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Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers

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Summary

Understanding the drivers and dynamics of global ultra-processed food (UPF) consumption is essential, given the evidence linking these foods with adverse health outcomes. In this synthesis review, we take two steps. First, we quantify per capita volumes and trends in UPF sales, and ingredients (sweeteners, fats, sodium and cosmetic additives) supplied by these foods, in countries classified by income and region. Second, we review the literature on food systems and political economy factors that likely explain the observed changes. We find evidence for a substantial expansion in the types and quantities of UPFs sold worldwide, representing a transition towards a more processed global diet but with wide variations between regions and countries. As countries grow richer, higher volumes and a wider variety of UPFs are sold. Sales are highest in Australasia, North America, Europe and Latin America but growing rapidly in Asia, the Middle East and Africa. These developments are closely linked with the industrialization of food systems, technological change and globalization, including growth in the market and political activities of transnational food corporations and inadequate policies to protect nutrition in these new contexts. The scale of dietary change underway, especially in highly populated middle-income countries, raises serious concern for global health.

KEYWORDS
food systems, nutrition transition, sugar sweetened beverages, ultra-processed foods

1 | INTRODUCTION

In this paper, our starting premise is that human diets are becoming more highly processed, with important consequences for global nutrition, public health and the environment. Although several schemas for categorizing foods according to their degree of processing have been proposed,[1] the NOVA system developed by Monteiro and colleagues has become the most widely used in research and policy.[1–3] This distinguishes between four categories of food: *unprocessed and minimally processed foods* as edible parts of whole foods, modified without adding new substances to extend shelf-life, safety or palatability, for example, milled cereals, meats, eggs, milk, vegetables, nuts and seeds; *processed culinary ingredients* as extracted substances, or substances collected from nature, for use in food preparation, for example, vegetable oils, vinegar, butter, sugar and salt; *processed foods* as combinations of culinary ingredients, unprocessed or minimally processed foods, for example, canned fish, cheese, artisanal breads and cured meats; and *ultra-processed foods* as ready-to-consume and ready-to-heat formulations, made by combining substances derived from foods with cosmetic additives, typically through a series of industrial processes, for example, soft drinks, confectionary, savoury snacks, many packaged breads and sweet biscuits.[4]

Foods in the first three NOVA categories have long been dietary staples. Basic food processing has played an important role in human nutrition and evolution ever since the use of fire began between 1.5 and 2 million years ago.[5–8] The conversion of foraged and cultivated foods into more palatable, safe, nutritious and durable forms—for example, through heating, cutting, grinding, drying, salting, fermenting and smoking—enabled hunter-gatherers and pastoral groups to thrive across many ecological zones and later in the agrarian era (beginning ~12 000 years ago) the growth of cities and entire civilizations.[5,7,8] This continues today in the production of artisanal foods and in the preparation of a wide variety of traditional and modern cuisines using combinations of culinary ingredients, unprocessed and minimally processed foods.[6,8] The mass production and global trade in non-perishable processed food commodities (e.g., sugar, tea, coffee and cocoa) accelerated during the colonial and mercantile-industrial eras (circa. 1870s onwards), alongside the invention of canning, refrigeration and steam-powered transport (e.g., frozen meat, butter and canned meats, vegetables and fruits).[8,9]

More recently (circa. 1950s onwards), ultra-processed foods (UPFs) have become a significant, and in some cases the main, source of dietary energy in high-income countries (HICs) including the United States, Canada, the United Kingdom and Australia.[3,4] Such foods have only became available on a truly global scale during the current era, characterized by the globalization of food systems (i.e., post-1970s).[1] They now play a key role in the 'nutrition transition' underway in low- and middle-income countries, involving a shift away from traditional diets towards those linked with obesity and diet-related non-communicable diseases (NCDs).[10–14] Because such countries—for example, Brazil, China, Indonesia, India and South Africa—are home to more than two-thirds of the world's population, the dietary changes that are occurring have major implications for global health.[13,14] These developments also affect nutrition equity.[15] In HICs, UPF consumption is inversely associated with socio-economic position,[16–18] whereas the reverse is observed in middle-income countries.[19,20] This indicates a 'social transition' in consumption, from higher to lower socio-economic groups, as country income increases.[21] Although the adverse health outcomes associated with some forms of basic food processing are well known (e.g., removing rice husks and resulting thiamin deficiency and beriberi in populations with staple white rice diets),[8] the adverse outcomes associated with more intensive forms of food processing, and in particular ultra-processing, have more recently come under scrutiny.[1]

