# Spray-encapsulation of Probiotics to Formulate Functional Probiotic Curd with Targeted- and Sustained Gastrointestinal Release: Understanding of Probiotic Release Pattern and Mechanistic Behaviour


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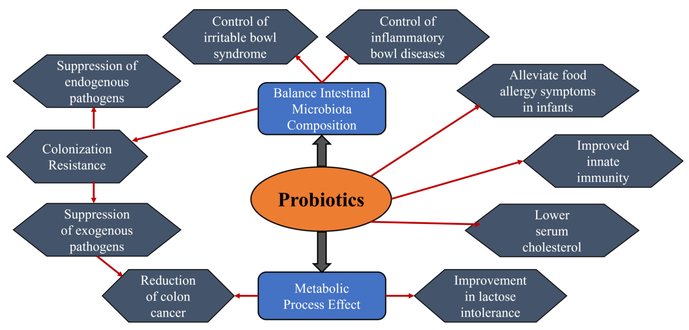
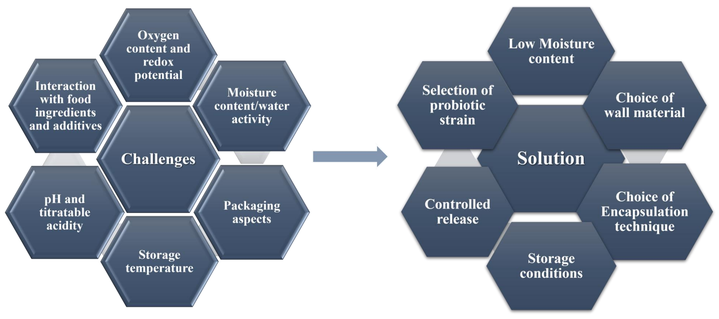
## Introduction

**Probiotics:** "Live micro-organisms, when ingested in sufficient numbers confer one or more specified health benefits for the host".



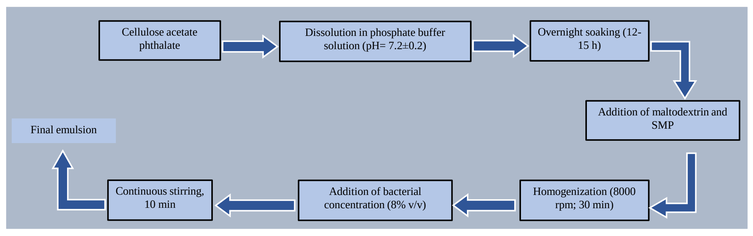




## Objectives

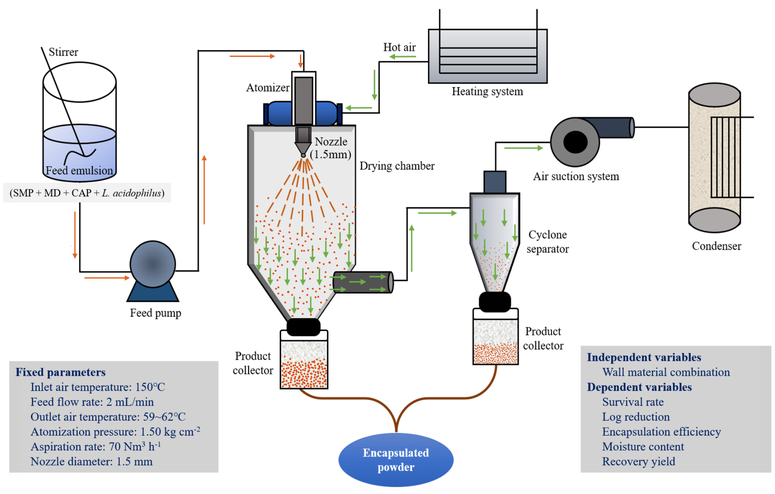
- Development of spray-encapsulated *L. acidophilus* powder using a composite wall matrix (MD+SMP+CAP).
- Study of sustained targeted release mechanistic behavior of *L. acidophilus* inside simulated gastrointestinal conditions.
- Formulation of Indian probiotic curd enriched with encapsulated probiotic *L. acidophilus* powder.

