UV-C Light Treatment to Extend the Shelf-life of Paneer (Un-ripened Soft Cheese)

ABSTRACT

Aim: Application of UV-C light to reduce the post-processing surface contamination and to extend the shelf-life of paneer

Study design: The study was aimed for 3×4 factorial design and the paneer samples were exposed to UV-C light for 60, 120 and 180 seconds and studied for its surface decontamination by microbiological studies and effect on sensory properties using 9-point hedonic scale after 3, 6 and 9, days of storage in a refrigerated conditions.

Place and duration of study: Karnataka Veterinary Animal and Fisheries Sciences University (KVAFSU), Dairy Science College, Mahagaon Cross, Kalaburagi, Karnataka, India

Methodology: A standard method was followed for the preparation of paneer. The paneer samples were treated with UV-C light in a UV chamber. Further, the samples were analysed for its Total Bacterial Count (TBC), Yeast and Moulds, and Coliform count, and sensory attributes such as flavour, colour and appearance, body and texture, and overall acceptability on a 9-point hedonic scale. The sensory evaluation of the sample was carried out by a panel of minimum 10 semi-trained judges who are well acquainted with the product features.

Results: The effect of varied exposure time of UV-C light and after storage days for a specific period was studied on the level of destruction of microbial-count and effect on the sensory characteristics. There was a significant (P=0.05) difference between the treated and non-treated samples in their microbial-count., and a log scale reduction in the bacterial and yeast and mould count on the surface by the effect of UV-C light was observed. The overall acceptability score for UV-C treated and non-treated sample was 8.36 and 8.10 at 0^{th} day, and 7.02 and 5.65 after 9 days, respectively. Hence, the result was comparable to that of non-treated paneer.

Conclusion: The chemical-free and cost-effective UV-C treatment for surface decontamination of microorganisms could be a viable technique to extend the shelf-life of paneer.

Recommendation: Combination of other non-thermal techniques with UV-C light and with different packaging method could be studied to enhance the keeping quality.

Keywords: *Ultraviolet, Paneer, Shelf-life, Microbial, Sensory*

1. INTRODUCTION

The total milk production of India crossed 221 million tonnes during 2021-22[1].Out of the total milk produced, nearly 50% is converted into traditional dairy products such as khoa, chhana, and paneer[2].Paneer a well-known heat-acid-coagulated milk product resembles an un-ripened soft cheese used as a base material for the preparation of variety of culinary dishes and snacks[3]. It is rich in protein, fat, and minerals like calcium and phosphorus, which provides sufficient nutrition for human beings. The market size of paneer stood at an approximate value of ₹494 billion in 2022. Further, The International Market Analysis Research and Consulting Group anticipate the market might reach ₹1,173 billion by 2028 at a cumulative average growth rate of 15.7% during 2023-2028[4]. The moisture content of paneer ranges from 50 to 60% and is more likely to degrade quickly, with a one-day shelf-life at ambient temperature[5].But, the paneer stored at 10°C, the shelf-life could be extended up to 6 days, though the freshness of the product was lost after 3 days[6]. By dipping it in brine solution, the shelf-life was extended from 7 to 20 days at 6 to 8°C [7].

The extension of the shelf-life of a paneer is an important consideration for the dairy industry because there is a high interest in expanding the distribution beyond the local market. Preservatives are also used to lengthen the shelf-life of paneer[8]. Also, different techniques such as vacuum packaging, low-temperature storage, dehydration, and heat sterilisation[9], treatment with brine, chlorinated water, sorbic acid, H_2O_2, delvocid, potassium sorbate and antioxidants, combined effects of supercritical-CO_2 (SC– CO_2) and a food-grade acid were studied[10,11]. The authors also explored

