Biological Forum – An International Journal 14(4a): 551-558(2022)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Optimization of Whey Protein Concentrate-Natural Deep Eutectic Solvents Based Edible Coating of Paneer

Nayuni Vandana[1], Esther Magdalene Sharon M.[2], Sivakumar G.M.[3] and Geetha P.[2]*
[1]Research Scholar, College of Food and Dairy Technology,
Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.
[2]Assistant Professor, College of Food and Dairy Technology,
Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.
[3]Associate Professor, College of Food and Dairy Technology,
Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.

(Corresponding author: Esther Magdalene Sharon M.)*
(Received 29 September 2022, Accepted 18 November, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Paneer is an indigenous milk product coagulated using heat and acid. It is very perishable, with a shelf life of 6 days at refrigeration temperature, although its quality is lost within three days due to spoilage by psychrotrophs, coliforms, yeasts, and moulds. The short shelf life of paneer has remained a main hurdle in its large-scale production and transportation to far-off places from the production plants. Paneer is a rich source of high-quality protein, minerals, fat and vitamins. The present study attempts to optimize the inclusion level of Whey Protein Concentrate - Natural Deep Eutectic Solvents (WPC-NADES) used for edible coating for the shelf-life extension of paneer. NADES have been identified to possess outstanding antimicrobial activity and are chemically and thermally stable against a wide range of spoilage and pathogenic microorganisms. Edible coating of paneer was done by dipping diced paneer cubes into a coating solution incorporating four different NADES solutions (Lactic acid: Fructose (LF); Lactic acid: Glucose (LG); Citric acid: Fructose (CF) and Citric acid: Glucose (CG))and whey protein concentrate (6, 8, 10, 12 and 14%) at 30 ± 1 for 10-15 min followed by drying. Response surface methodology (RSM) selected Lactic acid: Fructose (LF) NADES - 12% WPC coating as the optimized product based on the sensory score (texture, colour, and overall acceptability) for extending the shelf-life of paneer

Keywords: Paneer, Edible coatings, WPC, RSM, NADES.

INTRODUCTION

India is the world's leading producer of milk, with total milk production of 187.7 million tonnes in 2018-19 and is forecasted to rise to 240 million tonnes by 2025 (NDDB, 2020). Approximately 7% of India's milk production is converted into paneer preparation. Paneer is an indigenous milk product coagulated using heat and acid. Paneer is rich in protein and comparatively low-cost and forms an essential source of protein for vegetarians. Paneer has a biological value of 80 to 86 per cent, in addition to its high protein content and digestibility (Shrivastava and Goyal 2007). It is also a good source of fat, vitamins, and minerals such as calcium and phosphorus. It is highly perishable but has a reasonably long shelf life under refrigeration with a shelf life of 6 days, although its quality is lost within three days (Bhattacharya *et al*., 1971).

Various research workers have previously attempted to improve the shelf life of paneer by employing various preservation techniques such as chemical preservatives, surface treatments, packaging techniques, drying, and so on. The use of biodegradable packaging material in foods has introduced new ways for edible films and coatings, owing to greater environmental awareness. Antimicrobial coatings and films are novel ideas in the worldwide marketplace. Thus, an adequately designed edible coating and process for its application can be developed to preserve paneer.

Edible coatings are thin-layered biopolymer compositions that may be consumed and are often applied to the surface of food products by dipping, spraying, or brushing (Bourtoom, 2008). In food systems, edible films and coatings are suitable carriers for various bioactive molecules such as vitamins, antioxidants, and probiotics (Peltzer *et al.*, 2017).

Edible biopolymers and food-grade additives are used to make edible coatings and films. Proteins, polysaccharides (carbohydrates and gums), and lipids make film-forming biopolymers. An edible coating is obtained by mixing the appropriate carbohydrate, protein, and plasticizer. The edible coating improves food quality by protecting it from physical, chemical, and microbiological deterioration (Kester and Fennema 1986).

Edible films and coatings are typically manufactured from proteins, polysaccharides and lipids, alone or in combination. The use of edible coatings for dairy and food products is an emerging method for fortification with nutrients. Several food biopolymers (Jimenez *et al.,* 2012), such as alginates, carrageenan, pectin, starch, cellulose derivatives, soya protein, whey protein and casein, have been used as edible coating materials.