Evidence for the health implications of food processing is rapidly building.[22] Population-based cross-sectional and cohort studies applying the NOVA classification system in high- and middle-income countries find that a greater contribution of UPFs to total energy intake results in poorer dietary quality,[23–28] and also higher risks of all-cause mortality,[18,29–31] obesity,[32–36] cardio-metabolic diseases,[37–41] cancer,[42] gastrointestinal disorders,[43] asthma,[44] frailty[45] and depression.[46,47] Ecological studies and systematic reviews find that regular consumption of certain types of UPFs associates with adverse outcomes, including sugar-sweetened beverages (SSBs) with obesity and type 2 diabetes,[48–53] fast food with poor diet quality and obesity[54,55] and processed meat with colorectal cancer.[56] The level of processing per se as an independent risk factor comes from a randomized controlled trial finding that an ultra-processed diet relative to an unprocessed one causes excessive calorie intake and weight gain[57] and three cohort studies showing an association between UPF consumption and weight gain, obesity, type 2 diabetes or hypertension risk, which remains significant after controlling for nutrient composition and overall diet quality.[34,37,40]

Evidence for the mechanisms linking UPFs with adverse health outcomes is emerging.[22] This includes poor nutritional profile (e.g., as vectors for added sugars, sodium and trans-fats) and displacement of unprocessed or minimally processed foods and associated fibre and beneficial nutrients in the diet,[58–61] higher glycaemic load and reduced gut-brain satiety signalling resulting from alterations in the physical properties of foods (e.g., degradation of the food matrix by processing),[62–65] contamination with carcinogens formed during high-temperature cooking (e.g., carbohydrate-rich foods with acrylamide and meats with hetero-cyclic amines),[66,67] links between certain industrial food additives (or clusters of additives) and gut microflora dysbiosis, increased intestinal permeability and inflammation[68–70] and endocrine disruption from chemical plasticizers (e.g., bisphenols and phthalates) used in food packaging.[71–74] Certain properties of UPFs may also promote overconsumption, including their convenience,[75–77] hyper-palatability and quasi-addictiveness for susceptible individuals[78,79] and the use of sophisticated and intensive marketing practices, often targeting children.[80–82] High consumption of added sugars in early childhood is associated with inter alia increased preferences for sweet food[83] and dental caries.[84] Food processing also uses significant environmental resources in the form of energy, water and packaging materials and generates much of the plastic waste stream entering marine ecosystems.[85–87]

Recent studies also demonstrate the links between the nutrition transition and food systems dynamics—changes in the inputs, actors and activities relating to the production, processing, distribution, preparation, consumption and disposal of food.[13,88] Nutrition transition studies show that alongside changes in factors generally associated with economic development and food systems change—including income, urbanization, technology and labour markets—there is a shift away from traditional diets to those higher in animal-sourced foods, vegetable oils, refined carbohydrates and caloric sweeteners.[11,89,90] Comprehensive empirical studies now also implicate increasing processed and UPF consumption as a central feature of the nutrition transition.[14,91–94] A growing number of studies further demonstrate the importance of the underlying technological and political economy drivers of food systems. These include trade and investment liberalization, the global expansion of transnational food and beverage corporations (TFBCs) and their market and political activities, alongside changes in food production, processing and marketing technologies, and the failure of policies and regulations designed to protect and promote healthy diets in these new contexts.[90,91,95,96] As markets for UPFs stagnate in HICs, food and beverage corporations, mostly headquartered in the United States and Europe, are vigorously pursuing new growth opportunities throughout the Global South.[95–97]

Despite the importance for global nutrition and public health, few systematic analyses of global trends, patterns and drivers of UPF markets exist. In this analysis, we build on earlier work[14,98–100] and draw from a wider literature and more comprehensive data set to address several key questions. First, to what extent has growth in UPF markets continued, accelerated or abated in recent decades globally, across regions and countries, and in which product categories? Second, what are the contributions of UPFs as 'vectors' for ingredients linked with obesity and diet-related NCDs, including sweeteners, oils and fats, sodium and cosmetic additives? Third, have all regions and countries undergone a similar transition to more highly processed diets, or are there *transitions* with substantial differences between them? If there are differences among otherwise similar countries, what food systems and political economy factors may explain the observed trends and variations? Although defined as a 'processed culinary ingredient' by NOVA, we also include vegetables oils in our analysis, given the importance of this category in the nutrition transition and as an ingredient and cooking medium used in UPF manufacturing.[101]

2 | METHODS

Given the complexity of the research topic and the diversity of quantitative and qualitative data sources required to address the aim, we adopted a mixed methods synthesis review method.[102,103] This combined (a) a quantitative analysis of worldwide trends and patterns in the apparent consumption of UPFs, including 'risk ingredients' linked to various categories of foods, using per capita market sales data with (b) a qualitative semi-structured review of relevant literature on the drivers of food systems change, including political economy factors, to understand the results found in (a). Although the UPF concept, as defined by NOVA, includes both food and beverage categories, from hereon, we differentiate between UPFs and ultra-processed beverages (UPB) for analytical purposes.

