Development and optimization of active edible coatings to improve the shelf life of Indian soft cheese

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Research Article

Keywords: Paneer (Indian cottage cheese), Edible coating, Eugenol Essential Oil, Copper Nanoparticles, Response Surface Methodology

Posted Date: July 20th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3176359/v1

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Additional Declarations: No competing interests reported.
Title: Development and optimization of active edible coatings to improve the
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Abstract
The use of active packaging systems that contain antimicrobial agents is considered to be a prudent method of ensuring the quality and safety of food. The purpose of the study was to design an edible coating system to protect Paneer (Indian cottage cheese) using Glycerin, Pectin, and Casein; the coating components were optimized by using the Central Composite Design (CCD) method of Response Surface Methodology (RSM). Different antimicrobial compounds, Copper Nanoparticles (CNP), Eugenol Essential oil (EO), were added to the optimized edible coating to investigate their efficacy by tracking the alteration in physico-chemical parameters of Paneer during storage of 14 days. The changes in Paneer were investigated through water distribution, acidity variation, rheological alterations and microbiological analysis during the storage period. Microbe proliferation was reduced by an average of 88.6% when copper nanoparticles were loaded into casein film on the fourteenth day after storage. As a result of the study, a casein-based film containing CNP was able to successfully retain moisture, maintain an optimal pH and ensure the safety and quality of Paneer. Additionally, further research is needed to assess the implication of CNP loaded edible coatings in food packaging as a means to minimize the associated risk associated with CNP consumption.

Keywords: Paneer (Indian cottage cheese), Edible coating, Eugenol Essential Oil, Copper Nanoparticles, Response Surface Methodology

1. Introduction
There has been a recent shift in emphasis between waste reduction and recycling within the 3Rs waste management system (Reduce, Reuse, Recycle), by which the focus has shifted from recycling to waste reduction. In this context, scientists are exploring innovative strategies to minimize the generation of plastic waste, which is a significant concern for achieving the sustainable development goals set forth by the United Nations [1]. Among various sustainable approaches to address plastic waste, edible coatings have garnered significant attention due to their acclaimed benefits, including cost-effectiveness, environmental friendliness, biodegradability, and the potential to reduce food wastage. An edible coating is described as a thin layer of structural substance (protein, carbohydrate, lipid, or multi-component mixture) formed as a coating on the food product. Immersion in structural matrix or spraying of matrix onto the food is the standard method through which edible coating is applied onto the food product [2]. Apart from protective action, edible coating also improves the aesthetic quality of food products by improving physical and tactile strength, preventing agglomeration of particles and increasing the visual characteristics of the product surface.

Active form of edible coating incorporated with active compounds (antibacterial, antioxidant, probiotics) are used widely to preserve food products especially cheese [3,4]. Soft cheese like Paneer, have short shelf life (5-6 days) at refrigerated condition due to its high content of moisture (up to 60%). Several methods have been endeavored to enhance keeping quality of Paneer, including adding preservatives, packaging in modified conditions (vacuum packaging, modified atmosphere packaging), dehydration, and heat sterilization [5-8]. Besides increasing the quality of the Paneer, these methods negatively influenced the texture and flavor of the product. In recent years, the focus has been shifting to new strategies (innovative packaging, edible coating, and biopolymer packaging), which preserve Paneer’s quality and promote environmental sustainability [9-12].

The field of edible coatings has witnessed significant advancements in utilizing active compounds, including plant essential oils and nanoparticles, as potent antibacterial agents. These compounds not only exhibit bactericidal effects but also contribute to the preservation of food products by impeding the proliferation of free oxygen radicals. Notably, a recent study by Seydim et al. (2020) demonstrated that essential oils derived from plants effectively reduced surface contamination in Kashar cheese, comparable to other bio-preservatives like nisin and natamycin [13]. Nonetheless, the volatility and diffusivity of essential oils in food pose challenges that demand attention. Addressing this issue, the encapsulation of essential oils within biodegradable matrices emerges as a promising technique, enabling controlled release and enhanced retention of their active properties [14].