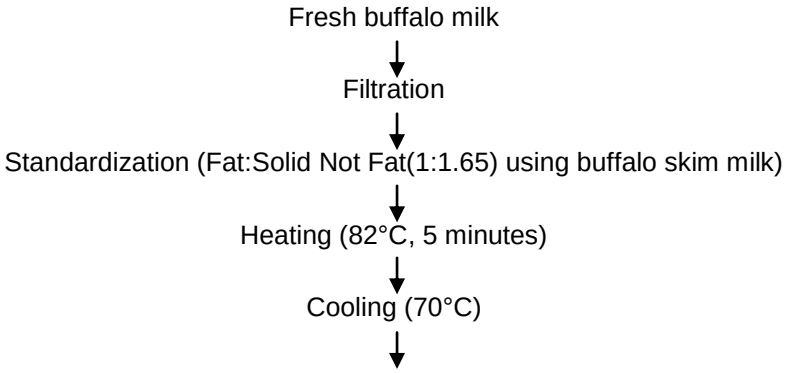
the use of natural herbs to extend the shelf-life of paneer like turmeric and aloe-vera extract, and, addition of fennel seed, star anise and chili[12,13]. Novel method like addition of ionic silver solution was also studied to extend the shelf-life of paneer[14]. However, chemical methods of preservation could increase the shelf-life of paneer, but it led to jeopardize the flavour and texture of the product. The application of non-thermal process techniques such as cold plasma, pulsed electric field, irradiation, pulsed light, and high pressure processing for food preservation have gained interest. In recent years, the application of UV-C light as non-thermal process techniques has attracted a lot of attention to the improvement of food safety[15,16]. Also, it has the potential to offer consumer products that have undergone minimum processing, and have the flavour and texture of fresh food[17]. Particularly, UV light has gained importance as a surface decontamination technique since its ability to decontaminate the surface of food products. The UV light also offers some technological advantages especially in developing countries in a small-scale production, due to its low maintenance cost, low installation cost and low operational cost with minimal energy use. Also, the UV irradiation could be used as an alternative treatment for fresh food products without causing undesirable quality changes and release of toxic disinfection by-products.[18].

UV radiation is a non-ionizing form of light, positioned in the segment of the electromagnetic spectrum between visible light and X-rays, (range:100 to 400 nm), comprises four main types: UV-A (315–400 nm), UV-B (280–315 nm), and UV-C (200–280 nm).[19]. The UV light of type UV-C has a good germicidal effect and are effective against various microorganisms, which include bacteria, viruses, protozoa, fungi, algae, and bacterial spores[20]. It deactivates the DNA of microorganisms and thus destroys their ability to proliferate[21], and the highest dose of 40 mJ·cm-2, inactivated microorganisms by more than 5 log, and effectively inactivated bacteriophage and pathogenic microbes in skim milk provided more opportunity for UV-C light application in foods[22]. The primary cause of the paneer spoilage is surface contamination from post-processing, which results in a decline in quality and a shorter shelf-life. Free surface of the paneer is the primary site for microbial access during processing, and further enzymatic and chemical reactions on the exterior of the milk product could cause undesirable changes and poor shelf-life quality[23]. Hence, the application of UV-C light could be an effective method to decontaminate the surface of paneer during post-processing and could extend the shelf-life. Considering the advantages of UV light and the limited studies on the surface sterilisation of dairy products with UV-light, a study was undertaken to assess the efficacy of this technique on the microbiological and sensory quality of paneer.

2. MATERIALS AND METHODS

2.1Preparation of Paneer

Fresh Buffalo milk was procured from a nearby farm and standardised to 4.5% fat and 8.5% SNF. The standardised milk was heated at 82°C in a process vat for 5 minutes and cooled to 70°C, followed by the addition of a 1% solution of citric acid with slow and continuous stirring until clear whey separated out. The mixture was allowed to settle down for 10 minutes and the whey was drained out through sterile cheesecloth. The curd was then collected and filled in a hoop lined with a sterile and strong cheese cloth. The hoop had a rectangular frame with the top and bottom open. Using a manually operated paneer press, pressure was applied to the top of hoop by rotating the hand-operated wheel. The pressed block of paneer was removed from the hoop and then immersed in chilled water (4-6°C) for 2-3 hours. The chilled block of paneer was then removed, and cut into 2×2 cm cubes, and taken for further studies. The schematic flow chart for the preparation of paneer is shown in Figure 1[24].