2.1 | Countries

Data on UPF and UPB sales volumes were available for 80 countries. For comparability, we followed Vandevijvere et al.[99] by classifying these countries by World Bank income category and Global Burden of Disease Study regions (Table S1). These included 38 HICs, 26 upper-middle-income countries (UMICs) and 16 lower-middle-income countries (LMICs), making up 47.5%, 32.5% and 20% of the total number of countries, respectively. The eight regions used were Africa, Central and East Asia, Central and Eastern Europe, Latin America and Caribbean, North Africa and Middle East, North America and Australasia, South and Southeast Asia and Western Europe.

2.2 | Data sources

Globally comparable, nationally representative longitudinal household expenditure or individual food intake survey data for UPFs and UPBs were unavailable. This at least partly reflects inadequate provision for these products in standard instruments for measuring dietary change in transitioning countries.[104] Consistent with similar analyses,[14,48,100] we instead adopted country-level sales volume data (kilograms sold through combined retail and food service channels) from the Euromonitor Passport database for the years 2006–2019, with projections to 2024.[105] Guided by the NOVA classification system, three of us (PB, PM and TM) agreed on grouping these into the UPF and UPB categories provided in Table 1. All non-UPF categories were excluded with the exception of vegetable oils, which we analysed separately as an important standalone ingredient used in cooking and UPF manufacturing. We further grouped the vegetable oils and sauces, dressings and condiments categories together, because these are typically used as ingredients in food preparation, whereas other categories are typically consumed as ready-to-eat or ready-to-heat foods.

Euromonitor collects sales data from trade associations, industry bodies, business press, company financial reports, company filings and official government statistics. People working within the food industry then validate the estimates.[105] The Euromonitor database has similar limitations to official government statistics and is not a scholarly database.[100] Sales data do not capture products sold through informal channels or wastage (i.e., the proportion of food sold but not consumed). From a nutritional standpoint, the data have not been validated, for example, by comparison to expenditure or survey data. However, it has some advantages. Unlike survey data, it is not subject to recall bias, and data are consistently reported across all countries over time using standardized measures.[100] The database also offers a disaggregated food and beverage classification, which allowed for reclassification into UPF and UPB categories.

To understand the role of UPFs and UPBs as 'vectors' for risk ingredients, we obtained volume (kg) data for the ingredients listed in Table 2 for each of the categories listed in Table 1. We included ingredient sources of added sugars, fat and sodium, as well as additives with cosmetic functions (e.g., artificial sweeteners, colorants, flavourings, emulsifiers, thickeners, bulking and gelling agents), which are a characteristic group of ingredients used in UPFs.[106] Artificial sweeteners were included in a separate category (low-calorie and non-caloric sweeteners [LCNCS]). Euromonitor calculates these ingredients's data as follows: (i) Recipes for the leading 2–5 branded products within each category and a generic recipe for the remainder of the market are sourced from patent literature, trade interviews and specialist knowledge; (ii) ingredients for the same leading 2–5 brands are sourced from nutrition information panels and for the remainder

TABLE 1 Ultra-processed food and beverage product categories used in the analysis and subcategories as defined by Euromonitor

