Opportunities and Challenges in the Processing & Formulation of more Healthful Foods

Advancing the Role of Science, Technology, and Communication in Making Healthful Foods and Diets: A Workshop

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Disclosures

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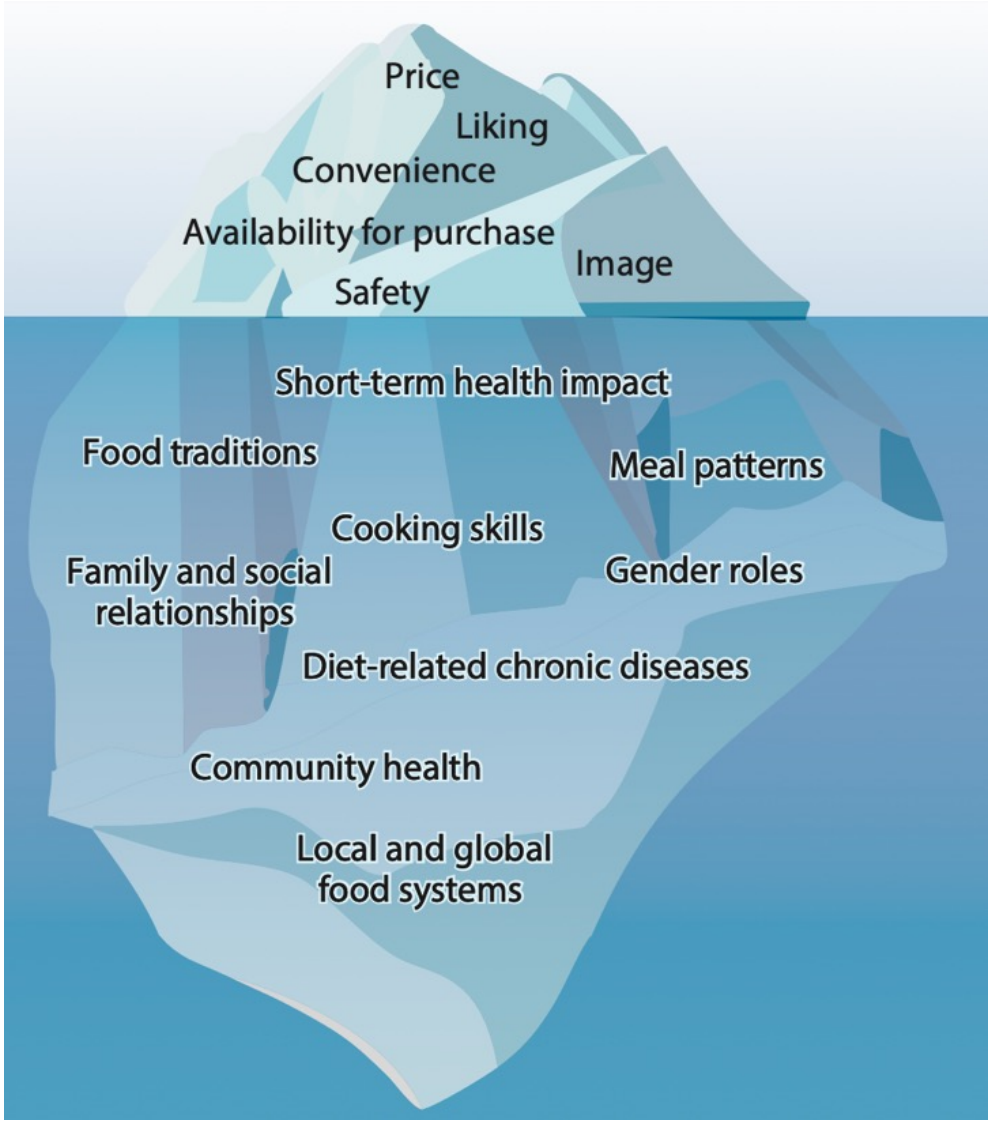
What is food processing?

"Food processing can be defined as the use of methods and techniques involving equipment, energy, and tools to **transform** agricultural products such as grains, meats, vegetables, fruits, and milk into food ingredients or processed food products."

