ABSTRACT

Context and Background

Personalization has become a defining trend in contemporary food and beverage consumption. Automated systems in segments such as beverages, coffee, and quick-service foods increasingly allow consumers to customize flavours, ingredients, and formulations at the point of consumption. However, the soft-serve ice cream segment remains largely unchanged, offering only a small number of pre-set flavours with negligible scope for real-time customization. This limitation persists despite strong consumer demand for personalised taste experiences, particularly in high-footfall public, commercial, and institutional environments.

The lack of customization in soft-serve ice cream is not a consumer-facing choice but a consequence of existing production and dispensing architectures. Conventional soft-serve systems depend on **bulk pre-manufacturing of one to three flavours per operational cycle**, which are stored under continuous cold or frozen conditions and dispensed unchanged upon demand. This approach makes it technically impractical to support per-serving flavour variation without significantly increasing inventory complexity, cold-storage requirements, energy consumption, and operational risk.

Problem Definition

Current soft-serve ice cream systems are structurally designed for **static flavour dispensing rather than dynamic flavour creation**. Their dependence on centralized or batch-based preparation, combined with uninterrupted cold-storage and freezing infrastructure, prevents real-time mixing, formulation, and customization at the point of sale. As a result, operators are constrained to limited flavour offerings, while consumers are denied meaningful choice and personalization.

In addition to restricting consumer experience, continuous cold storage significantly contributes to energy consumption, maintenance burden, and deployment limitations, particularly in decentralized or power-variable environments. Although shelf-stable dairy bases processed through Ultra-High Temperature (UHT) treatment and aseptically processed fruit concentrates are widely used in the food industry, they are not currently integrated into soft-serve systems capable of producing customized servings on demand.

Research Gap and Innovation Potential

The core research gap lies in the **absence of a customization-centric soft-serve processing architecture** that can:

- Formulate flavours dynamically at the point of consumption,
- Operate using ambient-stored dairy and flavour inputs,
- Achieve rapid texture and phase transformation suitable for soft-serve products, and
- Minimize or eliminate dependence on continuous cold-storage systems.

Existing research and commercial solutions focus primarily on improving cold-chain efficiency or optimizing centralized manufacturing, rather than rethinking the process flow to enable per-serving customization. Critical unresolved challenges include formulation control from UHT dairy bases, texture and overrun consistency, short-cycle thermal processing, hygiene assurance during repeated automated operation, and energy optimization for on-demand use cases.

These challenges span multiple domains, including food engineering, thermal systems design, process automation, and system reliability, and have not yet been addressed in an integrated manner.

Scope of the work

There is a great scope for developing and validating a **point-of-consumption soft-serve ice cream processing system** that prioritizes real-time flavour customization. The system shall be designed to generate individualized servings on demand by combining ambient-stored dairy bases with natural flavour inputs, without reliance on bulk pre-manufacturing or continuous cold storage.

The research shall follow a structured methodology comprising:

- Ingredient formulation and rheological studies for customizable soft-serve profiles,
- Process and thermal system design for rapid on-demand freezing,
- Prototype development and performance benchmarking,
- Energy consumption, hygiene and safety validation, and
- Controlled field trials in real-world deployment scenarios.

Expected Outcomes and Relevance

Successful resolution of this research problem is expected to enable a paradigm shift from static dispensing to **customization-driven soft-serve production**, offering:

- Enhanced consumer choice and experience,
- Reduced energy consumption and cold-chain dependency,
- Improved operational flexibility and scalability, and
- New pathways for sustainable, decentralized food processing systems.

The research aligns with Tamil Nadu's priorities in applied research, energy efficiency, and innovation-led manufacturing, while contributing to the development of indigenous technology solutions for automated food systems.

Note: IAMUSAPVENTURES PVT. LTD. has already demonstrated proof of concept for the above mentioned system in a lab setting and willing to collaborate with researchers from reputed institutes for developing a near-commercial system which can be demonstrated in an actual operational setting.