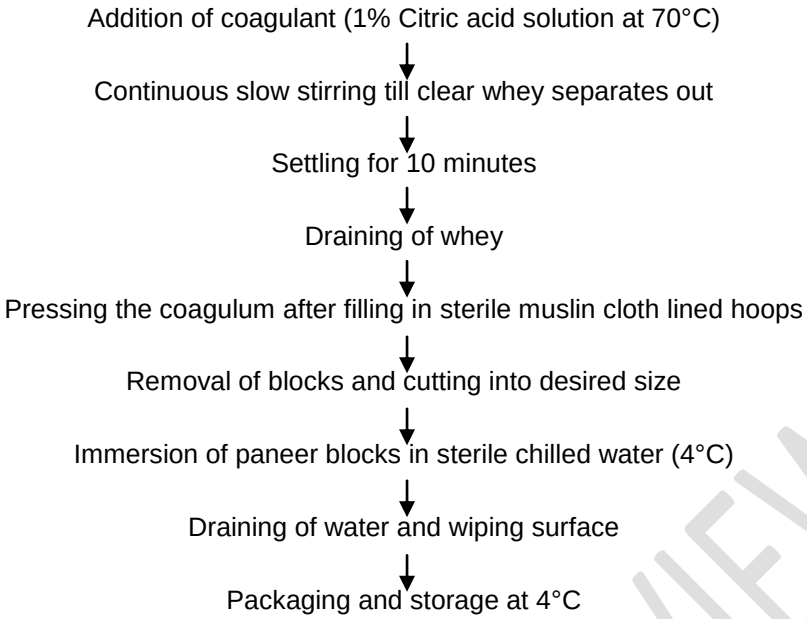


Fig. 1: Schematic Flow chart for manufacture of paneer

2.2 UV-C light treatment of Paneer

The paneer cubes were UV treated in a UV chamber containing 4 UV-C lamps with emission in the range 200–280 nm[19,25,26], with a reflector all the way inside the chamber to assure the exposure of UV light to all the surfaces of the sample. The samples were being exposed at three different exposure times, viz, 60, 120,and 180 seconds, selected based on the studies reported using UV-C light to extend the shelf-life of food products[27,28,29]. The treated paneer was packed in a LDPE pouch and stored at refrigeration conditions. The packed samples were drawn at regular intervals and then examined for their microbial and sensory attributes.

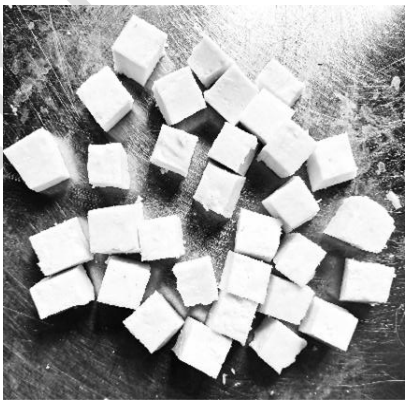


Fig. 2: Experimental paneersamples of size 2×2 cm

Fig. 3: UV-C light chamber with reflectors

2.3 Microbiological analysis of paneer

To verify the inactivation efficacy, paneer treated by UV-C light was analyzed for total bacterial count, yeast and moulds, and coliform counts and were expressed in terms of log cfu/g. The procedure was followed as per the standard method[30].These microorganism groups were chosen broadly as representative of spoilage microorganisms, potentially leading to product quality depletion and shelf-life reduction. The pour-plate method was used for microbiological examination. The saline solution for dilution used was tri-sodium citrate buffer at 2% concentration.

2.3.1 Total Bacterial Count

Standard plate count agar (SPCA), dissolved and sterilized, was used as the culture medium for the enumeration of the total plate count (TBC). Exactly, 1 mL of 1:100 diluted samples was aseptically transferred into sterile and labelled Petri dishes with the aid of a sterile pipette. Molten sterile agar medium of 10-15 mL volume, being maintained at around 40°C, was poured aseptically into Petri dishes, and the contents were spread uniformly by gently rotating the plates. Each sample was plated in duplicate. The medium was allowed to solidify without disturbing the plates, which were then inverted and incubated at 37°C for 48 h[30]. The microbiological count was recorded, and the population in the samples was expressed as log cfu/g of sample.

2.3.2 Yeast and mould count

Yeast and mould count of paneer was enumerated using potato dextrose agar. The pH of the agar was reduced to support the growth of yeast and moulds by addition of 2-3 drops of 10% sterile lactic acidacid just before pouring the agar into plates. Exactly, 1 mL of 1:10 diluted sample was aseptically transferred into Petri dishes with a sterile pipette. After solidification of agar, the plates were incubated at 22-25°C for 3-5 days in an inverted position [30]. At the end of the incubation period, the developed colonies were counted, and the population was expressed as log cfu/g of sample.

