

Omics-driven Safety and Allergy Management for Sustainable Food Systems: Enabling Consumer Acceptance of Cellular Agriculture and Future Foods

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Abstract

The transition to more resilient and sustainable food systems requires cellular agriculture, edible insects, and other emerging future foods. However, consumer acceptance and long-term dietary integration depend on demonstrated safety. Food allergy, a currently incurable and often lifelong immune disease affecting 240-520 million people globally, represents a major barrier to the adoption of novel foods. Seafood is the leading trigger of life-threatening food anaphylaxis in the Asia-Pacific region, and related emerging food products enter the market without adequate allergen risk assessment.

We developed an integrated multi-omics workflow combining quantitative mass spectrometry, *in silico* allergenicity prediction using AllerCatPro, and immunoassays using sera from allergy suffering individuals, anchored to clinical relevance.

Profiling of >100 regionally consumed fish and shellfish species revealed pronounced allergen variability associated with taxonomic identity, body size, geographical origin, aquafeed composition, environmental conditions, and food processing. Cell-cultivated eel and catfish exhibited >9,000-fold reductions in the major fish allergen parvalbumin, with no detectable IgE-binding by sera from fish-allergic patients, indicating that cellular agriculture can substantially reduce allergy risks. Edible insects displayed species-specific cross-reactivity with crustacean pan-allergens, indicating substantial risk for shellfish-allergic consumers. Isoform-resolved IgE profiles, including distinct α - and β -parvalbumin lineages, predicted clinical tolerance: all fish-allergic children tolerated gummy shark in oral food challenges, identifying this species as a clinically tolerated alternative. Gummy shark is one of only a few cartilaginous species globally that are harvested sustainably.

Our approach established molecular allergen profiles and translated them into actionable food safety risk mitigation strategies, enabling species- and preparation-specific diagnostics and dietary management. Rigorous risk assessments, which carefully evaluate allergic potentials, can convert a major barrier to consumer acceptance into a foundation of trust. Novel foods provide the opportunity for consumer-informed and safe dietary choices for a diverse and increasingly food-allergic global population.

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