In parallel, food scientists have recognized the remarkable disinfecting properties and smaller size of nanoparticles [15]. Incorporating nanoparticles into food matrices can be achieved through various methods, including coating, adsorption, and direct incorporation. Among the extensively studied nanoparticles in the realm of food systems, zinc, copper, and silver hold significant prominence. Copper nanoparticles, in particular, have garnered substantial attention due to their ease of production, cost-effectiveness, and broad-spectrum antimicrobial activity against pathogenic strains, fungi, and viruses [16]. Their integration into edible coatings showcases immense potential for advancing food safety and quality. The incorporation of copper nano-particles into the film can improve its mechanical and barrier properties. Furthermore, recent research suggests that nanoparticles larger than 100nm in
size are less toxic than those with a smaller diameter [17]. This finding has important implications for the use of nanotechnology across a range of industries and should be taken into consideration when assessing the potential risks and benefits of nanomaterials.

In the present study, active antimicrobial edible coatings were developed to preserve Paneer. This study determines the efficacy of different volatile and non-volatile antimicrobial-loaded packaging by unravelling the significant quality changes in Paneer during 14 days of refrigeration storage, including the textural characteristics, moisture dynamics, acidity fluctuation and microbial activity.

2. Materials and Methods

2.1 Raw Materials

Buffalo milk containing 6% Fat and 9% Solid Not Fat (SNF) was procured from Mother Dairy, Bindapur, New Delhi and is used for the formulation of Paneer in the laboratory. Edible ingredients used for fabricating edible coatings, like casein and Pectin, were purchased from Central Drug House Pvt. Ltd. (New Delhi). The Eugenol Essential Oil was provided by Loba Chemie. Analytical grade chemical reagents like Oxalic acid, Glycerin, Copper chloride, Copper nitrate, Phenolphthalein indicator, Sodium Chloride, Nutrient Agar and Sodium Hydroxide were purchased from Hi Media Laboratories Pvt. Ltd. (Mumbai).

2.2 Manufacturing of Paneer

Paneer samples were manufactured in-house from Buffalo milk with slight modification in the procedure given by Bhattacharya et al., (1971) [18]. Briefly 1 liter of milk was pasteurized to 90°C for 5 mins with constant stirring and subsequently cooled down to 70°C. Then, milk is curdled by using 1% citric acid to separate the coagulum from clear whey. The temperature of obtained coagulum was preserved above 63°C and left undisturbed for 5 mins. Next, the curd was compiled in a block with the help of muslin cloth and pressed to remove the excess whey. Finally, the pressed block was cut into pieces and immersed in cold water for 1 hour at 4°C.

2.3 Synthesis of Copper Nano-particles

The copper nanoparticles of size 117.7 nm were manufactured through the precipitation method [19] and the size was determined by using Dynamic Light Scattering (data not shown).

2.4 Nutritional Analysis

The moisture measurement in triplicate was estimated using the standard method provided by the
Association of Official Agricultural Chemists (AOAC, 2003) [20]. 5g sample in triplicate was desiccated in Hot Air Oven at a constant temperature of 100 ± 2°C. The ash content present in the Paneer sample was estimated by placing dried sample in muffle furnace at 550 ± 15°C (AOAC, 2003) [20].

Total protein in Paneer was estimated using the micro-Kjeldahl method (AOAC, 2003), while crude fat was calculated using the Gerber method provided by Bureau of Indian Standards (IS, 10484) [21]. Finally, the yield% of Paneer was determined according to the procedure given by Kumar et al., (2019) using the formula [22].

\[
\text{yield\%} = \frac{\text{weight of paneer (g)}}{\text{Volume of milk (L)}} \times 100
\]