2.3.3 Coliform count

The coliform count of paneer was enumerated using violet-red bile agar. Exactly, 1 mL of a 1:10 diluted sample was transferred aseptically into a sterile Petri plate, and the warm agar media was

poured over it and spread gently. The duplicate plates were then inverted and incubated at 37°C for 24 h[30]. The coliform count was expressed as log cfu/g of the sample.

2.4 Sensory evaluation of UV-C treated paneer

Sensory attributes play a vital role in determining the acceptability of a food product by a consumer. The evaluation was carried in a room temperature under a proper day lightning. The samples were served to panel of semi-trained judges (minimum of ten members, consisting male and female between the age group of 30 to 50 years) for evaluation of sensory attributes such as flavour, body and texture, colour and appearance, and overall acceptability on a 9-point hedonic scale[31,32]. The sensory panel was faculty of the institute who are well acquainted with the product features, willingness and availability for sensory evaluation. In the test result, a score of '1' represented 'dislike extremely' while a score of '9' represented 'like extremely'. The samples were coded appropriately before being served to the judges.

3.0 RESULTS AND DISCUSSION

3.1 Effect of UV-C light on microbiological qualities of paneer

The mean value of the results obtained for the samples exposed to UV-C light treatment at different time intervals of 60, 120, and 180 seconds and Non-UV-C treated samples after storage for a period of 0, 3, 6 and 9 days are shown in Table 1.

Table 1: Microbial count (log cfu/g) of UV-C treated for 60, 120, and 180 seconds, and Non-UV-C treated paneer stored for 3,6, and 9 days in refrigeration conditions

Sample (days)			0th Day	3rd Day	6th Day	9th Day
TBC	UV-C (s)	60	3.44	3.99	4.63	5.10
		120	3.15	3.68	4.34	4.87
		180	3.10	3.65	4.38	4.82
	Non-UV-C		4.86	5.12	5.42	6.33
Yeast and Moulds	UV-C (s)	60	1.52	1.65	1.66	1.88
		120	1.36	1.56	1.53	1.76
		180	1.32	1.52	1.56	1.71
	Non-UV-C		2.32	2.72	2.83	3.13

On 0th day, the paneer without UV-C light treatment had TBC counts of 4.86 log cfu/g. and the paneer exposed to UV-C light for 60, 120, and 180 seconds had a count of3.44, 3.15, and 3.10 log cfu/g, respectively. After a storage period of 3, 6, and 9 days, the paneer without UV-C light treatment had TBC counts 5.12, 5.42, 6.33 log cfu/g, respectively. The paneer exposed to different treatment time of UV-C light for 60, 120, and 180 seconds and stored it for 3 days had a TBC counts of 3.99, 3.68, and 3.65 log cfu/g, respectively.

Similarly, the paneer sample exposed to same treatment time and stored for 6 and 9 days, had a TBC counts of4.63, 4.34, 4.38 log cfu/g, and 5.10, 4.87, 4.82 log cfu/g, respectively. The results showed that there was a log reduction in the TBC when exposed to UV-C light at all the three different exposure times and different storage periods. The efficacy of UV-C light was observed and found to be highest with an exposure time of 60 seconds. A further increase in the time of UV-C light exposure did not cause a significant change in the reduction of TBC.

A similar kind of result was observed for yeast and mould counts. The paneer exposed to UV-C light for 60, 120, and 180 seconds had counts of 1.52, 1.36, and 1.32 log cfu/g, respectively. After a storage period of 3, 6, and 9 days, the paneer without UV-C light treatment had counts of 2.72, 2.83, and 3.13 log cfu/g, respectively. Whereas, the paneer samples treated at same time interval and stored for 3 days had yeast and mould counts of 1.65, 1.43, and 1.42 log cfu/g. Similarly, after storage for 6 and 9 days, had yeast and mould counts of 1.65, 1.56, and 1.52 log cfu/g, and 1.88, 1.76, and

1.71 log cfu/g, respectively. It was observed that there was a reduction in the yeast and mould count of samples with increase in the exposure time. The efficacy of UV-C light was observed and found maximum with the exposure time of 60 seconds. Further increase in the time of UV-C light exposure did not cause a significant change in the reduction of yeast and mould counts. The paneer samples did not have a coliform count for control and for the UV-C treated samples, irrespective of UV-C exposure time and the storage days.