Product categories	Subcategories
Total ultra-processed foods	Aggregation of all ultra-processed food categories
Baked goods	Dessert mixes, frozen baked goods, packaged cakes, packaged flat bread, packaged leavened bread, packaged pastries
Breakfast cereals	Ready-to-eat cereals
Confectionery & sweet spreads	Chocolate spreads, confectionery, jams and preserves, nut and seed based spreads
Dairy products & alternatives	Chilled and shelf stable desserts, chilled snacks, coffee whiteners, flavoured condensed milk, flavoured fromage frais and quark, flavoured yoghurt, margarine and spreads, processed cheese
Frozen processed potatoes	Frozen processed potatoes
Ice cream & frozen desserts	Frozen desserts, frozen yoghurt, impulse ice cream, take-home ice cream
Instant noodles	Instant noodles
Meat substitutes	Meat substitutes
Processed meat & seafood	Shelf stable meat, shelf stable seafood
Ready meals	Chilled lunch kits, chilled pizza, chilled ready meals, dinner mixes, dried ready meals, frozen pizza, frozen ready meals, shelf stable ready meals
Sauces, dressings & condiments	Sauces, dressings and condiments
Savoury snacks	Other savoury snacks, popcorn, pretzels, salty snacks, savoury biscuits soup
Sweet biscuits, snack bars & fruit snacks	Processed fruit snacks, snack bars, sweet biscuits
Vegetable oils[a]	Corn oil, olive oil, palm oil, rapeseed oil, soy oil, sunflower oil, other edible oil
Total ultra-processed beverages	Subcategories
Carbonated soft drinks	Carbonates
Concentrates	Concentrates
Dairy products & alternatives	Drinking yoghurt, flavoured milk drinks, milk alternatives
Functional & flavoured water	Flavoured bottled water, functional bottled water
Juice drinks & nectars	Coconut and other plant waters, juice drinks (up to 24% juice), nectars, reconstituted 100% juice
RTD tea, coffee & Asian speciality drinks	Asian speciality drinks, ready-to-drink coffee, ready-to-drink tea
Sports & energy drinks	Energy drinks, sports drinks

[a]Vegetable oil is classified as a culinary food ingredient in the NOVA food classification.

of the market from the generic recipe. The percentage of each ingredient in the total branded and generic recipes is then estimated; (iii) these percentages are multiplied by sales volumes to generate total ingredients volumes; (iv) the data are then validated by industry experts at ingredient companies and brand manufacturers.[105] Because assumptions are made regarding the recipes of leading and other brands, and also in relation to the sales volumes of the associated product categories, these data should be interpreted with caution. With the use of country population size estimates sourced from the World Bank's World Development Indicators database,[107] we converted the UPF and UPB category sales volumes, and the ingredients volumes supplied by these categories, to kilogram per capita. These data were not adjusted for energy intake.

Sweeteners were grouped into caloric (mono-, di- and polysaccharide sugars) and low-calorie (sugar alcohols) and non-caloric (non-nutritive) sweeteners.[108] The inclusion of added caloric sweeteners is important given the World Health Organization (WHO) recommendation to limit ‘free sugars’ intake to less than 10% of total energy intake and to less than 5% or $\sim$25 g d^{-1} for further health benefits.[109] Fruit juice was included as an important ingredient and source of added sugars in UPFs, calculated as 90 g of sugar/kg as the average sugar content per unit volume of apple and orange juice.[110] We characterized fats by their source (vegetable vs. animal) and state (solid vs. liquid at room temperature). The differentiation between solid vegetable fats and liquid vegetable oils was justified, given the higher industrial trans-fatty acid content of the former category and the association of partially hydrogenated vegetable fats with cardiovascular risk.[111] Sodium included all sources of added dietary sodium. Cosmetic additives included ingredients added to disguise undesirable sensory properties of the final product or to provide sensory properties especially attractive to sight, taste, smell and/or touch.[106]

TABLE 2 Ingredients categories used in the analysis

Category	Subcategory	Ingredients
Sweeteners	Caloric sweeteners	Monosaccharides (dextrose, glucose/corn syrup, fructose, high fructose corn syrup, honey, invert sugar, glucose/fructose syrup, fruit juice[a]), disaccharides (lactose, sucrose, brown sugar, molasses, treacle, isomaltulose, maltose syrup), polysaccharides (maltodextrin)
	Low-calorie & non-caloric sweeteners	Sugar alcohols (sorbitol, isomalt, mannitol, maltitol, maltitol syrup, lactitol, inositol, erythritol, xylitol), non-nutritive sweeteners (Acesulfame k, aspartame, saccharin, stevia, sucralose, cyclamate)
Fats	Vegetable fats (solid at room temperature)	Hydrogenated vegetable fat, hydrogenated vegetable oil, vegetable fat, cocoa butter
	Vegetable oils (liquid at room temperature)	Vegetable oils
	Animal fats	Animal fat (e.g., beef tallow, pork lard), milk fat (e.g., butter)
	Other fats	Long chain omega-3 fatty acids, short chain omega-3 fatty acids, powdered fats, stanol/sterol esters, waxes, other fats and oils
Sodium	Sodium	Monosodium glutamate, potassium chloride, sodium acetate, sodium chloride, disodium diphosphate, sodium bicarbonate, sodium metabisulphite, sodium sulphite, sodium sulphate, sodium triphosphate, sodium carbonate
Cosmetic additives	Cosmetic additives	Colours, flavours, flavour enhancers, thickeners and other structurants, emulsifiers, bulking and gelling agents

[a]Calculated as 90-g sugar/kg as the average sugar content per unit volume of apple and orange juice.

