COMMENTARY

Rethinking ultra-processed foods: Controversies, health evidence, and policy directions

Wei Wei,[1] Tianshu Han,[1] Yizhou Ma,[2] Fengzhong Wang,[3,4] and Peihua Ma[4,*]

[1]Key Laboratory of Precision Nutrition and Health, School of Public Health, Harbin Medical University, Harbin 150081, China

[2]Laboratory of Food Process Engineering, Wageningen University & Research, Wageningen 6708 PB, the Netherlands

[3]Institute of Food and Nutrition Development, Ministry of Agriculture and Rural Affairs, Beijing 100081, China

[4]Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences, Beijing 100193, China

*Correspondence: mapeihua@caas.cn

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Ultra-processed foods (UPFs) have become a focal point of nutrition science and public health debate, yet the evidence linking their consumption to adverse health outcomes remains contested. The widely adopted NOVA classification, fails to differentiate products of vastly different nutritional quality within the ultra-processed category, limiting its utility for risk stratification. A central question persists: whether processing per se exerts health effects independent of nutrient composition, potentially through alterations in food matrix structure, generation of neo-formed compounds, or degradation of bioactive constituents. This commentary critically examines UPF classification systems and the mechanistic plausibility of processing-related harms. We argue that evidence-based regulatory strategies must accommodate cultural, socioeconomic, and stakeholder contexts; premature convergence on universal mandates risks both scientific overreach and inequitable outcomes (Figure 1).

The classification controversies: boundaries and ambiguities

The NOVA framework, developed by Brazilian researchers in the early 2010s, introduced a classification scheme dividing foods into four tiers based on the nature and extent of industrial processing. UPFs (NOVA Group 4) are formulations composed largely of substances extracted or derived from foods, combined with additives such as emulsifiers, flavor enhancers, and colorants. Soft drinks, instant noodles, reconstituted meat products, and mass-produced confectionery fall squarely here. NOVA was conceived as a testable hypothesis: that processing itself, independent of nutrient composition, might drive diet-related chronic diseases.[1] Whether that hypothesis holds remains contested. Critics suggest NOVA may overstate the case by implying that industrial manufacturing necessarily compromises nutritional value. Fortified plant-based milks (or juice), high-fiber cereals, and whole-grain breads formulated with emulsifiers may exhibit nutritional profiles comparable to minimally processed counterparts and serve legitimate nutritional and functional roles for specific population groups, such as vegans, older adults, or individuals with limited capacity for home food preparation. However, these products are uniformly classified as NOVA Group 4 alongside sugar-sweetened beverages. This overlooks legitimate functions of processing: extending shelf life, ensuring microbiological safety, improving bioavailability of certain nutrients. This classification approach risks obscuring clinically relevant nutritional heterogeneity within the ultra-processed category and may generate consumer misperceptions regarding dietary quality. Proponents contend that such exceptions do not compromise the validity of observed population-level associations between UPFs intake and adverse health outcomes. Conversely, critics have called for methodological refinements that permit differentiation between nutritionally favorable and unfavorable ultra-processed products.

Processing and health: evidence, gaps, and research directions

The pragmatic rationale: why processing exists. Processing emerged for reasons beyond profit. Pasteurization, canning, and refrigeration drastically reduced foodborne illness. Modern supply chains depend on shelf-stable products to feed urban populations distant from agricultural production. There is an equity dimension here that public health messaging sometimes glosses over. UPFs consumption concentrates among lower-income groups and younger adults with demanding work schedules, not due to insufficient