Institute of Food Technologists

Impact of processed foods



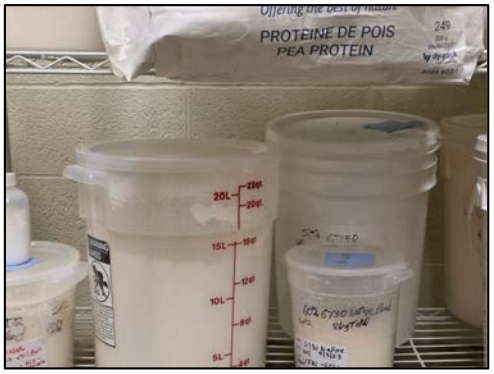
J. Ubbink and A.S Levine: *Annu. Rev. Food Sci. Technol. 16:1.1–1.24 (2025) https://doi.org/10.1146/annurev-food-111523- 122028*

Let’s start with the NOVA food classification system

Minimally processed foods

Processed foods

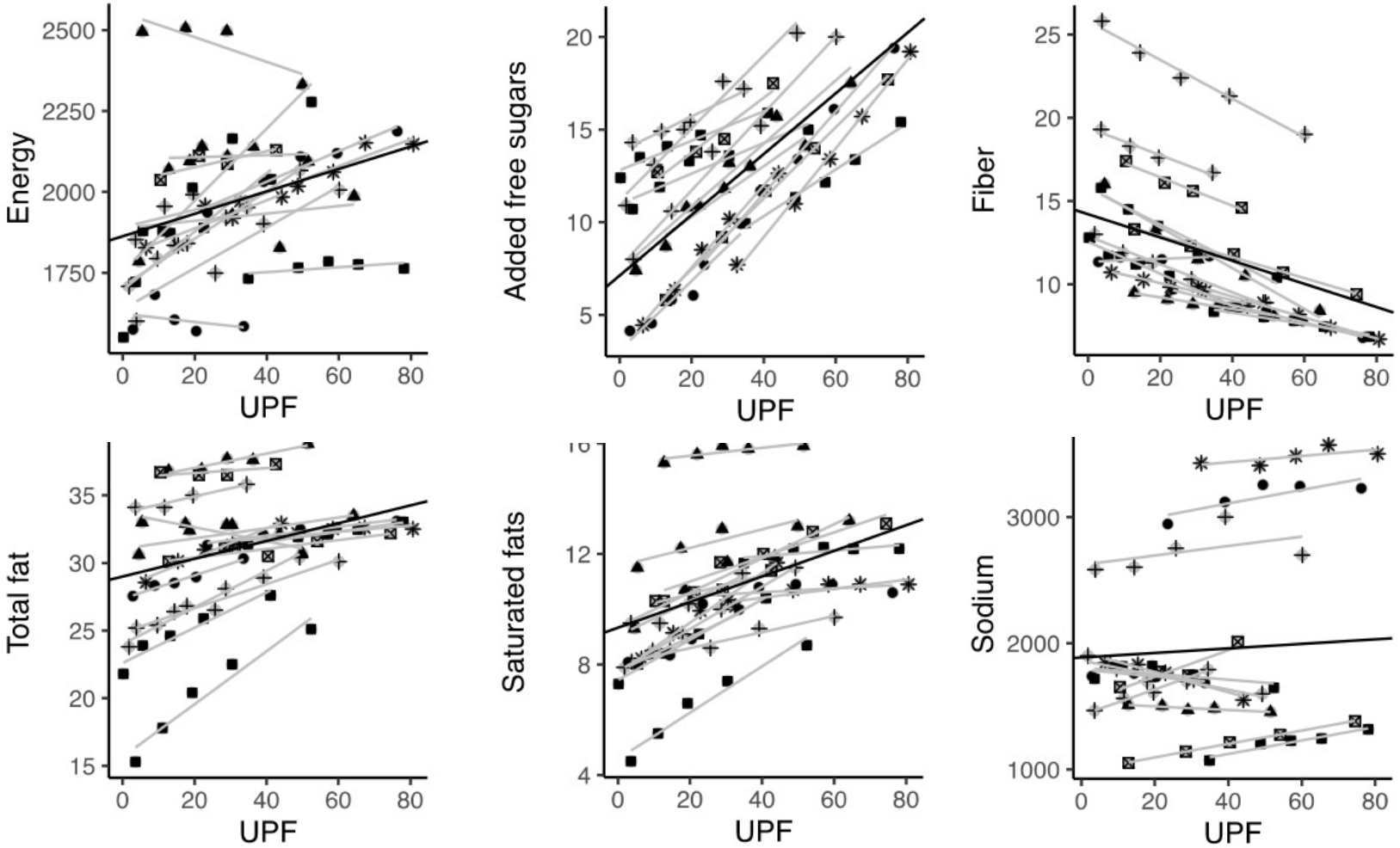
Ultraprocessed foods



Processed culinary ingredients

Industrial ingredients & additives

Correlations between UPF consumption and nutrient intake



D. Martini et al., *Nutrients* **13**, 3390 (2021)

UPF consumption *correlates* with several factors known to be related to less healthy diets