Whey protein. Whey protein and whey protein-based products are employed in a wide range of foodstuffs because of their nutritional and functional qualities (Jotarkar *et al.,* 2018). Whey is a rich source of dietary components, and its biological features have been shown to improve immunity and cure ailments such as atherosclerosis. Regarding nutritional value, whey protein is second only to egg protein as a first-class protein.

Whey proteins are high in essential amino acids like lysine, methionine, and cysteine, as well as other branched-chain amino acids, and many studies have been done on the composition and processing of whey for use in foods and animal feeds, as well as the nutritive, therapeutic, and functional properties of whey (Macwan *et al*., 2016).

The most often used plasticizers are water and glycerol; however other polyols or their derivatives, sugars, amides, amines, and ionic liquids, are also employed (Paiva *et al.,* 2014). The protein-based coatings are suitable barriers to gases (O_2 and CO_2) while permeable to moisture, making these ideal for hydrophilic surfaces such as paneer Dinika *et al.* (2020). The plasticizers mentioned above, however, have a few drawbacks: Polysaccharides can recrystallize with glycerol, increasing the material's stiffness; conversely, amines, amides, and ionic liquids can be hazardous and costly. NADES are eutectic liquids with characteristics close to ionic liquids (IL) with essential advantages in the environment, economy, and synthetic materials (Smith *et al.,* 2014).

Natural Deep Eutectic Solvents. Natural Deep Eutectic Solvents (NADES) can interact with Whey Protein Concentrate (WPC) to form an edible coating on the surface of the paneer due to the extensive property and promises to be an alternative plasticizer or solvent for biopolymer modification (Gupta *et al.,* 2021).

NADES have attracted scientific interest because of their favourable physicochemical properties (e.g., liquid state over a wide temperature range, low volatility, chemical and thermal stability, non-flammability, and non-toxicity of component ingredients) but also because of their long-term "green" properties.

NADES compounds are mostly nontoxic substances found naturally in food (Pereira *et al.,* 2015) that can be directly incorporated into food formulations without further purification. This is a unique advantage over conventional solvents (Savi *et al.,* 2019). NADES appear to be excellent natural products with good biological characteristics when manufactured from low-cost raw materials (Sánchez *et al.,* 2018). However, the impact of different NADES on paneer with whey protein concentrate has yet to be investigated.

Scope of the study. Paneer is an indigenous milk product coagulated using heat and acid. It is a perishable product with a shelf life of 6 days at refrigeration temperature. However, its quality is lost within three days, and there is a loss in the quality of whey protein during paneer preparation. Hence, there is a need to improve the nutritional qualities of paneer. To overcome the deterioration in paneer due to the growth of microorganisms on the surface during storage, edible coating of paneer using Whey Protein-Natural Deep Eutectic Solvents (WPC - NADES) promises to be a practical approach to extend the shelf life of paneer. This work studies the shelf-life extension of paneer by edible coating using Whey Protein Concentrate and Natural Deep Eutectic Solvents. Keeping this in view, the investigation on "Edible coating based on Whey Protein-Natural Deep Eutectic Solvents (WPC - NADES)" has been taken up to develop a cost-effective yet easily adaptable technology to extend the shelf life of paneer with the following objectives.

MATERIALS AND METHODS

A. Raw materials

Fresh cow milk was procured from the Model Dairy Plant, College of Food and Dairy Technology, Chennai, India. Milk was filtered through muslin cloth to remove foreign materials and standardized for the preparation of paneer. Whey protein concentrate (WPC) containing 80% protein (on a dry basis), Lactic acid, Citric acid, Glucose and Fructose was procured from the local market and used in the experiments for the preparation of coating solutions.

B. Preparation of plasticizer (NADES)

The preparation method for NADES was adopted from the studies by Gupta *et al*. (2021). NADES was obtained by complexation between a hydrogen bond acceptor and a hydrogen bond donor at an appropriate molar ratio on continuous stirring for different time and temperature combinations. The molar ratio of different plasticizers used for edible coating is given in Table 1.