## Materials and Methods

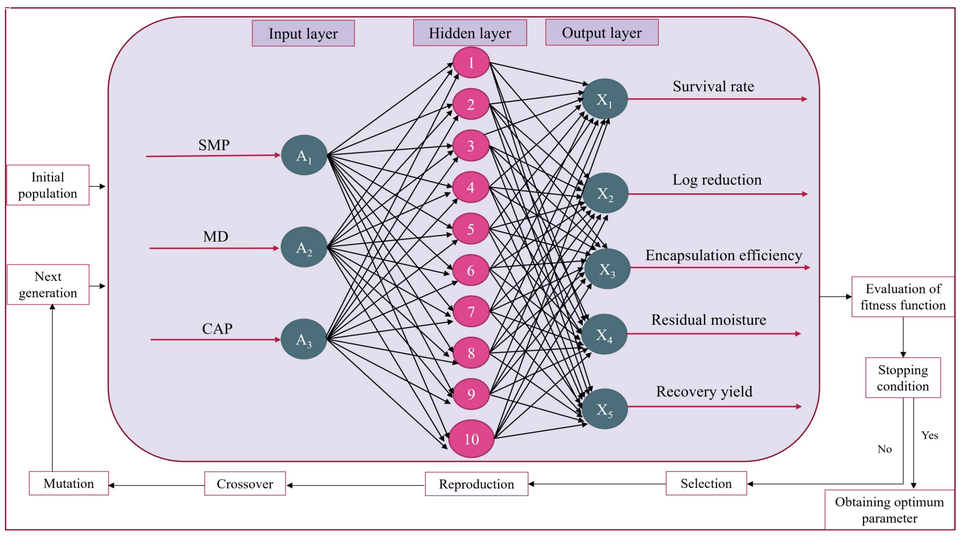
| Skim milk powder (SMP) (10-30% w/w) | Maltodextrin (DE 20) (MD) (10-30% w/w) | Cellulose acetate phthalate (CAP) (2-5% w/w) |
|---|---|---|
| • Suitable carrier for probiotic strains<br>• Prebiotic in nature<br>• Better flowability<br>• Better spreadibility<br>• Stabilizing agent<br>• Binding agent | • Hygroscopic in nature<br>• Easily digestible<br>• Cellular protection<br>• High solubility<br>• Better oxidative stability<br>• Prevent protein unfolding<br>• Higher $T_g$ value | • Physiologically inactive<br>• Enteric coating polymer<br>• Dissolution at higher pH (> 6)<br>• Significantly used in pharmaceutical capsules |




### Spray drying of *L. acidophilus*

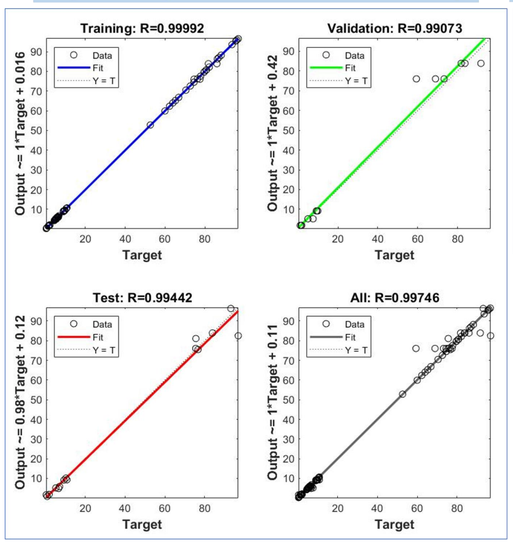



### ANN Model's Architecture

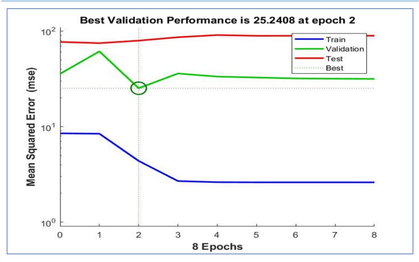



## Results and Discussion

### Regression Analysis of the Model Construct after Training




### Performance Assessment of the Generated Neural Model

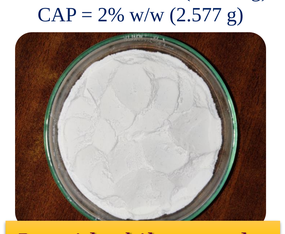



**Optimized wall material concentration:**

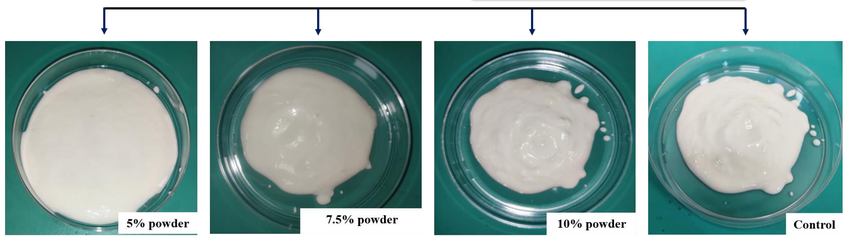
SMP = 10% w/w (12.885 g)