Health impact of ultraprocessed foods

Outcome	No. of studies	No. of participants	OR (random, 95 % CI)		P	I^2 (%)	P_{het}
Overweight/obesity[6–9,26]	5	73 169	1·39	1·29, 1·50	<0·00001	0	0·47
High WC[7,8,24,26]	4	31 908	1·39	1·16, 1·67	0·0003	49	0·12
Hyperglycaemia[12,24]	2	1113	1·10	0·34, 3·52	0·87	67	0·08
Hypertriacylglycerolaemia[12,24]	2	1113	0·95	0·60, 1·50	0·82	0	0·84
Low HDL-cholesterol[12,24]	2	1113	2·02	1·27, 3·21	0·003	0	0·86
Hypertension[12,24]	2	1113	1·31	0·50, 3·43	0·58	38	0·20
Metabolic syndrome[12,24]	2	1113	1·79	1·10, 2·90	0·02	0	0·49

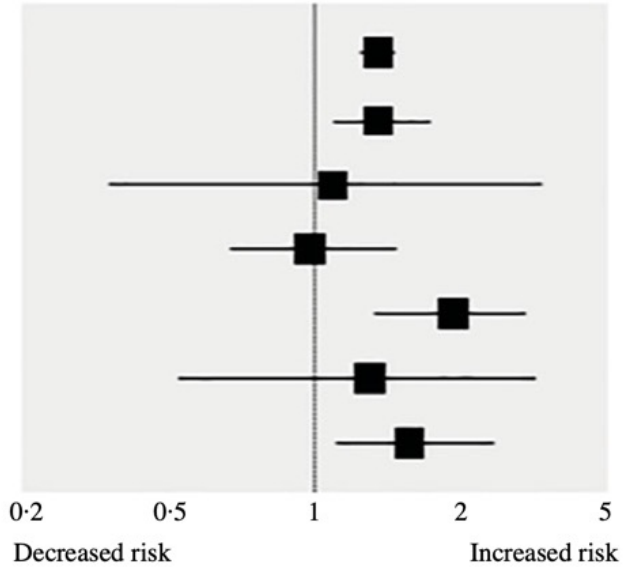


Fig. 2. Forest plot of cross-sectional studies investigating the association between ultra-processed foods consumption and different health outcomes. *P* value is for *Z* test of no overall association between exposure and outcome; P_{het} is for test of no differences in association measure among studies; I^2 estimates from heterogeneity rather than sampling error. WC, waist circumference.

G. Pagliai et al., *British J. Nutr.* **125**, 308–318 (2021)

Is it the *processing* that responsible for the negative health impact of UPFs?

Process classification

Minimally processed foods	Processed foods & prepared meals	Ultraprocessed foods
Washing	*Cutting*	*Smoking*	*Canning*	*Cooking*	*Blending*	*Extraction*
Sanitizing	*Grating*	*Salting*	*Freezing*	*Evaporating*	*Mixing*	*Concentration*
Cooling	*Slicing*	*Pickling*	*Drying*	*Baking*	*Shaping*	*Spray drying*
Freezing	*Juicing*	*Fermenting*		*Frying*	*Molding*	*Extruding*

Processed culinary ingredients	Industrial ingredients & additives
Threshing	*Pressing*	*Fractionation*
Dehusking	*Refining*	*Chemical synthesis*
Milling	*Fractionating*	*Chemical modification*
Sieving	*Crystallizing*	*Physical modification*
Bleaching		*Bioconversion*

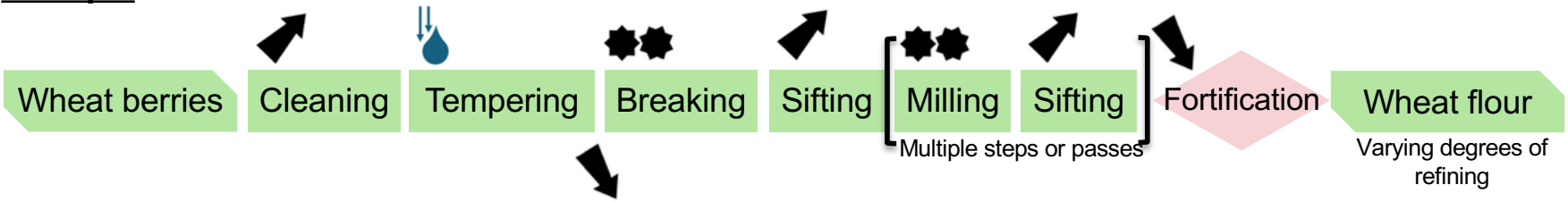
Unit operations

Thermal process | Cooling | Water removal | Water addition | Bioconversion | Separation

Cutting | Size reduction | High-shear process | Thermomechanical process | Chemical process