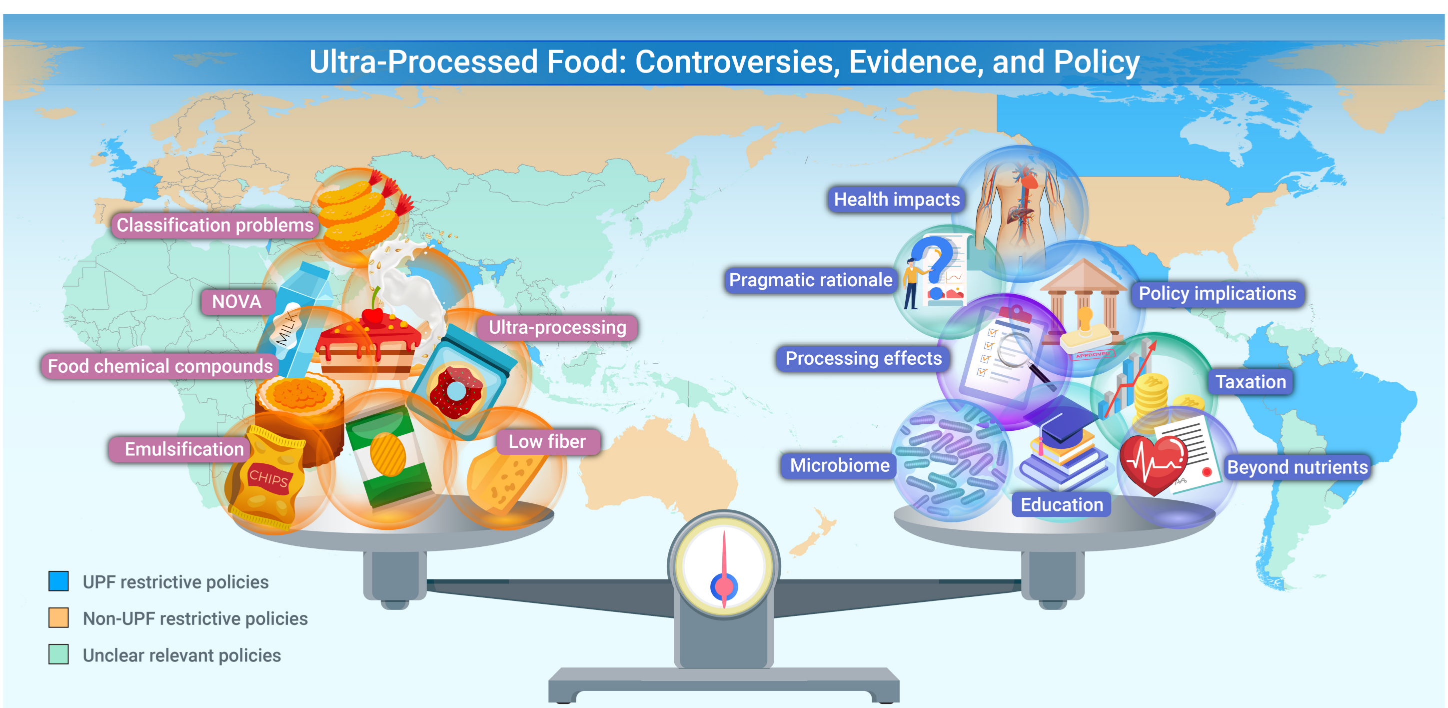

Figure 1. Reconsidering Ultra-processed foods (UPFs): classification challenges, mechanistic uncertainties, and policy implications

nutrition knowledge, but because time, financial resources, and food preparation infrastructure remain unequally distributed. For shift workers, single parents, or individuals lacking kitchen facilities, convenience foods may represent the only viable option for regular meal consumption. Recommendations to avoid UPFs therefore carry implicit assumptions about household resources that do not reflect the lived realities of economically disadvantaged populations.

Beyond nutrients: where the real debate begins. Acknowledging the practical necessity of processed foods does not preclude scrutiny of their health effects. UPFs vary considerably, but many commonly consumed products remain high in sodium, added sugars, and saturated fats while low in fiber and micronutrients.[2] Epidemiological studies have consistently reported associations between UPFs consumption and elevated risk of cardiovascular disease, type 2 diabetes, and certain cancers.[3] However, an umbrella review rated most outcomes as low or very low confidence, with only type 2 diabetes reaching moderate certainty.[2] Residual confounding poses a persistent challenge, as UPFs consumers differ systematically from lower consumers in socioeconomic status and lifestyle factors. A key unresolved question is whether processing itself, independent of nutrient composition, poses distinct risks. A randomized crossover trial by Hall et al. provides preliminary evidence: participants consuming ultra-processed diets ad libitum ingested approximately 500 kcal/day more than when offered nutrient-matched minimally processed diets.[4] These findings suggest that processing-induced changes in food structure and texture may accelerate eating rate and increase energy intake independent of nutrient composition. Further mechanistic research is warranted.