Table 1: Different plasticizers and their molar ratio used in the study.

Code Name	Plasticizer	Mole ratio
LF	Lactic acid: Fructose	5:1
LG	Lactic acid: Glucose	5:1
CF	Citric acid: Fructose: Water	1:1:2
CG	Citric acid: Glucose: Water	1:1:2

Accurately weigh the hydrogen bond acceptor (Lactic acid/Citric acid) and hydrogen bond donors (Fructose / Glucose) at the appropriate molar ratio in a screw-capped glass bottle. In case the hydrogen bond acceptor and hydrogen bond donors are in powder form, i.e., CF and CG NADES, water is added to obtain a solution. A magnetic bead was placed inside the glass bottle, closed tightly with a cap. The screw-capped bottle was kept in a magnetic stirrer at 80°C for 20 min. Until the clear liquid is obtained. The resulting NADES was cooled down gradually until it reached room temperature (25 ± 2°C). The process flow chart for the preparation of NADES is given in Fig. 1.

Complexation of HBA* and HBD** at the appropriate molar ratio
(Addition of water in case HBA and HBD are in powder form)
↓
Heating and stirring (80°C, 20-30 mins)
↓
Gently stirred until it transformed into a clear liquid
↓
Cooling to room temperature (25±2°)
**HBD- Hydrogen Bond Donor; **HBA- Hydrogen Bond Acceptor*

Fig. 1. Process flow chart for preparation of NADES.

C. Preparation of WPC - NADES edible coating solution

The method used for the preparation of WPC - NADES edible coating solution was adopted from Krochta (1997). The process flow chart for the preparation of the WPC – NADES edible coating solution is given in Fig. 2.

Whey Protein Concentrate (6-14%)
↓
Addition of plasticizer (NADES) and 50% of WPC (1:1)
↓
Stirring (5 min)
↓
Adjustment to pH of 7.0
↓
Stirring (5 min)
↓
Heating (90°C, 30 min.)
↓
Cooling to room temperature
↓
Filtration (muslin cloth)
↓
WPC – NADES Coating solution

Fig. 2. Process flow chart for preparation of WPC - NADES edible coating solution.

WPC solution was prepared by dissolving WPC (6, 8, 10, 12 and 14%) in distilled water. Natural Deep Eutectic Solvents were used at the rate of 50% (w/w) of WPC, respectively. The pH of the solution was adjusted to 7.0 ± 0.2 by using 1 N NaOH solution, followed by heating the solution at 90°C for 30 min with continuous stirring. Furthermore, the solution was filtered and cooled to room temperature and then used to coat the paneer.

D. Preparation of WPC - NADES edible coated paneer

The method used for paneer preparation and the edible coating was adopted from the studies by Kumar *et al.* (2019). WPC - NADES edible coating solution is used as the coating material on the paneer. The paneer cubes were dipped in a measured amount of coating solution. The surface of the paneer cubes was left to dry. The flow chart for paneer preparation and edible coating is given in Fig. 3.

Cow milk (3.5% Fat, 8.5% SNF)

↓

Heated to 90°C without holding

↓

Cool down to 85°C by keeping it in a cold-water bath

↓

Addition of citric acid at 85°C

↓

Coagulum was allowed to settle for 5 minutes.

↓

Whey was drained through a muslin cloth.

↓

Coagulum was pressed in hoops by applying a pressure of 0.08kg/cm^2 for 15 minutes.

↓

Paneer was immersed in chilled water at 4°C

↓

Dipping the paneer cubes in WPC – NADES Coating solution

↓

Surface drying

↓

Packaging

↓

Storage

Fig. 3. Process flow chart for preparation of WPC - NADES edible coated paneer.

E. Sensory analysis

Sensory evaluation of edible coated paneer was carried out using a 9-point hedonic scale assigning a score of nine (like significantly) to 1 (dislike extremely) as per Amerine *et al.* (2013)

F. Optimization of WPC-NADES used for edible coating of paneer

The type or level of NADES and WPC used for edible coating were considered independent variables. The sensory attributes, colour, texture and overall acceptability, were considered dependent variables. The independent and dependent variables of the experiment are shown in Table 2.

