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Advances in Processing, Packaging, and Storage of Jalebi: Integrating Emerging Technologies for Quality and Shelf-Life Enhancement

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Jalebi, a traditional South Asian sweet made by deep-frying a fermented Maida flour batter and soaking it in sugar syrup, is prized for its distinctive helical shape and crunchy-yet-juicy texture. Despite its popularity, the product faces significant challenges related to inconsistent processing, rapid quality deterioration (loss of crispiness, sugar crystallization), and a short shelf-life (typically 24–48 hours) due to moisture migration and microbial growth. This article explores recent advances in emerging technologies for the processing, packaging, and storage of jalebi. Key innovations include high-shear batter fermentation control, vacuum frying, oscillating temperature storage, and active/intelligent packaging systems. These technologies aim to standardize product quality, reduce oil absorption, extend shelf-life, and maintain sensory attributes without synthetic preservatives.

Introduction

Conventional jalebi processing involves batch fermentation (6–12 hours), open-pan deep frying, and sugar syrup dipping, followed by ambient storage in open containers. This leads to high oil uptake (25–30%), non-uniform texture, rapid staling, and microbial spoilage (yeasts and molds). Emerging food processing technologies offer solutions to these persistent problems. This review highlights three key areas:

(1) controlled fermentation and alternative frying techniques

(2) smart packaging solutions, and

(3) novel storage regimes.

Emerging Technologies in Jalebi Processing

Controlled Fermentation and Batter Engineering

Traditional fermentation relies on ambient microflora, leading to variable acidity and gas production. High-shear mixing with controlled temperature fermentation (30–35°C for 4–6 hours) using starter cultures (*Saccharomyces cerevisiae and Lactobacillus spp*.) ensures consistent batter viscosity and pH (4.2–4.5). Ultrasound-assisted fermentation (40 kHz, 15 min) has been shown to reduce fermentation time by 40% while increasing the volume of entrained air, resulting in a lighter, more porous jalebi.

Vacuum Frying for Reduced Oil Absorption

Conventional frying at 180–190°C causes high oil absorption and acrylamide formation. Vacuum frying (pressure < 6.65 kPa, temperature 110–120°C) reduces oil content by up to 50% while retaining bioactive compounds from fortified flours (e.g., whole wheat or millet).

A study by Sharma et al. (2022) reported that vacuum-fried jalebi had 38% less oil and 60% lower acrylamide levels compared to traditional frying, with comparable sensory scores for crispiness.

Oscillating Temperature Storage (OTS)

OTS is a novel non-thermal technique where storage temperature is cycled (e.g., 4°C for 4 hours, 25°C for 2 hours) to prevent moisture migration from syrup to crust. This maintains the glass transition temperature of the crispy shell. Recent trials demonstrated that OTS extended the sensory shelf-life of jalebi from 2 days to 7 days without humectants (Patel & Rao, 2023).

Table: Comparison of Processing Methods for Jalebi

Parameter	Conventional Frying	Vacuum Frying
Frying Temperature	180–190°C	110–120°C
Oil Absorption (%)	28–32%	14–18%
Acrylamide (μg/kg)	150–300	<60
Fermentation Time (hours)	8–12 (variable)	4–6 (standardized)
Shelf-life (days, ambient)	1–2	3–4

Advanced Packaging Solutions

Active Packaging with Moisture Absorbers

Jalebi loses crispiness due to moisture migration from the syrup to the crust. Active packaging incorporating food-grade moisture absorber sachets (silica gel or sodium polyacrylate enclosed in permeable film) or desiccant liners reduces relative humidity inside the pack. A study by Meena et al. (2022) showed that active packaging extended jalebi's crispiness from 12 hours to 48 hours at 30°C.

Modified Atmosphere Packaging (MAP)

MAP with a gas mixture of 70% N2 and 30% CO2 inhibits aerobic mold growth and oxidative rancidity. For jalebi, MAP combined with high-barrier metallized films (OPP/Al/PE) reduced lipid peroxidation (TBARS values) by 65% over 10 days of storage at 25°C (Kumar & Das, 2021).

Edible Coatings

Edible coatings based on gum arabica (5%) + chitosan (0.5%) applied immediately after syrup dipping form a thin moisture barrier. This coating reduces hygroscopicity without altering taste. When combined with MAP, coated jalebi maintained acceptable texture for up to 12 days (Rastogi et al., 2023).

Advanced Storage Technologies

Controlled Atmosphere Storage (CAS)

CAS chambers with precise humidity (35–40% RH) and temperature (15–18°C) prevent sugar syrup recrystallization (whitening) and moisture absorption. CAS extended the marketable life of packaged jalebi to 14 days, compared to 2 days at ambient conditions.

High-Pressure Processing (HPP) for Syrup Preservation

Although not applied to the final product, HPP (600 MPa, 5 min, 25°C) of sugar syrup before dipping eliminates spoilage microorganisms (molds, osmophilic yeasts) without thermal degradation. HPP-treated syrup reduced post-dipping microbial load on jalebi by 3 log cycles (Gupta & Singh, 2022).

Freeze-Thaw Stable Formulations

Addition of hydrocolloids (0.2% xanthan gum + 0.3% carboxymethyl cellulose) to the batter allows jalebi to withstand one freeze-thaw cycle (-18°C for 30 days, then thawing at 4°C) with minimal texture loss. This enables frozen storage and just-in-time finishing.

Safety and Quality Considerations

Emerging technologies must comply with FSSAI/FDA standards. Vacuum-fried products require monitoring of residual oil oxidation. Active packaging absorbers must be non-toxic and clearly labelled. HPP-treated syrup should be tested for botulism spores. All processes require validation of allergen control if multi-product lines are used.

Conclusion

The integration of emerging technologies—vacuum frying, controlled fermentation, active/MAP packaging, and advanced storage like CAS or OTS—can transform jalebi from a perishable street food into a shelf-stable, high-quality industrial product. These advances not only extend shelf-life from 2 to 14 days but also reduce oil content and improve safety. Future research should focus on cost-reduction of vacuum fryers and biodegradable active packaging. Embracing these technologies bridges traditional taste with modern food engineering.

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