Cereal ingredients

Group 1: Wheat flour



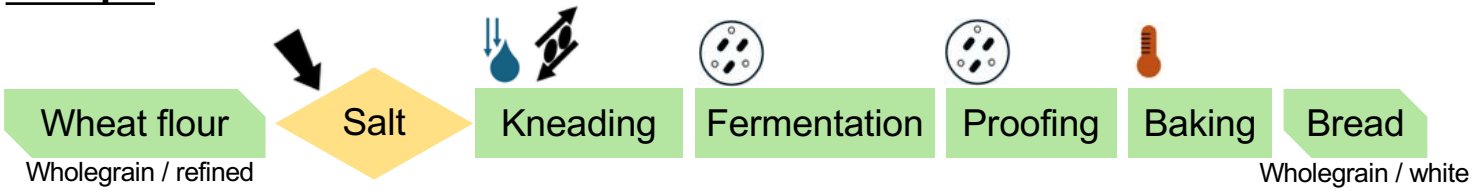
Group 1: Cornmeal

Minimally processed & processed | Processed culinary | Ultraprocessed

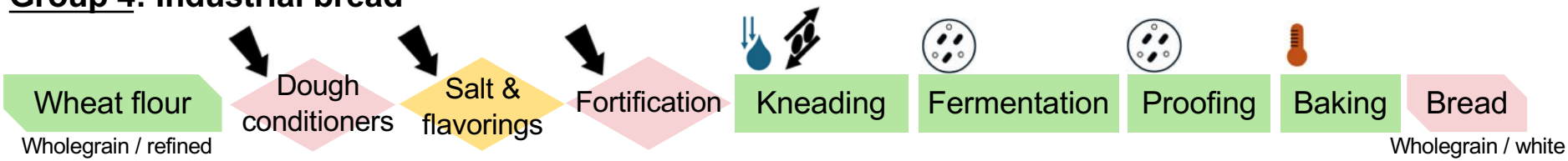
Common food ingredients often result from highly integrated, optimized processes allowing, within limits, to adjust the nutritional quality

