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# Food Processing:<br>The Essential Toolbox<br>for PRISM-Optimized Food Products

## Processing as the Bridge to Multi-Faceted Food Quality

Food processing represents a comprehensive scientific toolbox that enables the systematic optimization of food products across all six PRISM facets. As a sophisticated engineering discipline, processing provides the critical bridge between fixed formulations and desired food quality outcomes, transforming raw agricultural materials through controlled physical, chemical, and biological modifications to achieve optimal performance across nutrition, sustainability, safety, affordability, convenience, and palatability characteristics.

## Process-Structure-Properties Framework and PRISM Integration

The fundamental principle governing food processing-**"Process creates structure and structure encodes properties"**- directly aligns with PRISM's multi-faceted assessment approach. This Process-Structure-Properties (S-Pro$^2$) framework establishes that processing operations systema-tically influence food structure at molecular to macroscopic scales, which in turn determines the final product properties that PRISM evaluates across its six specialized facets /1/. When a fixed formulation enters the processing toolbox, it represents the baseline from which processing can optimize outcomes. This separation emphasizes formulation and processing as fundamentally independent levers for impacting food quality characteristics - the core principle underlying both NOURISH and the entire PRISM framework.

## Multi-Objective Processing Optimization Across PRISM Facets

Contemporary food processing operates within a complex optimization framework that directly addresses all six PRISM facets simultaneously:

**NOURISH (Nutrition Value)**: Processing optimizes nutritional value through controlled enhancement of bioavailability via cell wall disruption, strategic enzyme inactivation, and beneficial compound formation while minimizing nutrient losses. The generated food matrix structure determines nutrient release kinetics in the digestive tract, directly affecting bio-accessibility and bioavailability that NOURISH quantifies through ΔNRF measurements.

**EARTH (Sustainability)**: Processing integrates sustainability principles through energy recovery systems, water recycling protocols, and life cycle assessment optimization. These interventions create measurable changes in environmental impact that EARTH quantifies through Global Warming Potential differences (ΔGWP).

**SHIELD (Safety)**: Processing ensures safety through systematic elimination of pathogenic microorganisms via controlled thermal treatments, pH modification, and antimicrobial interventions following predictive microbiology models. Simultaneously, processing parameters are optimized to minimize formation of processing-induced contaminants, creating the complex safety profile changes that SHIELD is developing methodologies to measure.

**VALUE (Affordability)**: Processing achieves cost optimization through energy efficiency improvements, waste minimization strategies, and yield and quality enhancement techniques. These interventions affect the overall value proposition that VALUE aims to quantify beyond simple cost analysis.

**EASE (Convenience)**: Processing provides convenience solutions by extending shelf life, reducing preparation requirements, and optimizing storage characteristics. Processing also provides various options of food products that are easily integrated into rapidly changing life, social and culture settings in modern society. These modifications create measurable changes in user experience that EASE is developing protocols to assess.

**TASTE (Palatability)**: Processing engineers palatability through precise control of texture via protein denaturation and starch gelatinization, along with volatile compound management for optimal sensory appeal. These interventions create quantifiable changes in consumer satisfaction that TASTE aims to measure.

## The VALUE Facet: Critical Consideration for low income Countries

The VALUE facet assumes particular importance in low and lower-middle income country contexts, where traditional affordability metrics often fail to capture the complex relationship between cost, nutritional access, and food security. In these regions, VALUE optimization must address unique challenges including limited purchasing power, inadequate cold chain infrastructure, seasonal price volatility, and high rates of malnutrition.

Processing interventions within the VALUE framework can dramatically improve nutritional accessibility through several mechanisms. **Nutritional density enhancement** via fortification, biofortification, or concentration processes can deliver more essential nutrients per unit cost, effectively reducing the economic barrier to adequate nutrition. **Shelf-life extension**through appropriate thermal processing, dehydration, or fermentation eliminates spoilage losses that disproportionately affect low-income populations who cannot afford waste. **Local processing development** using regionally available ingredients reduces transportation costs and creates economic opportunities within communities.

**Seasonal price stabilization** through processing and storage enables year-round availability of nutritious foods at more predictable costs, protecting vulnerable populations from harvest-related price spikes. **Portion optimization** through processing can create smaller, more affordable package sizes that align with daily purchasing patterns common in low-income households, while maintaining nutritional adequacy.