2.5 Experimental design

Response surface methodology (RSM) was employed to statistically examine the effect of the primary coating components, namely, amounts of Casein, Glycerin and Pectin, on the Porosity, Titratable acidity and pH of the coated Paneer sample with the help of a Design Expert Software version 8 (Statease Inc., Minneapolis, MN). The central composite design (CCD) with four independent variables (Table:1) was utilized to acquire the experimental design. A full quadratic equation was generated to analyze the influence of the interaction of the independent parameters on the obtained responses, pH (Y1), Titratable acidity (Y2, %), and Porosity (Y3, %), of coated samples as follow (Eq. 1):

\[
Y_i = \alpha_0 + \sum \alpha_i X_i + \sum \alpha_{ii} X_i^2 + \sum \alpha_{ij} X_iX_j
\]

Equation 1

Where Yi signifies response function of dependent variable and \( \alpha_0, \alpha_i, \alpha_{ii}, \text{ and } \alpha_{ij} \) represents constant terms, linear, quadratic and interactive coefficients, respectively, and \( X_i \) and \( X_j \) signifies four independent variables. The regression analysis was carried out to examine the model's effectiveness based on the regression coefficient (R\(^2\)). Regarding the complex nature of food products, the R\(^2\) value above 0.80 was considered a good fit.

2.6 Edible coating of Paneer

27 edible coated Paneer samples were prepared by dissolving (8-12%w/v) casein, (2-5% w/v) glycerin and (0.5 to 1.5% w/v) pectin in (80-90%v/v) distilled water. The solutions were homogenized thoroughly for 30 minutes with the help of a Magnetic Stirrer. Paneer cubes were immersed in the solutions for 1 hour and dried at room temperature. Further, the optimized edible coating solution was combined with 1% (v/v) Eugenol essential oil and copper nanoparticles (CNP) (1% by weight of the polymer) and compared to plain (without antimicrobial) and control to examine its antimicrobial
properties. Samples were packed in zip-lock plastic pouches and stored under refrigeration conditions for shelf life analysis as shown in Fig:1.

2.7 Shelf-Life Studies

The coated Paneer sample was subjected to physicochemical and microbiological analysis for 2 weeks at refrigeration condition to examine the effectiveness of the edible antibacterial coating. Shelf life studies were performed on 0 days, 7th and 14th day of storage to investigate the effects of the coatings on the quality characteristic on Paneer.

2.7.1 Weight loss

The weight of each coated Paneer sample was measured on 0 days, 7th day and 14th day of storage. Weight losses are reported in per cent of the initial weight of Paneer.

2.7.2 pH

Triplicate measurements were carried out to study the deflection in pH of the coated and control Paneer samples using a digital pH meter (LT-10, Labtronics, Panchkula, Haryana) AOAC (1975) [23].

2.7.3 Water activity ($a_w$)

The amount of free water present in Paneer sample was quantify by measuring water activity in triplicates, using Water activity meter (4te-Aqualab, Maharashtra, India).

2.7.4 Titratable acidity

Alteration in Titratable acidity (expressed as percentage of lactic acid) in Paneer samples, was determined by standard titration method given by Bureau of Indian Standards (IS, 10484) [24].

2.7.5 Microbiological Assay

Edible coated and control Paneer samples stored at 0, 7th, and 14th days were analyzed for bacterial load using the Standard Plate Count method. 1g of Paneer sample was diluted with saline (0.85% NaCl) in the 1: 10 ratio, and the solutions were inoculated on Nutrient Agar (NA), followed by incubation at 37°C to enumerate bacterial colonies. All analyses were done in triplicates.

2.8 Texture Analysis
The texture of the edible coated Paneer sample and control sample was measured after the 14th day of storage and compared with fresh Paneer to better evaluate the quality characteristics and freshness. The Paneer samples were analyzed using Texture Analyzer (TA.XT plus Texture Analyser) using the following settings: Paneer cubes of dimensions (1.5 × 1.5 × 1.5 cm) were cut and analyzed by using pre-test speed 3 mm/s, test speed 1mm/s, post-test speed 2mm/s, surface trigger force 5 g, and strain 65%. The obtained results were interpreted and manifested in quantifiable factors like hardness, springiness, adhesiveness, chewiness, cohesiveness, and gumminess.