Cereal products

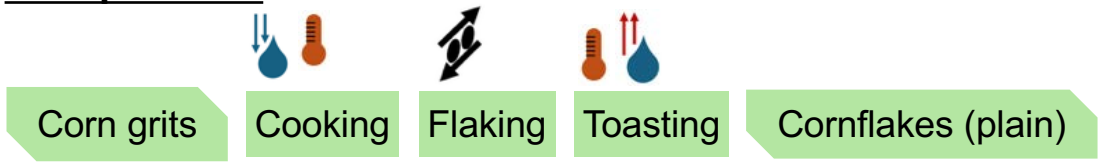
Group 3: Artisanal bread



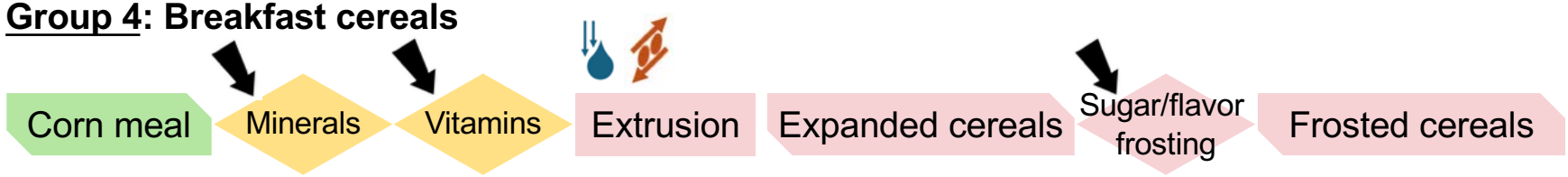
Group 4: Industrial bread



Group 1 or 3?: Cornflakes

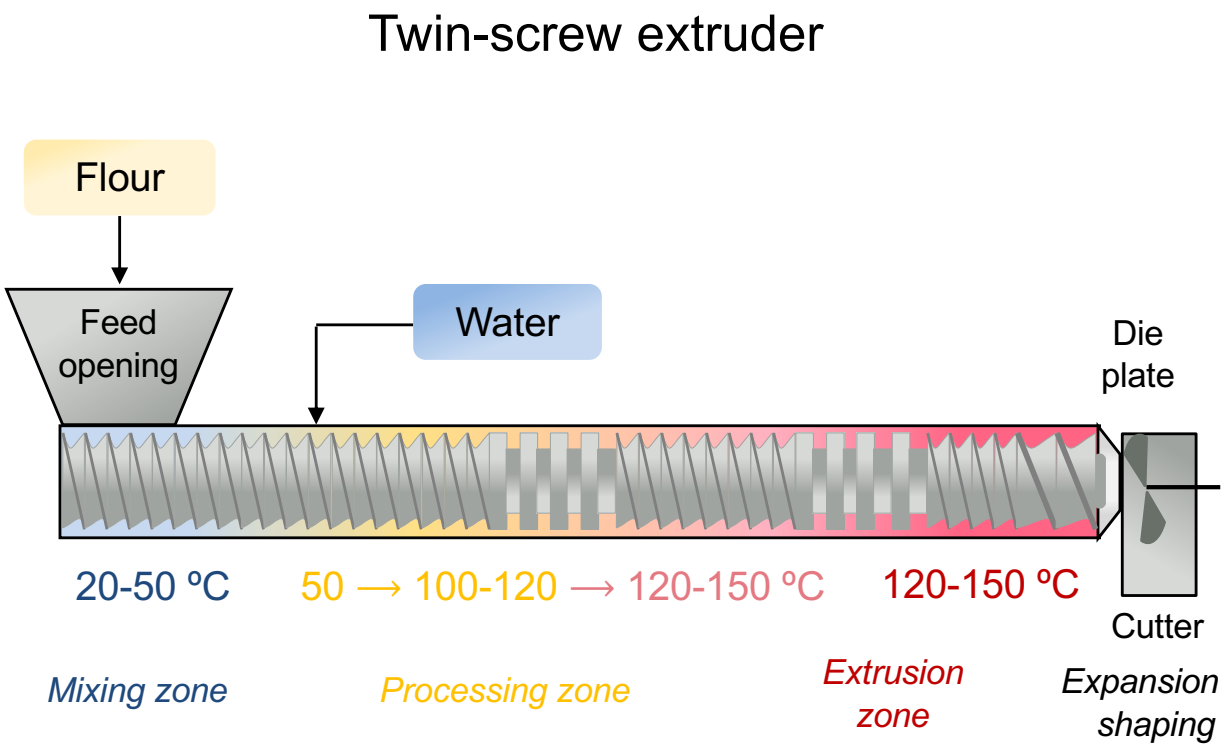


Group 4: Breakfast cereals



"Food processing" is a combination of ***processing*** and ***formulation***

Ultraprocessing: Extrusion cooking

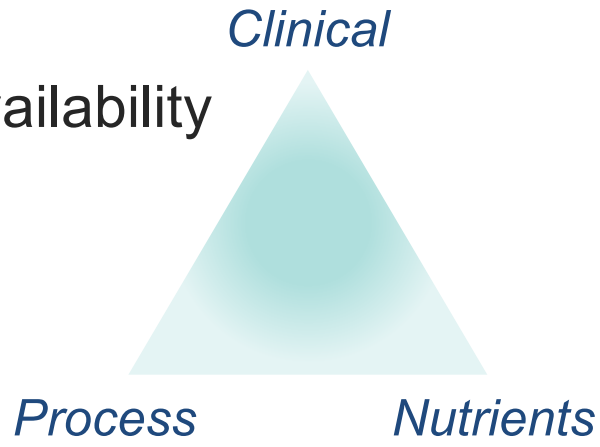


Extrusion is a *thermomechanical* process

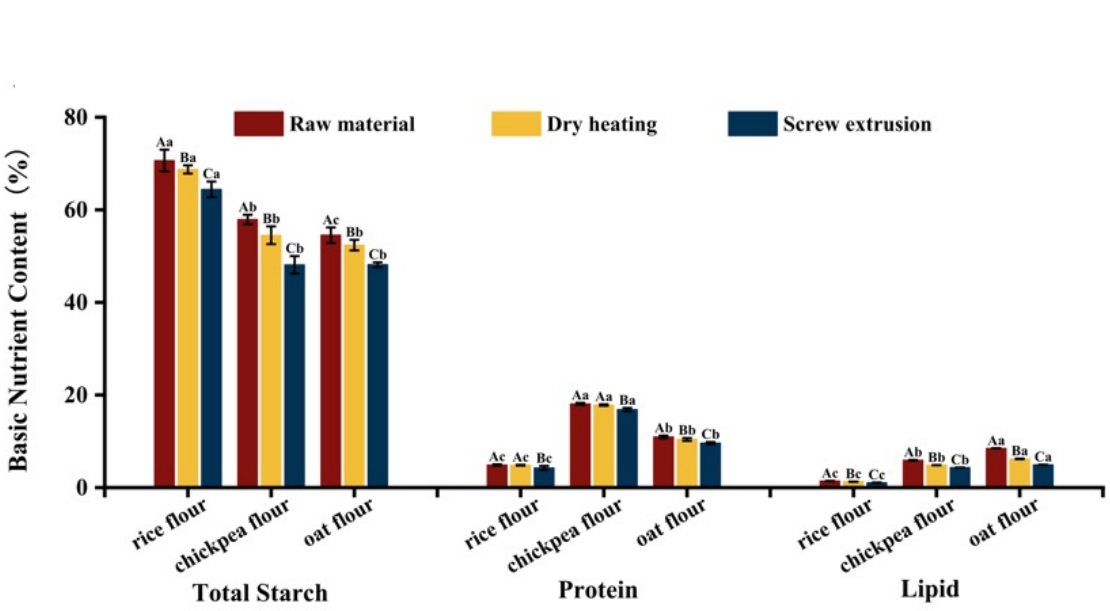
What about the effect of extrusion on nutritional quality?