Optimal (Custom) design provided by Design Expert Software is a very effective tool for optimizing the level of the edible coated ingredients to obtain an acceptable product. It allows an understanding of the interactions and the relationships between the components. It uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations that can be graphically represented. Optimal (Custom) Design of response surface methodology (RSM) using Design Expert software (version 8.0.7.1, Minnesota, USA) was chosen to determine the combinations of the experiment with NADES and WPC considered as independent variables. The independent variables were assigned minimum and maximum levels based on preliminary trials. The experimental design consisted of twenty-five runs, as outlined in Table 3.

The 25 combinations of WPC – NADES coated paneer were subjected to sensory evaluation using a 9-point hedonic scale. The sensory attributes, colour, texture, and overall acceptability were considered as responses. The average of responses obtained from panellists was entered into design expert software. Using design expert software, the panellist's scores were optimized. The optimized WPC (%) and NADES type in edible coated paneer were chosen based on the desirability of the design and the range assigned to each of the responses. For optimization, the goal for responses texture, colour and overall acceptability were kept in range, maximum and maximum, respectively.

Table 2: Independent and dependent variables for edible coating of paneer.

Independent variable	
Edible coating Ingredients	
NADES (Plasticizer)	Lactic acid: Fructose (5:1) Lactic acid: Glucose (5:1) Citric acid: Fructose (1:1) Citric acid: Glucose (1:1)
Whey Protein Concentrate (Polymer)	6%, 8%, 10%, 12% & 14%
Dependent variable	
Sensory Evaluation	Colour, Texture, Overall acceptability

Table 3: Response surface methodology - Optimal (Custom) Experimental design for WPC – NADES edible coating of paneer.

Run	NADES	WPC (%)
1	LF	10
2	CF	10
3	LG	6
4	CF	12
5	CF	8
6	LF	6
7	LF	12
8	CF	14
9	CF	6
10	LG	12
11	LF	12
12	CG	14
13	LF	14
14	LG	14
15	LG	10
16	CG	10
17	LF	10
18	LG	6
19	LF	6
20	CG	8
21	CG	6
22	LF	8
23	CG	12
24	LG	8
25	LG	8

RESULTS AND DISCUSSION

The sensory attributes, *viz*., texture, colour and overall acceptability, were considered responses for optimizing NADES and WPC edible-coated paneer. The average of responses obtained from the panellists was entered in D- optimal (custom) design software. The ideal NADES and WPC (%) for the edible coating of paneer were optimized using D- optimal (custom) design based on texture, colour and overall acceptability. The results of experimental runs with corresponding responses are presented in Table 4.

Table 4: D-optimal (custom) experimental design matrix with the experimental data quality of paneer.

Run	NADES	WPC (%)	Texture	Colour	Overall Acceptability
1	LF	10	8	8.2	7.6
2	CF	10	8.3	8.26	8.24
3	LG	6	7.65	7.5	7.1
4	CF	12	7.65	7.81	7.1
5	CF	8	8.2	8.12	8
6	LF	6	7.98	7.85	8.1
7	LF	12	8.63	8.58	8.65
8	CF	14	7	7.5	7.1
9	CF	6	7.85	7.59	7.75
10	LG	12	7.9	8.1	8.13
11	LF	12	8.62	8.59	8.64
12	CG	14	7.5	8.16	7.5
13	LF	14	8.5	8.21	8.28
14	LG	14	7.8	7.94	7.65
15	LG	10	8.5	8.45	7.75
16	CG	10	7.74	7.85	7.68
17	LF	10	7.65	8.22	7.4
18	LG	6	7.98	7.52	7.4
19	LF	6	7.81	7.85	8.2
20	CG	8	8.33	8.15	8.16
21	CG	6	8	7.98	7.6
22	LF	8	7.7	8.26	8
23	CG	12	7	8	7.5
24	LG	8	8.2	7.98	7.6
25	LG	8	8.2	7.95	7.6