2.3 | Analysis

We first estimated per capita sales volumes of the UPF and UPB categories for each country and country income and region category for all available years. Next, we estimated per capita volumes of sweeteners, fats, sodium and cosmetic additives supplied from these categories. Artificial sweeteners and monosodium glutamate, despite being cosmetic additives, were included in the categories of LCNCS and sodium, respectively. Growth in UPF and UPB sales, and of ingredients, was estimated by calculating the compounding annual growth rate (CAGR) for the period 2009–2019, representing the mean annual growth rate over a one decade period. The analyses and graphical outputs were generated using R version 3.6.2 (Foundation for Statistical Computing).

2.3.1 | Semi-structured literature search and review

Given the broad and multifaceted nature of the topic, we used a combination of structured and branching searches to source literature on UPFs, the nutrition transition and related food systems and political economy drivers. Scholarly databases (Medline, Scopus and Google Scholar) were searched using the search string: '*processed food*' AND 'nutrition.' To identify drivers, these terms were used in combination with key words derived from food systems conceptual frameworks.[112,113] We further searched the websites of key international organizations for relevant grey literature including the WHO, Food and Agricultural Organization, Global Panel on Agriculture and Food Systems for Nutrition, Global Nutrition Report and the International Panel of Experts on Sustainable Food Systems. We did not set any date limits on these searches. We included studies in English, published in peer-reviewed journals or scholarly books and reports. Study quality was appraised by relevance to the aim of the review and whether it had clearly described aims, study design and methodology including data sources, a coherent statement of findings and justifiable conclusions. All documents were uploaded to the qualitative analysis software NVivo (QSR International) and coded using the food system frameworks as an initial guide. This allowed for the identification and development of themes. The thematic results were then synthesized and interpreted in relation to the results of the quantitative component of the analysis.

3 | RESULTS

As a first step, we described trends and patterns in per capita sales of UPFs and beverages by country, income level and region.

3.1 | Global trends and patterns in UPF and beverage sales

Figures 1 and 2 and show changes in per capita sales volumes by region for UPFs and beverages, respectively. Figures S1 and S2 and

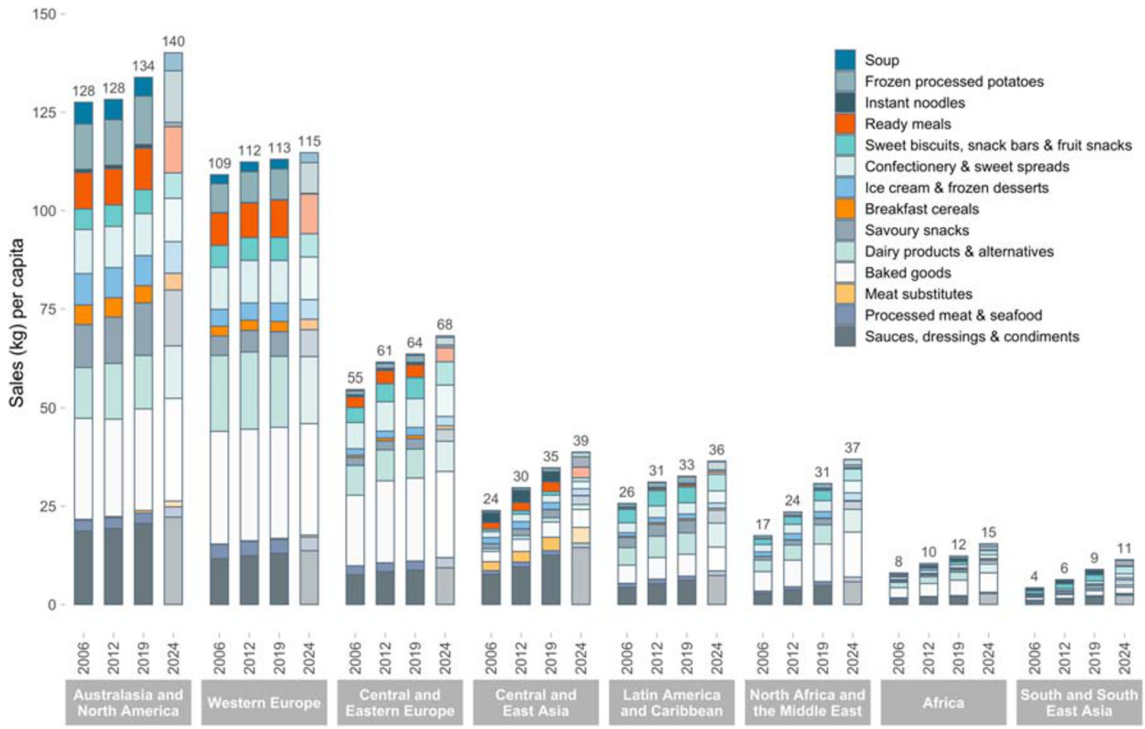

FIGURE 1 Ultra-processed foods sales (kg) per capita by region, 2006–2019 with projections to 2024

