CA (Bhattacharya et al. 1971). But the panelists felt that the taste was within the acceptable limit.

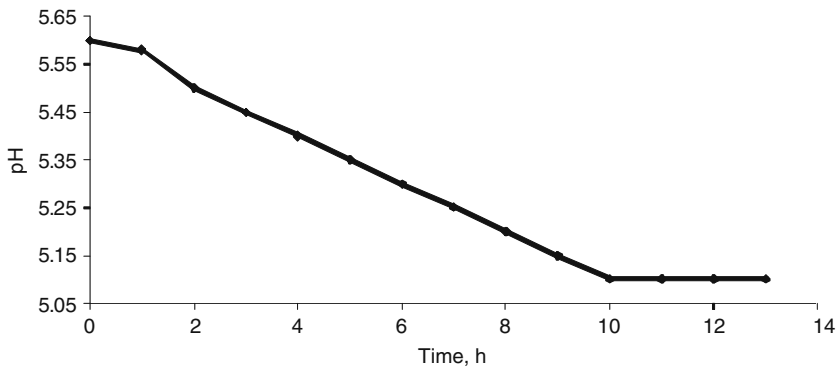

Fig. 2 Changes in pH of paneer during diffusion in 0.1% citric acid solution at 5°C (n=3)

Table 3 Effect of modified atmospheric packaging (MAP) on sensory score of diffused paneer packed in PET/PE during storage at 30±1 C

Paneer type	Storage period, days								
	0	1	2	4	6	8	10	12	14
Colour and appearance									
R1	7.8^{ap}	6.8^{aq}	5.2^{ar}	–	–	–	–	–	–
R2	7.5^{bp}	7.1^{bq}	6.5^{br}	6.1^{as}	5.5^{at}	–	–	–	–
R3	7.5^{bp}	7.2^{bq}	7.0^{cr}	6.7^{bs}	6.4^{bt}	5.6^{au}	–	–	–
R4	7.4^{bp}	7.3^{cp}	7.2^{dp}	7.0^{cq}	6.8^{cr}	6.5^{bs}	6.3^{t}	6.1^{u}	5.9^{v}
Flavour									
R1	7.7^{ap}	6.5^{aq}	5.1^{ar}	–	–	–	–	–	–
R2	7.5^{bp}	7.0^{bq}	6.4^{br}	6.0^{as}	5.4^{at}	–	–	–	–
R3	7.5^{bp}	7.3^{cp}	7.0^{cq}	6.6^{br}	6.2^{bs}	5.3^{at}	–	–	–
R4	7.2^{cp}	7.2^{dp}	7.0^{cp}	6.9^{cq}	6.8^{cq}	6.6^{br}	6.5^{r}	6.2^{s}	5.8^{t}
Body and texture									
R1	7.9^{ap}	6.7^{aq}	5.5^{ar}	–	–	–	–	–	–
R2	7.6^{bp}	7.2^{bp}	6.7^{bq}	6.3^{ar}	5.8^{as}	–	–	–	–
R3	7.5^{bp}	7.2^{bq}	7.0^{cq}	6.7^{br}	6.3^{bs}	5.4^{at}	–	–	–
R4	7.2^{cp}	7.1^{bp}	7.0^{cp}	6.9^{cpq}	6.8^{cq}	6.6^{bqr}	6.4^{r}	6.3^{rs}	5.9^{t}
Overall acceptability									
R1	7.8^{ap}	6.7^{aq}	5.3^{ar}	–	–	–	–	–	–
R2	7.5^{bp}	7.1^{bq}	6.6^{br}	6.2^{as}	5.5^{at}	–	–	–	–
R3	7.5^{bp}	7.2^{bq}	7.0^{cq}	6.7^{br}	6.3^{bs}	5.4^{at}	–	–	–
R4	7.2^{cp}	7.2^{bp}	7.1^{cp}	6.9^{cpq}	6.8^{cq}	6.7^{bq}	6.5^{r}	6.3^{r}	5.9^{s}

R1-raw paneer + air, R2-diffused paneer + air, R3-raw paneer + MAP, R4-diffused paneer + MAP, (n=3)

Means with different superscripts (a,b.c…) in a column and means with different superscripts (p,q,r….) in a row differ significantly ($p \leq 0.05$)

Table 4 Effect of MAP in sensory score of diffused paneer packed in PET/PE during storage at 7±1 C