3. Result and discussion

3.1 Nutritional Analysis

Moisture levels are essential characteristics which determine the type and shelf life of any cheese. Paneer (Indian cottage cheese) contains 54% moisture and 21% fat, which falls in the standard range provided by the regulatory body of India (FSSAI), i.e. not more than 60% and not less than 20%, respectively [25]. A high level of moisture (more than 50%) makes the texture of Paneer soft and supple like other varieties of soft cheese (Feta, Queso Fresco) [26,27]. The protein and ash content per 100g of Paneer were 18.28g and 2.58g respectively. The yield of Paneer obtained was 16.34% and is considered an important economic implication and thus has a significant value in the dairy sector. The important process parameters which have a significant impact on the yield and nutritional parameters of Paneer are type of raw material (milk and coagulant), strength of coagulant, the temperature of coagulation, and the amount of liquid (whey) drained during coagulation [22].

3.2 Fitting the response surface models

By fitting the quadratic design in the experimental model, 27 experiments runs were obtained (Table-2) and performed in duplicate. Porosity, titratable acidity and pH were the studied response for the design. The goodness of the fitted model is determined through high value of coefficient of determination ($R^2$) for the studied responses (Table-3).

[Table: 2 HERE]

[Table: 3 HERE]

3.3 Effect of independent variables on edible coated Paneer Sample

The study demonstrated the combined effect of concentrations of casein, pectin, glycerin and water on the porosity, titratable acidity, and pH of the edible-coated Paneer samples.

3.3.1 Porosity

The collaborative effect of two selected independent variables at the center of other independent variable could be studied through the response surface. The combined effect of independent factors on Porosity was studied by analyzing response surface presented in Fig -2a & 2b. The interaction factors
with p<0.0.5 was considered for evaluating the effect on Porosity. As, shown in Figure-1a the water content of edible coating had a positive effect on the Porosity of Paneer. Moisture in edible coating helps to maintain the porous structure of Paneer. However, high moisture content could also raise concerns for shelf stability.

Meanwhile, the inclination of the response surface is more towards a lower concentration of glycerin and casein, confirming that a lower concentration of glycerin and casein favors Porosity. Nevertheless, casein and other polymers like pectin are prerequisite components that involve controlling the viscosity of the film-forming solution [28]. Higher concentrations of casein and other biopolymers in the edible coating will negatively affect the structure of Paneer in terms of Porosity.

### 3.3.2 Acidity

The response surface presented in Fig-2c elicit interacting effects of the independent variables (casein, glycerin, water and pectin) on the acidity of Paneer. The single interaction factors (glycerin and casein) had p<0.0.5 and only this has been considered for evaluating the effect on acidity. The response surface graph depicts a slight inclination of the curve towards higher concentrations of casein and glycerin. After reaching the maximum limit, both factors witness decline in elevation. These data were explicit that an optimum concentration of glycerin and casein is required to maintain the acidity of Paneer within the permissible limit (i.e. below 0.50%).

### 3.3.3 pH

The pH of Paneer is the foremost criterion when defining the quality characteristics of Paneer. There was no significant (p<0.0.5) influence of the interacting factors on the pH of Paneer. Henceforth effect of independent factors has been studied in the case of pH. Fig-2d elicits the effect of the concentration of casein on the pH of Paneer. As shown in response surface graph, the concentration of casein has positive effect on the pH of Paneer.

### 3.4 Optimization of Edible Coating

A numerical and graphical optimization approach using a maximum desirability index was applied to established the optimum levels of the independent factors. The optimized formulation of edible coating that yields maximum porosity and minimum titratable acidity was generated as follows: casein 8%, glycerin 4.6%, pectin 0.65 %, and water 86%. Using the above combinations, the predicted property of Paneer are porosity19%, titratable acidity 0.52% and pH-6.