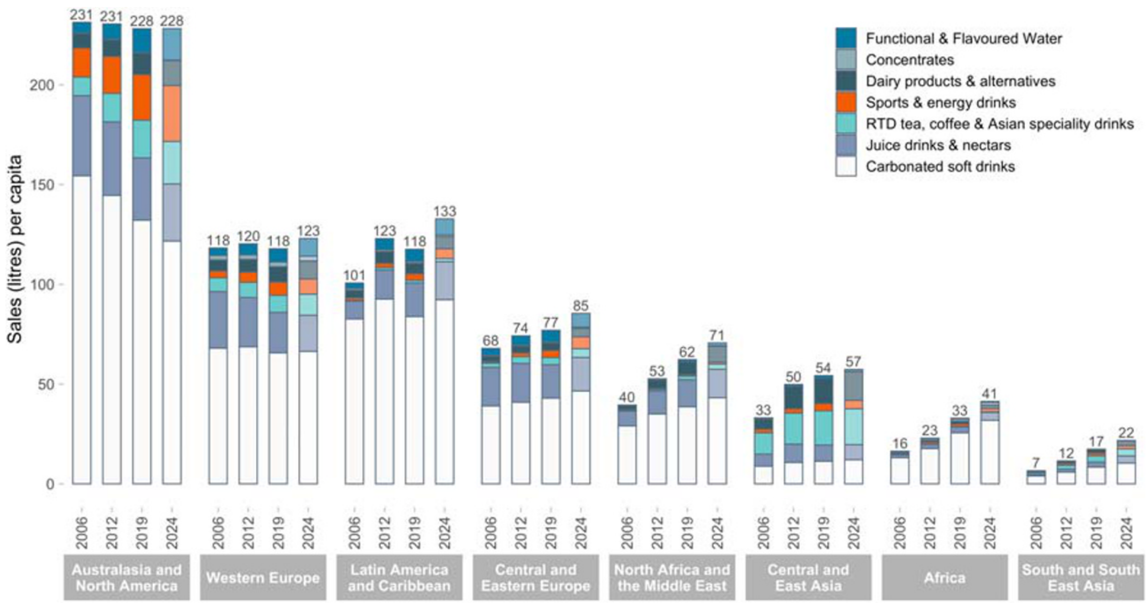

FIGURE 2 Ultra-processed beverage sales (litres) per capita by region, 2006–2019 with projections to 2024

Tables S2 and S3 provide category-specific sales data for country income categories and highly populated countries. All regions except Western Europe demonstrated strong UPF sales growth. Sales were markedly higher in Australasia and North America and Western Europe than in other regions. UPB sales growth was strong in all regions except Australasia and North America, Western Europe and Latin America and Caribbean, where it was stagnant or declining. UPB sales were also markedly higher in Australasia and North America, Western Europe and Latin America and Caribbean than in other regions.

Total per capita UPF sales in HICs were 3.4- and 11.3-fold higher than in UMICs and LMICs, reaching 109.3, 32.3 and 9.7 kg/capita, respectively, in 2019. UPB sales were 2.4- and 8.9-fold higher reaching 161.6, 68.5 and 18.1 L/capita, respectively. UPF sales were increasing across all country income groups, with CAGRs of 0.4%, 2.8% and 4.4%, respectively, in HICs, UMICs and LMICs during the

2009–2019 period. UPB sales in HICs were 2.4- and 8.9-fold higher than in UMICs and LMICs, at 161.6, 68.5 and 18.1 L/capita, respectively. In HICs, UPB sales grew at a CAGR of 0.1% compared with 2.2% and 6.6% in UMICs and LMICs, respectively. Total UPB sales growth was projected to stagnate in HICs but continues strongly in UMICs and LMICs.