Paneer type	Storage period, days										
	0	1	2	4	6	8	10	15	18	20	25
Colour and appearance											
R1	7.8^{ap}	7.7^{ap}	7.5^{aq}	7.0^{ar}	6.5^{as}	5.5^{at}	–	–	–	–	–
R2	7.5^{bp}	7.4^{bp}	7.2^{bq}	6.9^{br}	6.8^{br}	6.5^{bs}	5.8^{at}	–	–	–	–
R3	7.6^{cp}	7.4^{bq}	7.3^{cq}	7.2^{cr}	7.0^{cs}	6.9^{cs}	6.8^{bt}	6.5^{au}	6.2^{av}	5.8^{aw}	–
R4	7.5^{bp}	7.5^{cp}	7.4^{dp}	7.2^{cq}	7.1^{dq}	7.0^{dr}	6.9^{cr}	6.6^{bs}	6.4^{bt}	6.1^{bu}	5.9
Flavour											
R1	7.8^{ap}	7.7^{ap}	7.4^{aq}	6.9^{ar}	6.2^{as}	5.1^{at}	–	–	–	–	
R2	7.5^{bp}	7.4^{bp}	7.2^{bq}	7.1^{bq}	6.8^{br}	6.4^{bs}	5.5^{at}	–	–	–	–
R3	7.5^{bp}	7.4^{bp}	7.3^{cq}	7.1^{br}	7.0^{cr}	6.8^{cs}	6.7^{bs}	6.2^{at}	5.9^{au}	5.5^{av}	–
R4	7.5^{bp}	7.4^{bp}	7.3^{cq}	7.2^{cq}	7.1^{dr}	6.9^{ds}	6.8^{cs}	6.5^{bt}	6.3^{bu}	6.0^{bv}	5.8
Body and texture											
R1	7.8^{ap}	7.7^{ap}	7.5^{aq}	7.0^{ar}	6.3^{as}	5.2^{at}	–	–	–	–	–
R2	7.6^{bp}	7.4^{bq}	7.3^{bq}	7.2^{bq}	6.9^{br}	6.5^{bs}	5.6^{at}	–	–	–	–
R3	7.5^{cp}	7.4^{bp}	7.3^{bq}	7.2^{bq}	7.0^{cr}	7.0^{cr}	6.8^{bs}	6.4^{at}	6.1^{au}	5.7^{av}	–
R4	7.5^{cp}	7.5^{cp}	7.4^{cp}	7.2^{bq}	7.1^{dr}	7.0^{cr}	6.9^{cr}	6.5^{bs}	6.3^{bt}	6.1^{bu}	5.9
Overall acceptability											
R1	7.8^{ap}	7.7^{ap}	7.5^{aq}	7.0^{ar}	6.3^{as}	5.4^{at}	–	–	–	–	–
R2	7.5^{bp}	7.4^{bp}	7.3^{bq}	7.0^{ar}	6.8^{bs}	6.5^{bt}	5.6^{au}	–	–	–	–
R3	7.5^{bp}	7.4^{bp}	7.3^{bp}	7.1^{bq}	7.0^{cq}	6.9^{cr}	6.8^{br}	6.4^{as}	6.1^{at}	5.7^{au}	–
R4	7.5^{bp}	7.5^{cp}	7.3^{bq}	7.2^{cq}	7.1^{dq}	7.0^{dr}	6.9^{cr}	6.6^{bs}	6.4^{bt}	6.1^{bu}	5.8

R1-raw paneer+air, R2-diffused paneer+air, R3-raw paneer+ MAP,R4-diffused paneer+MAP (n=3)

Means with different superscripts (a,b.c…) in a column and means with different superscripts (p,q,r….) in a row differ significantly ($p \leq 0.05$)

Table 5 Physico-chemical and microbiological characteristics of HT-paneer

Paneer type	Moisture,%	Fat,%	Protein,%	Ash,%	a_w	pH	SPC, $\log_{10}$cfu/g	YMC, $\log_{10}$cfu/g
Raw	52.5[a]	23.4[a]	21.0[a]	1.6[a]	0.994[a]	5.5[a]	5.3[a]	2.4[a]
D	52.0[b]	23.0[b]	20.5[b]	3.5[b]	0.970[b]	5.1[b]	3.1[a]	2.0[b]
D+MAP	51.5[c]	23.0[b]	21.0[a]	3.5[b]	0.970[b]	5.1[b]	2.3[c]	Nil

D Diffused, *MAP* modified atmospheric packaging, *HT* Hurdle technology, *SPC* standard plate count, *YMC* yeast and mould counts (n=3). Means with different superscripts in a column differ significantly at $p \leq 0.05$, (n=3)

Body and texture scores decreased ($p \leq 0.05$) from 7.7 for control to 7.0 for 0.1% CA diffused samples (Table 2), possibly due to solubalization and softening of proteins by CA at the surface of the product (Bhattacharya et al. 1971).