### 3.5 Shelf Life studies

#### 3.5.1 Moisture loss
Prevention of moisture loss from the food sample is one of the foremost objectives which is addressed by the application of edible coating. The moisture removal from the Paneer sample during storage is the consequence of the continuous migration of water molecules from Paneer samples to the environment resulting in the attenuation of weight. The maximum weight loss of up to 55% was reported in the case of untreated Paneer samples, followed by Plain and EO samples, and the highest moisture retention was observed Fig-3a in the case of CNP-coated Paneer samples after 14 days of storage, giving an average moisture loss of 40% during the entire shelf-life study. This could be inferred from the results that casein-pectin-based edible coating assists in retaining moisture in Paneer.

3.5.2 Water Activity

The variations in water activity (aw) of edible-coated Paneer samples as storage time elapsed are presented in Fig-3b. After 14 days of storage, control Paneer samples reported the least water activity. Since water activity is a function of moisture present in a food sample, changes in the aw of edible coated Paneer samples are proportional to the moisture loss during storage. Moreover, all treated Paneer samples reported trivial moisture loss compared to the control sample. Moisture retention in Paneer will help maintain the structural integrity but also pose a threat to the proliferation of microbes as high-water activity supports them [29]. Thus, the edible coating should be tailored in a way which helps maintain the sensory characteristics of the food product without compromising the safety aspect.

[FIGURE: 3 HERE]

3.5.3 pH

As presented in Fig-4a, pH of the Paneer sample gradually decreases during storage. In addition, the edible coated Paneer samples showed slight variation from 0 days to the 14th day of storage. This elucidates that edible coating in conjugation with antimicrobial compounds can effectively inhibit the growth of microbes; thereby pH of Paneer did not show much variation. Except the control sample, rest all the coated Paneer samples’s pH were within the range (5.7–6.0) reported by other researchers [30].

3.5.4 Titratable acidity

The change in titratable acidity during storage of different edible coated Paneer samples is illustrated in Fig: 4b. The acidity of the control Paneer sample on the 7th day and 14th day was significantly higher than coated Paneer due to the proliferation of microbes. Various studies quoted the optimum range of acidity for Paneer as 0.47–0.59 % [31,32]. The acidity of all the Paneer samples was within the range of up to seven days of storage. However, after seven days, all Paneer samples noticed a steady rise in acidity. This spike in acidity could be possible due to peptization and bacterial fermentation. The CNP-coated Paneer sample reported the least rise in acidity, followed by the EO-coated Paneer sample. This inferred that Copper nano-particles help to inhibit the growth of lactic acid bacteria during storage. A similar bacteriostatic effect of copper nano-particles was also reported by Youssef et al., (2020) on processed cheese [33].

[FIGURE:4 HERE]
3.5.5 Antibacterial activity

The data regarding microbial quality of Paneer stored at refrigerated conditions for 14 days with respect to standard plate count (SPC) is illustrated in Fig:5. The bacterial densities observed in the control sample of Paneer were 4.97×10^5 CFU/g at 0 days, which increased to 6.35×10^6 CFU/g at 14 days. On 14th day of storage, the maximum bacterial load was observed in the case of EO coated Paneer samples 10.55×10^7 which was almost 40 times greater than control. The presence of copper nanoparticles in the edible coating system resulted in 88.6% decline in microbial population at 14th day of storage. Reduction in microbial densities of CNP incorporated edible coating is attributed to the credible mechanism of copper, which either through endocytosis or direct diffusion cause the cell death. CNP have higher surface area to size ratio which permitted them to profusely bind with the cell membrane and invade the bacterial cell, causing permanent impairment of genetic material and usher them to death. Moreover, the generation of hyperactive oxygen compounds creates oxidative stress within the cell, contributing to the bactericidal effect [34].

Interestingly, after the 14th day of storage, lower population densities of bacteria were found in the control and plain coating Paneer samples compared to the samples preserved with EO coating. This might be ascribed to changes in physical parameters during storage. It was observed that EO coated sample had the highest water activity (Figure -3b) among all the other samples on the 14th day of storage which might help in the proliferation of bacteria, resulting in a higher bacterial growth rate [29]. Moreover, the lipophilic nature of Eugenol oil ascribes to its poor effectiveness in food matrices containing high amounts of protein and fat, consequently unable to inhibit the proliferation of bacteria which grows in water. Simultaneously, Paneer's excellent nutrient availability helps bacteria repair their damage faster and, thus, positively supports growth [35].