The experimental data obtained was analyzed, and the factorial model was selected as the best fit. The factorial models thus developed with actual variables for Texture (T), Colour (C) and Overall Acceptability (OA) are as follows:

$$T = 7.92 + 0.1925A_1 + 0.1265A_2 + 0.1165A_3 - 0.0694B_1 + 0.0646B_2 + 0.0438B_3 + 0.0076B_4 + 0.2829A_1B_1 + 0.0364A_2B_1 - 0.1556A_3B_1 + 0.1228A_1B_2 - 0.0690A_2B_2 - 0.1319A_3B_2 - 0.1683A_1B_3 + 0.0147A_2B_3 - 0.0187A_3B_3 - 0.0355A_1B_4 + 0.0240A_2B_4 + 0.0103A_3B_4$$

$$C = 8.02 + 0.1980A_1 - 0.0320A_2 - 0.1690A_3 + 0.0440B_1 - 0.0902B_2 + 0.0220B_3 - 0.0021B_4 + 0.0605A_1B_1 + 0.0555A_2B_1 - 0.0930A_3B_1 + 0.0084A_1B_2 - 0.0573A_2B_2 - 0.0720A_3B_2 - 0.0510A_1B_3 - 0.0060A_2B_3 + 0.0310A_3B_3 - 0.0273A_1B_4 + 0.0291A_2B_4 + 0.0154A_3B_4$$

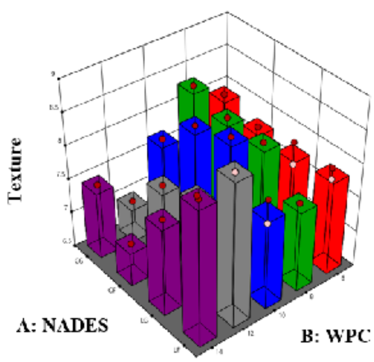
$$OA = 7.7 + 0.3358A_1 - 0.1032A_2 - 0.1413A_3 - 0.0206B_1 + 0.0521B_2 + 0.0138B_3 - 0.0151B_4 + 0.1111A_1B_1 + 0.1536A_2B_1 - 0.1994A_3B_1 + 0.1388A_1B_2 - 0.0501A_2B_2 - 0.0822A_3B_2 - 0.1298A_1B_3 - 0.0798A_2B_3 + 0.1013A_3B_3 - 0.0584A_1B_4 - 0.0066A_2B_4 + 0.0707A_3B_4$$

The sign and magnitude of coefficients indicate the effect of the variable on the responses.

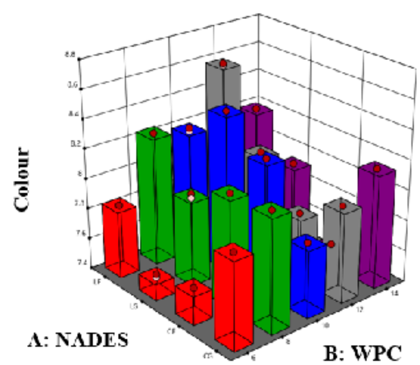
The ANOVA table for the factorial model is given in Table 5. The ANOVA table, the p-value indicates that the model was significant and shows the variations in responses. The f-value shows lack of fit was non-significant, indicating that the model fit the actual data within the limit. The coefficient of regression (R^2) near one indicates that the model was good. The conditions met by the model provide reasonable predictions for average outcomes. ANOVA for the selected factorial model. The effect of WPC (6-14%) - NADES (LF, LG, CF & CG) on texture, colour and overall acceptability of edible coated paneer are presented in the form of three-dimensional graphs in Fig. 4.

Table 5: Analysis of variance (ANOVA) for selected Factorial Model.

