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DEVELOPMENT OF THERMOSTABLE EDIBLE PACKAGING MATERIALS BASED ON STARCH–PROTEIN COMPOSITES FOR HOT FOOD APPLICATIONS: A CRITICAL REVIEW

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ABSTRACT

This narrative review critically examines starch–protein edible composites as potential packaging materials for hot meals, with particular emphasis on thermal transitions, wet-state mechanical integrity, water resistance, processing routes and food-contact safety. The analysis integrates peer-reviewed literature on starch-based films, starch–protein compatibility, plasticizer selection and recent modification strategies. A central distinction is made between thermal stability measured by differential scanning calorimetry or thermogravimetry and practical serviceability during contact with hot, aqueous and fatty foods. Protein blending can improve cohesion and modify film barriers, but the outcome depends on protein chemistry, pH, blend ratio, plasticizer content and processing history. Available evidence supports formulation optimization and application-specific testing rather than a general claim that edible starch–protein packaging is already suitable for all hot meals. A validation framework combining thermal, mechanical, moisture, migration, sensory and microbiological measurements is proposed.

Keywords

starch–protein composites; edible packaging; hot food; thermomechanical stability; water vapor permeability; gelatinization; food-contact safety.

INTRODUCTION

Conventional single-use food containers create a strong incentive to explore renewable, consumable alternatives. Starch is abundant, inexpensive and film-forming, but starch-only films often show moisture sensitivity, brittle behavior at low plasticizer loading and inadequate performance relative to synthetic packaging [1–3]. Proteins provide additional hydrogen-bonding and network-forming functionality; their incorporation can alter strength, elongation, permeability and heat response [4,5]. The

specific challenge for hot food is not simply whether a dry film avoids thermal decomposition: it must remain intact during contact with steam, liquid water, oil and food at elevated temperatures. This review therefore considers hot-food suitability as a coupled thermal–hydro–mechanical problem.

Starch structure and film formation. Amylose and amylopectin ratio, botanical source, gelatinization conditions and retrogradation influence film microstructure and flexibility [1,6]. Heating starch in water disrupts native granules and permits network formation on drying; however, subsequent water uptake can soften the matrix and accelerate loss of load-bearing capacity. The choice of starch source should therefore be linked to the intended geometry, storage humidity and serving temperature rather than film appearance alone.

Protein incorporation and interfacial compatibility. Casein, gelatin, albumin and plant proteins introduce different conformations, charge distributions and gelation behavior. Jagannath and colleagues demonstrated that starch–protein film compatibility and blending conditions can be reflected in thermal transitions and barrier behavior [4]. Recent systematic literature on starch–protein interactions emphasizes the importance of intermolecular interactions and crosslinking chemistry [5]. A protein-rich network may strengthen a film under some conditions, but phase separation or excess hydrophilic protein can worsen moisture resistance. Any formulation must be evaluated experimentally rather than assumed to benefit from protein addition.

Plasticizers, crosslinking and reinforcement. Glycerol and sorbitol improve processability by increasing chain mobility, while often lowering stiffness and increasing sensitivity to moisture; their effects vary with concentration and matrix chemistry [1]. Food-compatible crosslinking, controlled thermal processing, lipid-containing layers and edible reinforcement are plausible strategies to limit swelling. However, improvements measured in dry tensile tests may not persist after exposure to hot broth. All ingredients, processing aids and reaction products must be assessed for their intended food-contact and consumption conditions.

Thermal stability versus hot-service performance. Thermogravimetric decomposition onset, glass transition, melting-related events and gelatinization are

different phenomena and should not be used interchangeably. A film can exhibit a relatively high dry-state degradation temperature while losing shape rapidly in hot water. Practical testing should include timed immersion or surface contact, wet tensile or puncture measurements, leakage, seam integrity and deformation under a defined load. Reviews published in 2024–2026 identify continuing gaps in moisture resistance, standardization and scale-up of starch films [1–3,7,8].

METHODOLOGY

This article is a critical narrative review, not an experimental study or a systematic meta-analysis. Literature was selected for direct relevance to edible starch films, starch–protein interactions, processing and thermal/barrier performance, with preference for identifiable journal articles and DOI-linked records. The studies were synthesized thematically, separating reported findings from the proposed experimental protocol. No original measurements, numerical effect sizes or comparative significance tests are claimed.

RESULTS AND DISCUSSION

Across the reviewed literature, three coupled trade-offs emerge: (i) flexibility versus resistance to deformation, (ii) film cohesion versus hydration-driven swelling, and (iii) thermal processing tolerance versus palatability and safety. For hot dishes, moisture-driven weakening is likely to be a more immediate operational limitation than thermal decomposition. This is an inference from the reviewed material-property literature, not a verified universal ranking of failure modes.

Table 1. Qualitative comparison of formulation strategies reported or discussed in the literature

Strategy	Potential benefit	Critical qualification
Starch + protein	Network cohesion; tunable strength	Compatibility and wet-state behavior depend on blend
Glycerol or sorbitol	Flexibility and easier casting	Can increase moisture sensitivity

Edible crosslinking	Potentially reduced solubility	Requires safety and sensory validation
Edible lipid-rich layer	Potential moisture barrier improvement	Adhesion and hot-oil behavior require testing
Thermal/processing optimization	More uniform structure	Overheating can impair sensory properties

Table entries are qualitative design hypotheses, not measured rankings or experimental results. Sources: [1], [4], [5], [7].

Proposed experimental validation for hot meals. A useful research design would compare a starch control with at least three starch–protein ratios, each at controlled plasticizer levels. Films or formed trays should be conditioned at defined relative humidity before testing. Differential scanning calorimetry, thermogravimetric analysis and dynamic mechanical analysis can characterize transitions and modulus changes. Tensile strength, elongation, puncture resistance, thickness, swelling, water solubility, water vapor transmission and contact angle should be measured both before and after thermal exposure. Simulated hot-food trials should specify food temperature, water and fat content, contact duration, applied load and whether the package is consumed. Food-contact migration, microbial safety, allergens and sensory acceptability must be documented independently of biodegradability.

CONCLUSION

Starch–protein composites are promising candidates for edible hot-food packaging, but practical thermoresistance cannot be inferred from dry-state thermal stability alone. Protein selection, molecular compatibility, plasticization and moisture control govern the balance between strength, flexibility and barrier behavior. The most defensible development pathway is an application-specific formulation program with combined thermal and wet-mechanical tests, followed by food-contact safety and sensory evaluation. The available literature motivates this approach but does not yet establish a universally heat-stable edible package for hot meals.

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