MD = 11.281% w/w (14.536 g)

CAP = 2% w/w (2.577 g)



*L. acidophilus* powder




### Release profile of *L. acidophilus* for various models at different *in-vitro* conditions

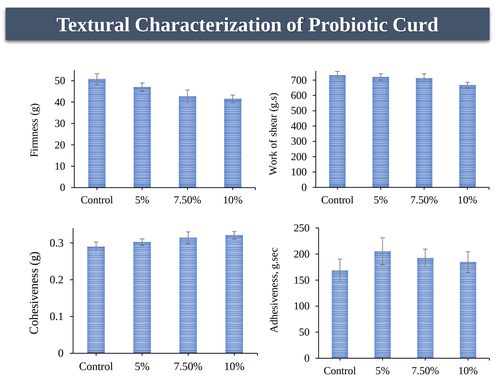
| Condition | Zero order Model | | First order Model | | Hixson-Crow Model | | Higuchi Model | | Korsmeyer-Peppas Model | | Baker-Lonsdale Model | | Release Mechanism |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $R^2$ | $K$ | $R^2$ | $K$ | $R^2$ | $K$ | $R^2$ | $K$ | $R^2$ | $K$ | $R^2$ | $K$ | |
| SGF | **0.987** | 0.648 | 0.914 | 0.0029 | 0.929 | -0.303 | 0.653 | 0.2206 | 0.928 | 0.0198 | 0.625 | 0.0032 | ***n*= 2.044 (Super Case-II transport)** |
| SIF | **0.994** | 0.617 | 0.948 | 0.0031 | 0.907 | -0.248 | 0.781 | 0.1985 | 0.894 | 0.0147 | 0.684 | 0.0038 | ***n*= 2.04 (Super Case-II transport)** |
| pH 2 | 0.975 | 0.805 | 0.988 | 0.0897 | 0.793 | -0.4133 | 0.964 | 2.4549 | **0.993** | 0.1026 | 0.916 | 0.0032 | ***n*= 0.76 (Anomalous transport)** |
| pH 3 | 0.972 | 0.5535 | 0.965 | 0.0638 | 0.844 | -0.375 | 0.972 | 1.1071 | **0.975** | 0.0508 | 0.784 | 0.0016 | ***n*= 1.129 (Super Case-II transport)** |
| pH 4 | **0.999** | 0.48 | 0.993 | 0.0581 | 0.867 | -0.3689 | 0.883 | 1.5054 | 0.998 | 0.0466 | 0.782 | 0.0016 | ***n*= 1.12 (Super Case-II transport)** |

**SGF, SIF, pH 4 → Zero order model; pH 2, 3 → Korsmeyer-Peppas model**

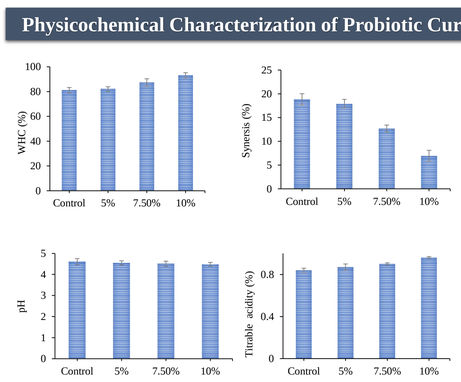
**Super case II Transport** (Time independent) = Erosion, swelling and relaxation of polymeric chain. Stresses and state-transition in hydrophilic glassy polymers which swell in water or biological fluids.

**Anomalous transport** (Time dependent) = Erosion controlled release + Diffusion controlled release

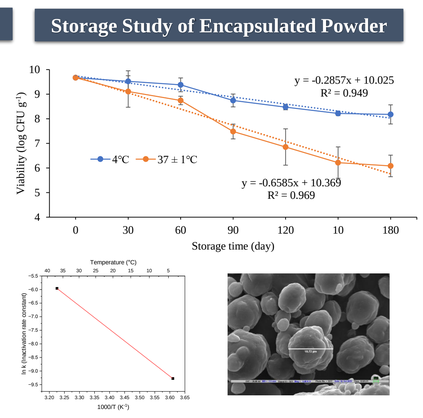
### Textural Characterization of Probiotic Curd