3.6 Texture Profile Analysis

The textural analysis (Table:4) depicts a considerable variation in fresh Paneer (procured fresh to better evaluate the rheological properties of Paneer), control and edible coated Paneer stored for 14 days at refrigerated conditions. There was a colossal rise in the hardness value of stored Paneer with respect to fresh due to moisture loss. However, CNP coated Paneer sample has high moisture retention, followed by EO coated sample. Similar findings were also reported by Saravanakumar et al., (2020) in their study, who concluded that copper nanoparticles help to limit moisture loss in food products [36]. Other textural attributes like hardness, chewiness, and gumminess are also related to the moisture content in an inverse variation [36]. Therefore, CNP coated Paneer sample was reported to have the least chewiness and gumminess among all other stored samples due to high water retention in the Paneer matrix.
Springiness is another critical attribute which determines the elastic recovery of food samples by measuring the rate at which deformed food material acquired its original shape and size when the deforming force is removed. Up to 48% loss of elasticity had been observed in stored samples with respect to the fresh Paneer sample. However, the reported values could be more conscientious and confounded with multiple factors like differences in operational parameters of instruments and conditions; therefore, they provide indecisive and comparative results.

TABLE :4 HERE

Conclusion

An active edible matrix was prepared using biodegradable substances to lengthen shelf stability of Paneer (Indian Cottage cheese). High moisture content and good nutrient availability make Paneer more susceptible to microbiological contamination during manufacturing, processing, storage and transportation. The short shelf stability of Paneer stored at refrigeration conditions is attributed to a dramatic moisture content loss and an abrupt change in hardness value. This elucidated the need for an additional protection that should have initiated to maintain the quality characteristics of Paneer without jeopardizing the flavour and texture. The outcomes obtained in this study evaluate the aptness of different genera of antimicrobial compounds to inhibit microbial load. The current study provides an insightful outcome that edible coating loaded with Copper Nano-particles can retain the moisture content of Paneer besides providing a sound barrier against bacterial colonies. This work also unveils that the nutrient composition and structure of any food product is a critical parameter for designing a novel preserving technique. To reduce the uncertainty of using active antimicrobial packaging for the preservation of Paneer, other volatile and non-volatile antimicrobial-loaded films should be compared and evaluated in future studies.

Conflict of Interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Credit author’s contribution

Priyanka Prajapati: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing Original Draft, Writing - Review & Editing, Visualization. Dr. Meenakshi Garg: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing Original Draft, Writing - Review & Editing, Visualization. Saamir Akhtar: Methodology, Investigation, Writing Original Draft. Tehrir H. Ansari: Methodology, Investigation, Writing Original Draft. Dr. Rajni Chopra: Conceptualization, Methodology, Validation, Writing - Review & Editing, Visualization. Purnima Anand: Methodology, Validation, Investigation, Writing - Review & Editing. Susmita Dey Sadhu: Conceptualization, Validation, Investigation, Writing - Review & Editing.

Funding Declaration

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.
Data availability

Data available within the article.

Acknowledgment

The authors acknowledge with thanks for the technical assistance and other supports received from the Department of Food Technology of Bhaskaracharya College of Applied Sciences, University of Delhi, New Delhi, India.