The observation made here was that the complete destruction of microorganisms on the surface of paneer could not be achieved by UV-C light treatment at different time of exposure. This could be due to the surface characteristics of the paneer. Non-smooth, crevices, and irregular surface of the paneer could restrict the penetration of UV-C light on the whole surface, and the microorganisms present in the crevices and pores eluded from the UV-C light and showed their growth during the storage period. Also, the penetration depth of the UV-C light on the solid food products could be less deep compared to clear the liquid food products, which affected the destruction of microorganisms below the surface of the paneer. The authors reported that the application of UV-C light irradiation could be used for the surface decontamination of fresh food products and factors such as food product surface characteristics, and location of organisms were found to play significant role[33]. The inactivation of inoculated *Penicillium roqueforti* and *Listeria monocytogenes was studied* in the packed and unpacked cheeses by UV-C light application and reported reductions of 1.32 log and 1.24 log in packed and unpacked cheeses[34]. Higher inactivation rates of organisms were observed on apple fruits with smoother surfaces and markedly lower for fruits that have uneven surfaces such as strawberries and raspberries that are impervious to UV-C irradiation[35]. Similarly, the efficacy of UV-C light on the surface decontamination of blueberries was tested and found it more effective in reducing *E. coli* O157:H7 compared to electrolyzed water and ozone treatments[36], and delayed mould growth on the surface of cheese during storage [37].

3.2 Effect of UV-C light on sensory quality of paneer

The samples were assessed for their sensory quality using a 9-point hedonic scale and the mean value of the results were evaluated (Table 2). The overall acceptability was higher at 8.36 for the 0^{th} day and 7.02 after storage for 9 days, while it was 8.10 and 5.65 for control sample, respectively. Similarly, the other sensory attributes such as flavour, body and texture, and, colour and appearance was 5.30, 5.00, and 5.94 for control sample after storage for 9 days, while it was 6.90, 6.30, 6.60 for UV-C treated samples. There was a noticeable difference in the flavour, body and texture, colour and appearance, and overall acceptability between the UV-C treated and non-treated samples, and an overall acceptability score was significantly high for the UV-C treated sample. The reduction in the surface microbial load after exposure to UV-C light resulted in reduced surface spoilage.

Table 2. Organoleptic qualities of UV-C treated and Non-treated Paneer

	Non-UV-C Treated Paneer				UV-C Treated Paneer			
Number of Storage Days	**Flavour**	**Body & Texture**	**Colour & Appearance**	**Overall Acceptability**	**Flavour**	**Body & Texture**	**Colour & Appearance**	**Overall Acceptability**
0	8.00	7.24	7.94	8.10	8.30	8.20	8.14	8.36
3	7.50	6.60	7.30	7.40	7.84	7.80	7.76	7.74
6	7.24	6.30	6.90	7.14	7.64	7.40	7.46	7.44
9	5.30	5.00	5.94	5.65	6.90	6.30	6.60	7.02

A similar kind of observation was reported when the food samples were exposed to UV-C light treatment. Cheese surface was exposed to UV-C light and reported a 1-2 log reduction on *Pseudomonas* spp. without changes in colour, texture and surface appearance[28].Likewise, UV light was exposed to raw milk and the authors reported that no change in raw milk with respect to composition, free fatty acid profile, and oxidation[38][39].

4.0 CONCLUSIONS

The effect of UV-C light-treated paneer was assessed on microbial load and found a significant decrease in the treated sample. However, the antimicrobial effect of UV-C light on the paneer surface would be limited to a very thin surface layer of the product. In addition, the surface roughness, irregularities on the surface of the paneer could restrict the penetration of UV-C light into the different site. The samples exposed to UV-C light showed a log reduction in the microbial load compared with the control sample. These results confirm that the UV-C light treatment exerts partial destruction of microorganisms, but it is not able to inhibit microbial growth during storage. Also, UV-C light only acts on the product surface and does not significantly penetrates into the depth of the solid food. The sensory characteristics of UV-C light treated paneer were assessed on a 9 point hedonic scale and were accepted with an overall score of 8.36, compared to 8.10 for control. Hence, increased storage days of paneer could be achieved for UV-C treated paneer without vacuum packaging and modified atmospheric packaging in refrigerated conditions. Further, the effect of combined studies of UV-C light with other non-thermal techniques and different packaging method could be explored to increase the shelf-life of paneer.

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