Figure 3 shows combined per capita UPF and beverage sales volumes versus the CAGR for each country, differentiated by income level and population size. Figures S3 and S4 show these data for UPF and UPB separately. There is wide variation between countries at the same income level. Among HICs, the United States and Germany have remarkably high sales, whereas South Korea and Singapore have comparatively low sales. Among UMICs, Mexico stands out with high sales, largely attributable to UPBs, whereas China has comparatively low sales. South Africa stands out as an African country with high sales and growth in UPFs and even more so in UPBs. Several countries in Africa, South Asia and South-East Asia had remarkably high sales growth in both UPFs and beverages, including Cameroon, India and Vietnam, although from a low per capita baseline.

There were notable differences in the types and volumes of categories sold. A wider variety of UPFs were sold in HICs, including higher volumes of animal-sourced foods (e.g., dairy foods, processed meat and seafood), convenience foods (e.g., ready meals, snack foods and confectionary) and those requiring refrigeration (e.g., frozen desserts, processed frozen potatoes and dairy foods). In HICs, the ready meals, savoury snacks, sweet biscuits and fruits snacks, meat substitutes and instant noodles categories had the strongest sales growth, which offset near zero or declining growth in all other categories. In UMICs and LMICs, nearly all categories had moderate to strong growth, although the baked goods and sauces, dressings and condiments categories were dominant by volume.

Carbonated beverages comprised the majority of UPB sales globally, with volumes growing in most regions, except Australasia and North America, Western Europe and Latin America and Caribbean with small declines or stagnant growth. In Africa, carbonated beverages comprised the large majority of beverage sales. In several regions, declines in carbonated beverages have been offset by significant growth in other beverage categories. East and South-East Asia, for example, showed remarkable growth in ready-to-drink (RTD) coffee, tea and Asian speciality drinks; Australasia and North America and Western Europe in sports and energy drinks; and Latin America and Caribbean in juice drinks and nectars.

Although not an UPF, we also examined changes in vegetable oil sales. Figure 4 shows changes in per capita vegetable oil sales volumes by region. Figure S5 shows the same data by country income level. There were marked differences between the types and volumes sold. Sunflower oil dominated sales in North Africa and the Middle East and in Central and Eastern Europe; soy oil in Latin America and Caribbean, Australasia and North America and Central and East Asia; palm oil in South and South-East Asia; and olive oil in Western Europe. Palm oil is by far the highest volume oil type sold in LMICs. Total vegetable oil sales in UMICs and LMICs exceeded those in HICs at 10.6, 8.7 and 7.8 kg/capita, respectively, in 2019. Vegetable oil sales increased by just 0.6% CAGR in HICs but grew markedly at 4.1% and