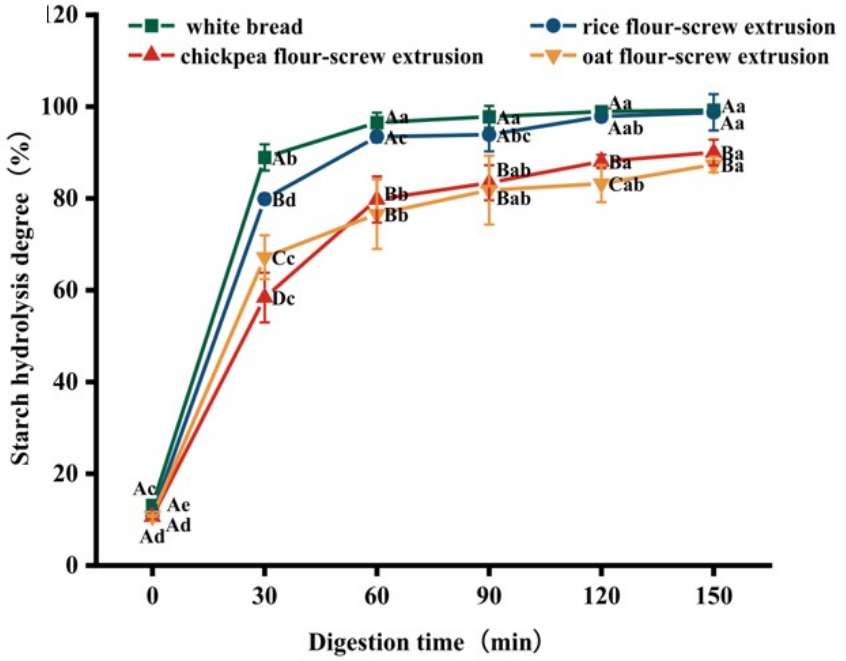
Broadly applicable parameters *quantifying* process impact

- **Nutrient-based parameters**
  - Change in nutrient content; release rates; hydrolysis rates
  - Generated toxic compounds (e.g. acrylamide)
- **Process-based parameters**
  - **Mechanical**: Shear rate; residence time; specific mechanical energy (SME)
  - **Thermal**: Temperature, residence time, specific thermal energy (STE)
  - **Structural**: Degree of conversion, product structure
- **Clinical parameters**
  - Nutrient absorption rates: glycemic index; bioavailability
  - Diversity of microbiome
  - Gut comfort; stool formation



In-vitro study: Effect of oat extrusion on starch digestion





Liu et al, *Food Biosci.* **69**, 106929 (2025)

- Some losses of macronutrients during extrusion
- Starch hydrolysis rate dependent on flour type and fiber content
- **But**: Rate of starch hydrolysis extruded oats < white bread