The overall acceptability scores also decreased ($p \leq 0.05$) from 7.9 to 7.2 with increase in CA concentration in diffusion solution (Table 2), but they were non-significant up to 0.05%. The score of 7 and above (liked moderately) for 0.1% CA level indicated that the product is still very much acceptable. Hence, 0.1% CA and 3% NaCl were selected for further studies.

Equilibration of NaCl and CA concentration in paneer From Figs 1 and 2, it is clear that the diffusion of NaCl and CA were continuous up to 10 h as indicated by continuous drop in a_w and pH, further continuation of diffusion process up to 12 h didn't reduce the a_w and pH of paneer indicating that equilibrium had been attained at 10 h itself at 5°C.

Effect of MAP on HT paneer Sensory scores of all samples decreased ($p \leq 0.05$) during storage period (Tables 3 and 4) irrespective of storage temperatures due to surface discolouration and dry shrunken surface appearance, slightly hard body and spongy texture and the off-flavour (Bhattacharya et al. 1971). The raw (R1), diffused (R2), raw+Map (R3) and diffused+MAP (R4) paneer remained acceptable for 1, 4, 6 and 12 days at room (30±1°C) and 6, 8, 18 and 20 days at refrigeration (7±1°C) temperature respectively (Rai et al. 2008), with respect to all sensory attributes. The hurdles along with MAP helped to enhance the shelf-life. Same effect was also notice by Conte et al. (2009) in cheese packed using MAP.

Physico chemical and sensory characteristics of HT paneer Application of hurdles altered the sensory characteristics like yellowish to dull white colour and appearance, slightly salty acidic flavour and slightly hard body as also observed by Kanawjia et al. (2000) and Dermiki et al.

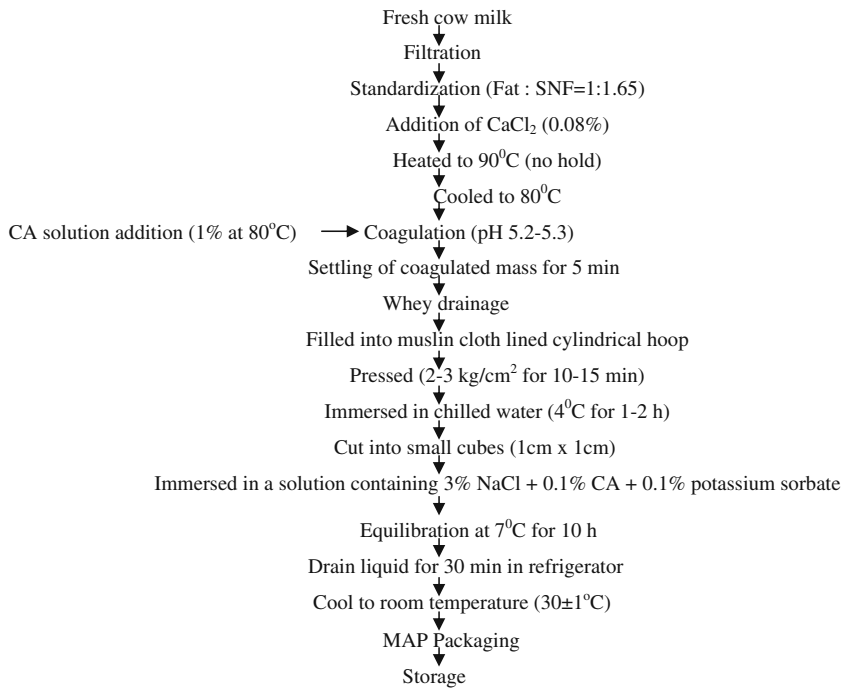

Fig. 3 Preparation of paneer by HT and MAP

(2008). Changes in moisture, fat and protein contents in HT paneer due to diffusion and MAP were marginal while diffused and MAP paneer had lower ($p \leq 0.05$) a_w, SPC and yeast and mould counts and higher ash contents compared to raw paneer (Table 5).

Preparation of paneer by adopting HT and MAP is presented in Fig. 3.

Conclusion

Shelf-life of paneer could be significantly enhanced by adopting MAP with a gas mixture (CO_2:N_2=50:50) prepared by adopting HT comprising of 3% NaCl, 1% CA and 0.1% potassium sorbate. Keeping quality of paneer was extended from 1 to 12 days at room (30±1°C) and 6 to 20 days at refrigeration (7±1°C) temperature without much affecting the sensory and physico-chemical characteristics of paneer.

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