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### TABLES

#### Table 1: Concentration of independent variables used in RSM

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Independent variables</th>
<th>Levels</th>
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<tr>
<td></td>
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<td>Low (-α)</td>
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<tr>
<td>X₁</td>
<td>Casein (%)</td>
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<tr>
<td>X₂</td>
<td>Glycerin (%)</td>
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<td>X₃</td>
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<td>X₄</td>
<td>Water (%)</td>
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#### Table 2: Experimental data obtained after applying Central Composite Design (CCD)

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<th>Response variables</th>
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<tbody>
<tr>
<td>Runs</td>
<td>Porosity (%)</td>
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<tr>
<td>casein (%)</td>
<td>Titratable acidity (%)</td>
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<tr>
<td>Glycerin (%)</td>
<td>pH</td>
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<tr>
<td>Pectin (%)</td>
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<td>Water (%)</td>
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Table 3: Final equation of response variables and their respective $R^2$

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<thead>
<tr>
<th>Variables</th>
<th>Equation</th>
<th>$R^2$</th>
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<td>Porosity</td>
<td>$+18.91+0.079X_1+0.57X_2+0.44X_3+0.49X_4+$ $+0.13X_1X_2+0.25X_1X_3+0.81X_1X_4-0.55X_2X_3+0.77X_2X_4+$ $+0.23X_3X_4+0.087X_1^2+0.23X_2^2-0.55X_3^2-1.06X_4^2$</td>
<td>84.12%</td>
</tr>
<tr>
<td>Titratoble acidity</td>
<td>$+1.13-0.011X_1+0.049X_2+0.11X_3+5.958E-003X_4+$ $+0.11X_1X_2-0.054X_1X_3-0.030X_1X_4+0.011X_2X_3+0.033X_2X_4+$ $+0.035X_3X_4-0.11X_1^2-0.091X_1^2+0.012X_2^2-0.050X_3^2$</td>
<td>81.97%</td>
</tr>
<tr>
<td>pH</td>
<td>$+6.89+0.88X_1+0.037X_2+0.12X_3+0.093X_4-0.072X_2X_3+0.12X_4X_3-$ $-0.011X_1X_2+0.18X_2X_3+0.10X_3X_4-1.875E-003X_3X_4+0.18X_3^2+$ $0.23X_2^2+0.48X_2^2+0.32X_3^2$</td>
<td>82.37%</td>
</tr>
</tbody>
</table>

Table 4: Texture Profile of Fresh, control and edible coated Paneer

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Fresh</th>
<th>Control</th>
<th>Plain coating</th>
<th>EO coating</th>
<th>CNP coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (N)</td>
<td>169.11±1.12</td>
<td>2390.02±0.7</td>
<td>3553.82±0.25</td>
<td>1156.47±0.83</td>
<td>694.84±0.37</td>
</tr>
<tr>
<td>Springiness</td>
<td>0.84±1.04</td>
<td>0.51±0.00</td>
<td>0.58±0.01</td>
<td>0.47±0.0</td>
<td>0.43±0.0</td>
</tr>
<tr>
<td>Cohesivness (Ns)</td>
<td>0.65±0.01</td>
<td>0.63±0.01</td>
<td>0.65±0.00</td>
<td>0.65±0.0</td>
<td>0.61±0.0</td>
</tr>
<tr>
<td>Gumminness</td>
<td>111.03±0.80</td>
<td>1487.83±1.81</td>
<td>2338.3±0.58</td>
<td>755.22±0.61</td>
<td>431.04±0.9</td>
</tr>
<tr>
<td>Chewiness (N)</td>
<td>94.47±0.51</td>
<td>755.12±0.23</td>
<td>755.23±0.7</td>
<td>361.64±0.89</td>
<td>187.01±1.7</td>
</tr>
</tbody>
</table>

Values are mean ± SD
Figure 1: Illustration of methodology to manufacture active edible coatings for Paneer.
Fig 2: a, b) Response surface graph of interaction factor on Porosity,

1c : Response surface graph of interaction factor on Titratable acidity

1d: Effect of concentration of casein on pH

Fig 3: Effect of antimicrobial incorporated edible coating on quality attributes of stored Paneer samples a) moisture loss, b) water activity
Fig 4: Effect of antimicrobial incorporated edible coating on quality attributes of stored Paneer samples a)pH, b) Titratable acidity

Fig 5: Effect of antimicrobial incorporated edible coating on microbial count of stored Paneer samples.