Observational studies: UPF consumption and morbidity

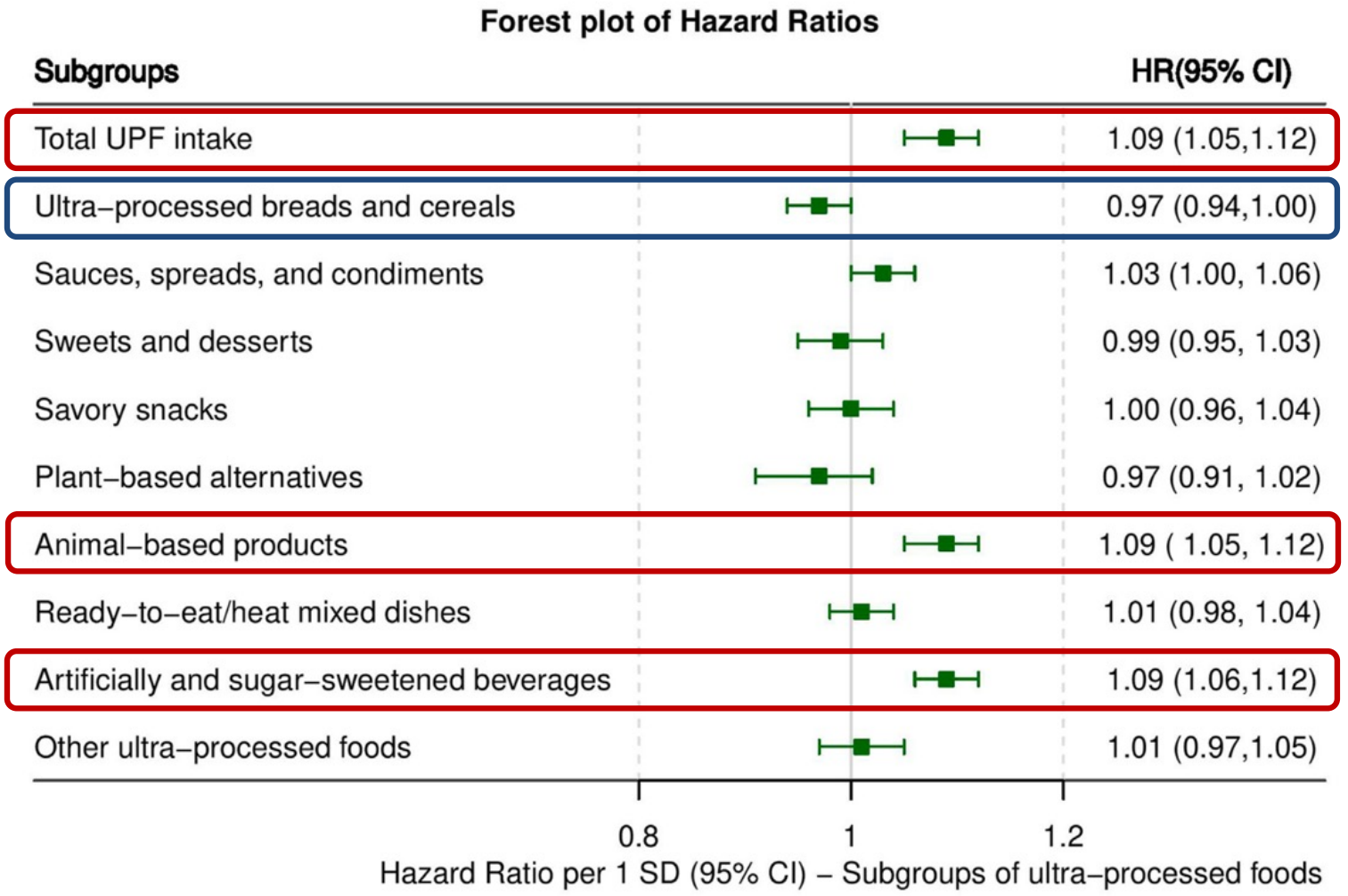


***Fig. 3*: Associations between subgroups of ultra-processed food consumption[a] and risk of cancer-cardiometabolic multimorbidity.** Cancer

R. Cordava et al., The Lancet Regional Health – Europe **35**: 100771 (2023)

Processing vs. formulation

Processing

Formulation

Degree of formulation	Degree of processing: *Minimal*	*Intermediate*	*High*
Low	• Pasteurized milk • Fresh fruits & vegetables • Frozen fruits & vegetables • Fresh & frozen meat • Fresh fish & seafood • Canned fish • Honey	• Butter • Vegetable oils • Whole grain flours • Refined flours • Fat-reduced yogurt • Coffee • Potato chips (salted) • Whole grain bread • Cheese • Pasta & noodles • Cornflakes • Salted & cured meats • Canned soups	• Fat-reduced Greek yogurt • Milk powder • Ultrafiltered milk • Ice cream • Almond milk • Cocoa drink • Pastries • Chocolate
High	• Prepackaged salads • Trail mix • Granola (unsweetened)	• Cookies • Guacamole • Hummus • Sausages • Soft drinks • Fruit yogurt (with sugar) • Granola (sweetened)	• Frosted breakfast cereals • Infant formula • Products for clinical nutrition • Candy bars • Ready-to-eat meals • Plant-based meat analogues • Frozen pizza

Green: Foods that fit with the MyPlate plan

Red: Foods that do not fulfill the following MyPlate recommendations: 1. Move to low-fat or fat-free dairy milk or yogurt (or lactose- free dairy or fortified soy versions); 2. Choose foods and beverages with less added sugars, saturated fat, and sodium