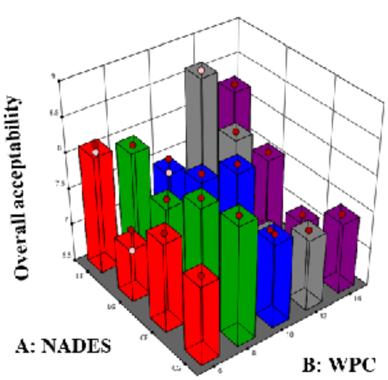
Source	Texture		Colour		Overall acceptability	
	F- value	P-value	F- value	P-value	F- value	P-value
Model	8.66	0.0126	649.10	< 0.0001	16.98	0.0026
AB	10.22	0.0093	366.88	< 0.0001	17.08	0.0028
R^2	0.9705	-	0.9996	-	0.9847	-
Adj R^2	0.8585	-	0.9981	-	0.9267	-
Model precision	11.2587	-	90.4167	-	14.5937	-



(a) Texture



(b) Colour



(c) Overall acceptability

Fig. 4. Effect of WPC (6-14%) -NADES (LF, LG, CF & CG) on (a) Texture, (b) Colour and (c) Overall acceptability of edible coated paneer.

The optimized levels of WPC-NADES were chosen based on desirability. The paneer coated with 12% WPC containing lactic acid and fructose (LF) was selected as the best solution by D-optimal (custom) experimental design with optimized texture (8.330), colour (8.500) and overall acceptability (7.750). The goal for optimization, along with constraints and responses, are given in Table 6. The purpose of the WPC-NADES optimization was to maximize the sensory scores. This result coincided with the findings of Jotarkar *et al.* (2018) who carried out process optimization by maximizing the sensory score for Whey protein concentrate (WPC) - iron-based edible coated paneer shows Response surface methodology.

Table 6: The goal for optimization, along with constraints and responses.

Parameters	Goal	Constraints		Importance	Solution
		Lower limit	Upper limit		
NADES	In range	LF	CG	3	LF
WPC (%)	In range	6	14	3	12
Texture	Maximize	7.0	8.63	3	8.625
Colour	Maximize	7.5	8.59	3	8.585
Overall acceptability	Maximize	7.1	8.65	3	8.645

From the experimental results, the statistical analysis indicated that the factorial model was significant ($P < 0.001$), and the lack of fit was non-significant ($P > 0.05$). Paneer coated with 12% WPC containing lactic acid and fructose at a 5:1 mole ratio was selected as the optimum solution by using Design Expert Software with texture (8.625), colour (8.585) and overall acceptability (8.645). Henriques *et al.* (2013) suggested that WPC-based coatings might exhibit improved functionality and provide opportunities for increased use of coating technology in the food industry to increase the shelf life of foods. Gupta *et al.* (2021) stated that 10 % starch lactic: fructose NADES is most suitable for extending the shelf life of straw berries up to 20 days. The comparison of the actual and predicted value for the factorial model is presented in Table 7.

Table 7: Comparison of Actual and Predicted value of the response.

Parameters	Predicted value*	Actual value@
Texture	8.625	8.312
Colour	8.585	8.289
Overall acceptability	8.645	8.399

* Predicted value obtained from Design Expert™ package; @ Actual value obtained from Design Expert™ package.

CONCLUSION

This study demonstrated that WPC-NADES-based edible coating doesn't affect the sensory quality of paneer. Product with LF NADES and 12% WPC edible coating was optimized based on sensory scores of texture (8.625), colour (8.585) and overall acceptability (8.645). Minimum effects on sensory properties and high quality were provided by LF-12% WPC. The factorial models were found to be adequate, as there was no significant lack of fit in any of the response variables.

FUTURE SCOPE

The shelf-life studies of WPC-NADES edible coated paneer with and without packaging interventions must be studied to know the commercial feasibility of this technique.

Acknowledgement. The authors are thankful to Tamil Nadu Veterinary and Animal Sciences University for the financial support and for providing the required facilities during the study.
Conflict of Interest. None.

REFERENCES

Amerine, M. A., Pangborn, R. M. and Roessler, E. B. (2013). *Principles of sensory evaluation of food*. Elsevier.

Bhattacharya, D. C., Mathur, O. N., Srinivasan, M. R. and Samlik, O. (1971). Studies on the method of production and shelf life of paneer (cooking type of acid-coagulated cottage cheese). *J Food Sci Technol Mysore*.

Bourtoom, T. (2008). Edible films and coatings: characteristics and properties. *International food research journal*, *15*(3), 237-248.

Dinika, I., Verma, D. K., Balia, R., Utama, G. L. and Patel, A. R. (2020). Potential of cheese whey bioactive proteins and peptides in the development of antimicrobial edible film composite: A review of recent trends. *Trends in Food Science & Technology*, *103*, 57-67.