The VALUE facet must also consider **infrastructure-appropriate processing technologies** that function effectively without reliable electricity or sophisticated supply chains. This includes solar drying, ambient-stable packaging, and processing methods that utilize locally available energy sources. **Nutritional bioavailability enhancement** through processing becomes particularly crucial in developing regions where monotonous diets may limit nutrient absorption, making techniques like fermentation, germination, or complementary protein combinations essential for maximizing nutritional impact per cost unit.

Importantly, many of these critically needed processed foods may be categorized by ambiguous and misleading food classification systems (such as NOVA) as "ultra-processed," despite their essential role in addressing malnutrition and food security. Such classification labels should be of no concern - or even ignored - in these contexts, as they fundamentally fail to reflect the appropri-ateness and vital functionality of these processed food products for populations facing urgent nutritional needs. The NOVA system's focus on processing extent rather than nutritional outcomes creates misleading assessments that could discourage the development and adoption of processing solutions specifically designed to combat malnutrition in resource-constrained environments.

Ultimately, VALUE optimization in developing country contexts requires processing solutions that simultaneously reduce costs, enhance nutritional density, extend accessibility, and integrate with local economic systems—ensuring that good nutrition becomes economically viable for those who need it most urgently.

## Reverse Engineering for PRISM Optimization

Modern food processing employs a **reverse engineering approach** that aligns perfectly with PRISM's comprehensive assessment goals. Based on researched structure-property relationships across all six PRISM facets, optimal structures for desired multi-faceted performance are first identified. Subsequently, appropriate processing operations and parameter settings are selected to generate these optimal structures from fixed formulations.

This cascade approach enables efficient optimization by tuning structural outcomes across multiple processing steps, allowing manufacturers to systematically address all PRISM facets while maintaining the fundamental separation of formulation and processing impacts that enables precise measurement of each factor's contribution to final food quality /1/.

# Systems Integration and PRISM Implementation

Contemporary food processing employs systems engineering approaches, integrating process analytical technology (PAT), real-time monitoring, and digital twins to optimize multiple PRISM objectives simultaneously. This holistic framework enables the design of processing systems that deliver products optimized across all six PRISM facets while meeting economic and regulatory requirements.

The systematic application of processing as a comprehensive toolbox ensures that fixed formulations can be transformed into food products that achieve optimal performance across nutrition value, sustainability, safety, affordability, convenience, and palatability—precisely the multi-dimensional assessment that PRISM provides through its six specialized facets. However, optimization of such multi-faceted food product quality aspects often leads to different system optima, as improvements in one PRISM facet may need to balance with optimization goals in another. For instance, intensive thermal processing might enhance safety and convenience but potentially compromise nutritional value and sustainability.

Therefore, based on scientific knowledge and practical experience, decisions for "Pareto frontier-compromised" solutions must frequently be found, where the optimal balance across all six facets represents the best achievable trade-off rather than individual facet maxima. This is particularly relevant when considering that scientifically optimized processed foods may receive misleading classifications from systems like NOVA, which conflate processing extent with nutritional quality. Such ambiguous classification systems fail to recognize the sophisticated engineering required to achieve multi-objective optimization and may discourage the development of beneficial processed foods. The PRISM framework provides a more nuanced and scientifically grounded alternative that evaluates the actual functionality and appropriateness of processed foods across all relevant quality dimensions.This establishes food processing as the essential bridge between ingredient selection and compre-hensive food quality optimization within the PRISM framework, enabling informed decisions about multi-objective compromises that serve diverse consumer needs and market requirements while moving beyond misleading simplifications of food processing's role in nutrition and public health.

Related Publications:


/1/ Ahrné, L., Chen, H., Henry, C.J., Kim H-S., Schneeman B. & Windhab E.J. (2025). Defining the role of processing in food classification systems - the IUFoST formulation & processing approach. ***npj Science of Food*** **9, 56 (2025).** https://doi.org/10.1038/s41538-025-00395-x

/2/ Windhab E.J., Ahrné, L., Chen, H., Henry, C.J., Kim H-S., Schneeman B. (2025); "Food Processing"; *IUFoST Sci. Information Bulletin (SIB)/task force*, *September 2025*; available online September 2025 https://iufost.org/scientific-council/iufost-scientific-information-bulletins-sibs