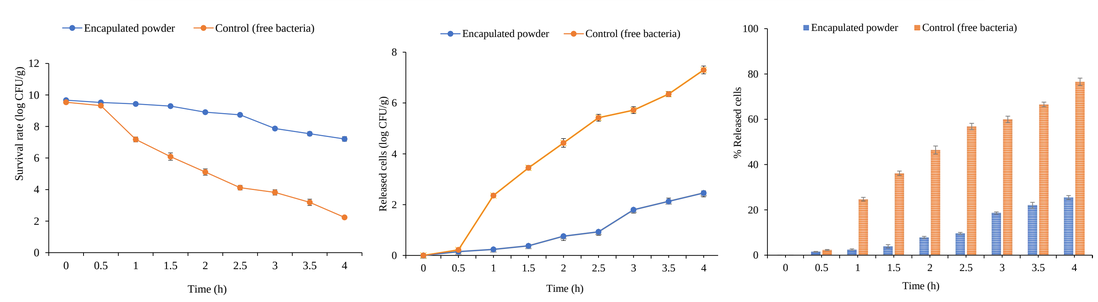

### Physicochemical Characterization of Probiotic Curd



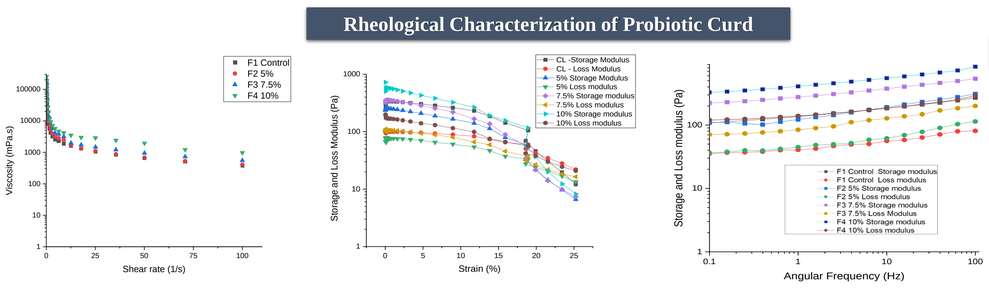

### Storage Study of Encapsulated Powder




### Simulated Gastrointestinal Digestion of *L. acidophilus* Powder




### Rheological Characterization of Probiotic Curd

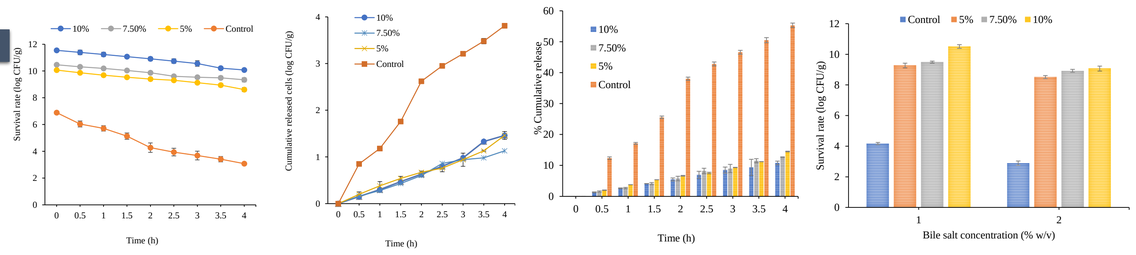



### Sensory Quality Analysis of Probiotic Curd

| Scale factors | S1 | S2 | S3 |
|---|---|---|---|
| F1 | 0 | 0 | 0 |
| F2 | 0.0691 | 0.0385 | O.1927 |
| F3 | 0.4632 | 0.3738 | 0.7418 |
| F4 | 0.8902 | 0.8983 | 0.8627 |
| F5 | 0.6567 | 0.5558 | 0.3116 |
| F6 | 0.1167 | 0.1930 | 0.0125 |

F1: Not satisfactory; F2: Fair; F3: Satisfactory; F4: Good; F5: Very good; F6: Excellent; S1: Curd@ 5% (w/w) encapsulated powder; S2: Curd@ 7.5% (w/w) encapsulated powder; S3: Curd@ 10% (w/w) encapsulated powder

### Simulated Gastrointestinal Digestion of Encapsulated Powder-Enriched Probiotic Curd




## Conclusion

- The research demonstrates the feasibility of developing a spray-encapsulated probiotic powder with enhanced bioavailability and sustained release in the human GI tract.
- The successful formulation of functional probiotic-enriched curd was achieved for daily dietary consumption to strengthen the gut microbiota.

## Key Message

- The research outcome showed the techno-economic feasibility of consuming encapsulated probiotic powder either via capsule form or by incorporating it into dairy-based food formulations in the daily dietary intake to improve the gut microbiota.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