Gupta, V., Thakur, R. and Das, A. B. (2021). Effect of natural deep eutectic solvents on thermal stability, syneresis, and viscoelastic properties of high amylose starch. *International Journal of Biological Macromolecules*, *187*, 575-583.

Henriques, M., Santos, G., Rodrigues, A., Gomes, D. M. G. S., Pereira, C. and Gil, M. (2013). Replacement of conventional cheese coatings by natural whey protein edible coatings with antimicrobial activity. *Journal of Hygienic Engineering and Design*, *3*, 34-47.

Jimenez, A., Fabra, M. J., Talens, P. and Chiralt, A. (2012). Edible and biodegradable starch films: a review. *Food and Bioprocess Technology*, *5*(6), 2058-2076.

Jotarkar, P. S., Panjagari, N. R., Singh, A. K. and Arora, S. (2018). Effect of whey protein iron based edible coating on the quality of Paneer and process optimization. *International Journal of Dairy Technology*, *71*(2), 395-407

Kester, J. J. and Fennema, O. R. (1986). Edible films and coatings: a review. *Food technology (USA)*.

Krotchta, J. M. and De Mulder-Johnston, C. (1997). Edible & biodegradable polymer films: Challenges and opportunities. *J Food Technol-chicago*, *51*, 2-8.

Kumar, R., Mishra, D., Sutariya, H., Chaudhary, M. B. and Rao, K. J. (2019). Effect of different coagulants on the yield, sensory, instrumental colour and textural characteristics of cow's milk Paneer. *International Journal of Dairy Technology*, *72*(4), 617-625.

Macwan, S. R., Dabhi, B. K., Parmar, S. C. and Aparnathi, K. D. (2016). Whey and its utilization. *International Journal of Current Microbiology and Applied Sciences*, *5*(8), 134-155.

NDDB, 2021. Statistical database. National Dairy Development Board, Anand

Paiva, A., Craveiro, R., Aroso, I., Martins, M., Reis, R. L. and Duarte, A. R. C. (2014). Natural deep eutectic solvents–solvents for the 21st century. *ACS Sustainable Chemistry & Engineering*, *2*(5), 1063-1071.

Peltzer, M. A., Salvay, A. G., Delgado, J. F. and Wagner, J. R. (2017). Use of edible films and coatings for functional foods developments: A review. *Functional foods sources, health effects and future perspectives*, 1-26.

Pereira, F., Kloskowski, A. and Namieśnik, J. (2015). Perspectives on the replacement of harmful organic solvents in analytical methodologies: a framework toward the implementation of a generation of eco-friendly alternatives. *Green Chemistry*, *17*(7), 3687-3705.

Sánchez, A. C., Castro, M. C. R., Biernacki, K., Gonçalves, M. P. and Souza, H. K. (2018). Natural deep eutectic solvents as green plasticizers for chitosan thermoplastic production with controlled/desired mechanical and barrier properties. *Food Hydrocolloids*, *82*, 478-489.

Savi, L. K., Dias, M. C. G. C., Carpine, D., Waszczynskyj, N., Ribani, R. H. and Haminiuk, C. W. I. (2019). Natural deep eutectic solvents (NADES) based on citric acid and sucrose as a potential green technology: a comprehensive study of water inclusion and its effect on thermal, physical and rheological properties. *International Journal of Food Science & Technology*, *54*(3), 898-907.

Shrivastava, S. and Goyal, G. K. (2007). Preparation of Paneer: A review. *Indian journal of dairy science*, *60*(6), 377-388.

Smith, E. L., Abbott, A. P. and Ryder, K. S. (2014). Deep eutectic solvents (DESs) and their applications. *Chemical reviews*, *114*(21), 11060-11082.

How to cite this article: Nayuni Vandana, Esther Magdalene Sharon M., Sivakumar G.M. and Geetha P. (2022). Optimization of Whey Protein Concentrate-Natural Deep Eutectic Solvents Based Edible Coating of Paneer. *Biological Forum – An International Journal*, *14*(4a): 551-558.