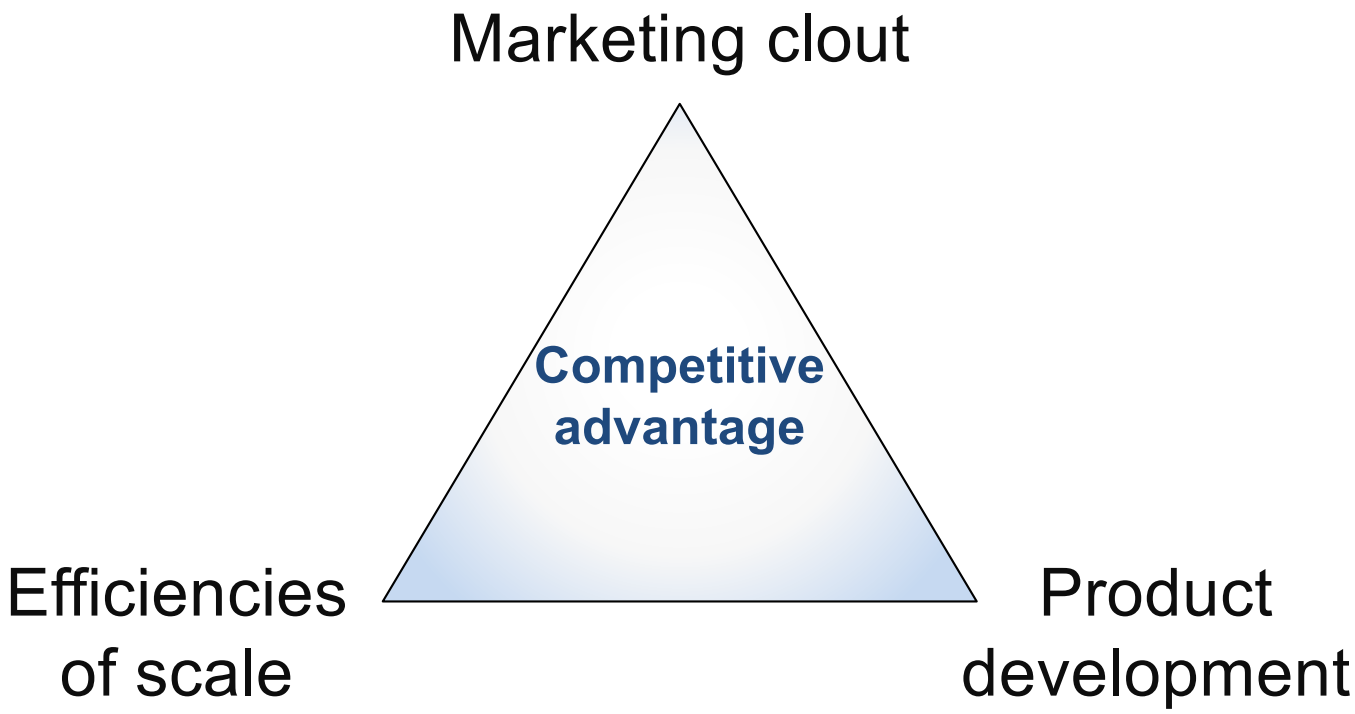
Orange: May fit the MyPlate plan depending on composition and formulation

A.S. Levine and J. Ubbink: *Obesity Science and Practice* 1-5 (2023) https://doi.org/10.1002/osp4.657

Is formulation always the issue?

Ultraprocessed foods can be formulated to meet nutritional requirements

Formulated foods result from product development



"Ultraformulated" foods are the quick wins from industrial R&D

J. Ubbink and A.S Levine: *Annu. Rev. Food Sci. Technol.* **16**, 1.1–1.24 (2025)

Creating competitive advantage in the food industry

TABLE 2. Scores for Top 10 Sources of Competitive Advantage

Factor	Mean now	Mean in 5 years
High quality product	5.2	5.0
Efficiency in production	4.9	4.2
New product development	4.4	4.8
Strong marketing & sales organization	3.4	3.4
Competitive pricing	3.3	3.0
Established relationships with retailers	2.9	2.6
High-quality raw materials	2.6	2.4
Highly motivated workforce	2.5	2.5
Strong brand image	2.4	2.4
Knowledge of customers' needs	2.2	2.5
Process innovation	1.6	2.1

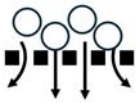
Source: Data derived from survey.

W.B. Traill & M. Meulenberg, *Agribusiness* **18**(1),1–21 (2002)

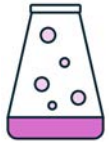
- New product development is key to business success
- Little industry incentive for process innovation apart from efficiency

Critical importance of advances in food processing

Bioconversion &
precision fermentation



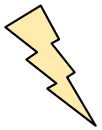
Advanced fractionation
technologies



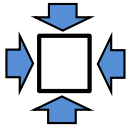
Less chemistry, it but remains
important (e.g. certain vitamins)

Advanced drying technologies,
lower water & energy usage

Optimized thermomechanical
processing



Pulsed electric field &
cold plasma processing



High-pressure processing

Current challenges:

- Improved nutrient retention
- Lower resource usage
- Reduced waste levels
- Improved functionality
- Upcycling of agricultural waste
- Food uses of novel, sustainable crops

Perspective on food process technology

- Advances in food technology are critically needed to:
  - Improve nutritional quality of foods and ingredients
  - Lower resource usage
  - Decrease waste
  - Enable food uses of new crops
- Formulation vs. processing is a useful scheme to analyze health impact of processed foods
  - Processing mostly not the reason ultraprocessed foods are unhealthy
  - Identifies critical role of formulation in developing “unhealthy” foods
  - Reformulation to eliminate “empty calories” and enhance nutrient content of formulated foods
- What could NOVA directionally get right?
  - Large class of ”developed foods” do not fit with dietary guidelines and disrupt traditional food pattern
  - Important focus on whole foods and food prepared at home aligns with dietary guidelines