Mechanisms, technologies, and research frontiers. The health relevance of food processing depends fundamentally on the physicochemical nature and intensity of the processes applied. Fardet's framework distinguishes mechanical operations (e.g., milling, grinding, pressing), thermal processes (e.g., frying, baking, extrusion at 120–200°C under high shear), and fermentation. These categories differ markedly in their effects on food structure and chemistry. Thermal processes, particularly intensive operations such as extrusion and high-temperature treatment, can profoundly alter food matrices. Reduced particle size and disrupted cell-wall structures can accelerate gastric emptying and intestinal enzymatic access. In starch-rich foods, such alterations often produce postprandial glycemic responses 20–60% higher than structurally intact counterparts with identical macronutrient composition, underscoring the importance of matrix effects beyond nutrient content alone.

Chemical complexity adds an additional layer of uncertainty. Foods contain more than 139,000 distinct chemical compounds, the majority of which are not captured in standard nutrient databases and have been described as "nutrition dark matter".[5] Thermal processing can induce thousands of new reaction products, including Maillard reaction intermediates, advanced glycation end products, and lipid oxidation products. Food-derived small molecules collectively interact with more than 18,000 proteins of the human proteome, suggesting that processing-induced chemical shifts could influence metabolic pathways. Chronic exposure to such byproducts may exert cumulative effects that escape detection in short-term feeding studies.[5] Emerging processing technologies further complicate this landscape. Non-thermal methods such as high-pressure processing (400–600 MPa) and pulsed electric fields (15–40 kV/cm) can preserve heat-labile nutrients, yet induce protein unfolding, aggregation, or membrane permeabilization through distinct physicochemical mechanisms. Similarly, structural innovations including oleogels and microencapsulated delivery systems alter lipid crystallinity, interfacial tension, and digestion rates, potentially modulating bile acid signaling and gut microbiota composition. These technologies have entered commercial use only within the past two decades, and long-term human data remain scarce, leaving open whether they mitigate or introduce novel health risks.

Resolving these uncertainties requires methodological advances beyond observational epidemiology. Critically, study design must shift from the heterogeneous ultra-processed category toward targeted intervention trials focused on specific processing technologies, alongside controlled feeding studies that vary structural parameters while holding nutrient composition constant. This reorientation should be supported by high-resolution analytical platforms to monitor food matrix transformations affecting nutrient bioaccessibility; foodomics approaches integrating metabolomics, proteomics and lipidomics with machine learning to characterize processing-induced chemical diversity and identify candidate biomarkers; and mechanistic interrogation through population trials, gut organoid systems, organ-on-a-chip platforms and in vivo studies to elucidate effects on metabolic homeostasis, gut microbial ecology and systemic health outcomes.

Policy implications: from classification to regulation

Whether the NOVA framework should directly inform regulation remains contested, in part because national contexts differ markedly in dietary patterns, food systems, and public health priorities. Several Latin American countries have adopted an assertive stance. Brazil incorporated NOVA into its national dietary guidelines in 2014, advising citizens to avoid UPFs. This approach has since been extended through front-of-pack warning labels, marketing restrictions, and school food policies across the region. In these contexts, NOVA has functioned less as a mechanistic model than as a precautionary public health tool. United States and Europe have adopted a more cautious posture. The 2025 U.S. Dietary Guidelines Advisory Committee issued categorical recommendations, but citing insufficient certainty across multiple health outcomes. European regulators continue to debate labeling schemes without formal endorsement of NOVA as a regulatory standard. At the global level, WHO expert consultations underscored the political sensitivity of translating an evolving scientific framework into policy. Disputes over expert balance and stakeholder representation highlighted the difficulty of translating an evolving scientific framework into globally applicable policy.

These divergent responses suggest that a tiered approach may be more defensible than uniform regulation. Certain categories such as sugar-sweetened beverages and energy-dense snacks are consistently associated with adverse outcomes and may justify targeted action. In contrast, fortified cereals or plant-based alternatives occupy a more ambiguous nutritional space and may warrant differentiated treatment. Systems such as the Food Compass score attempt to address this heterogeneity by integrating processing alongside multiple nutritional attributes.

While processing has become a central concept in nutrition discourse, the evidence base remains insufficiently granular to support universal mandates. Blanket regulatory condemnation of UPFs therefore risks unintended consequences: consumer confusion regarding dietary choices, disproportionate impacts on lower-income populations with limited alternatives, and market incentives for superficial reformulation rather than genuine nutritional improvement. Policy development would benefit from greater mechanistic clarity, improved classification tools, and sensitivity to social and economic context. Premature regulatory convergence may be less productive than continued, regionally tailored experimentation informed by an expanding evidence base.

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DECLARATION OF INTERESTS

The authors declare no competing interests.