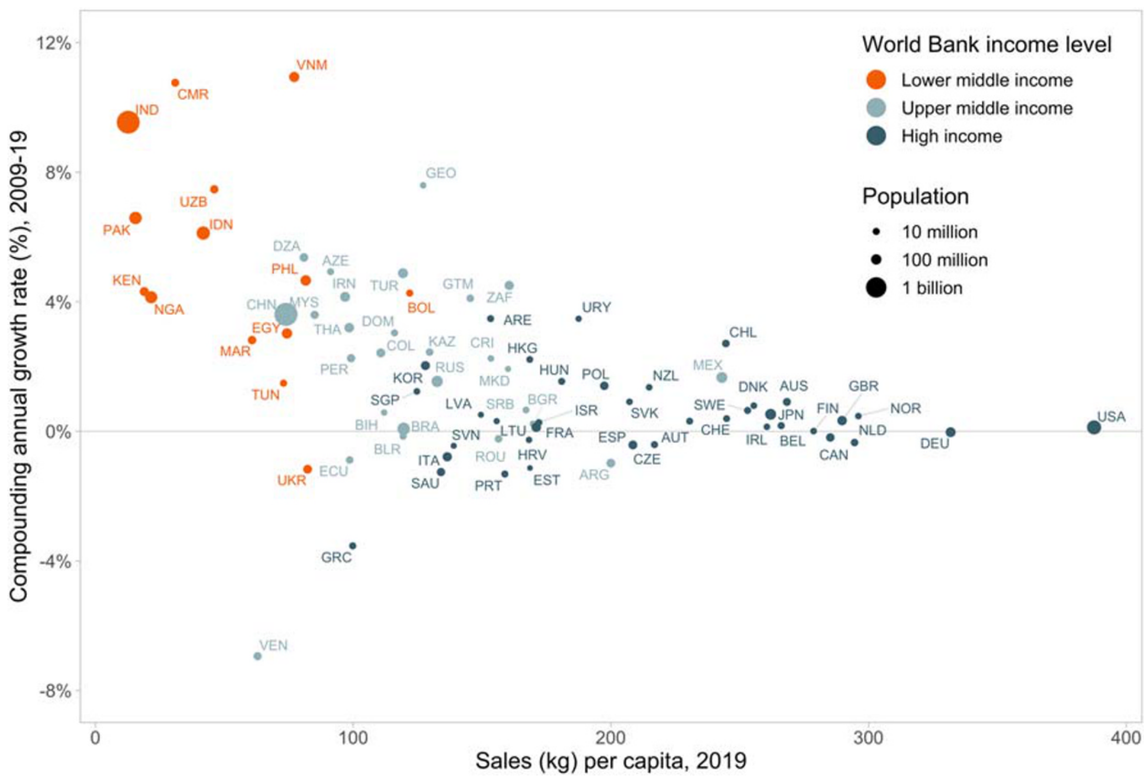

FIGURE 3 Combined ultra-processed food and beverage sales (kg) per capita in 2019 versus compounding annual growth rate (%) for the 2009–2019 period, for countries classified by income and population size

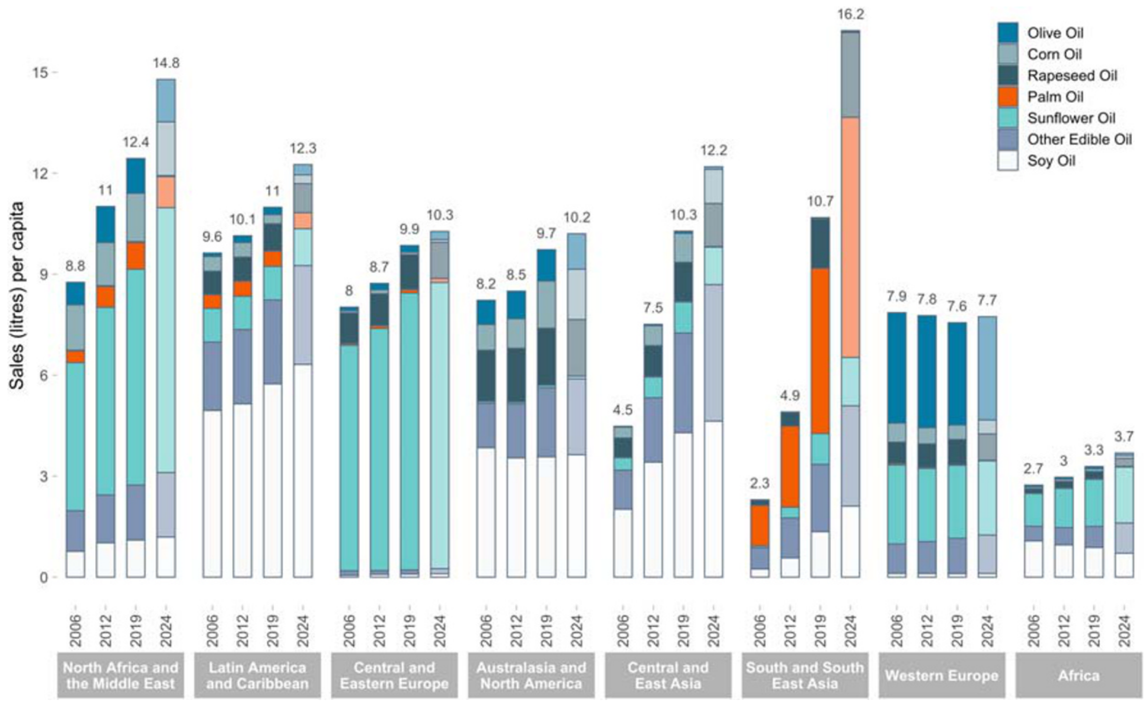

FIGURE 4 Vegetable oil sales (litres) per capita by region, 2006–2019 with projections to 2024

11.6% in UMICs and LMICs, respectively, during the 2009–2019 period. The two food categories mainly used in meal preparation—vegetable oils and sauces, dressings and condiments together comprised 46% and 57% of total sales in UMICs and LMICs, respectively, compared with 21% in HICs.

3.2 | Global trends and patterns in ingredients supplied from UPFs and beverages

In a second step, we determined volumes of 'risk ingredients' supplied from UPFs and beverages, including sweeteners, fats, sodium and cosmetic additives.

Figure 5 shows changes in per capita volumes of sweeteners, fats, sodium and cosmetic additives from UPFs and beverages by region. Figure S6 shows these same volumes by country income. Tables S4 and S5 provide further ingredients sales volume and growth rate data by country income and region, respectively. Irrespective of country income level, caloric sweeteners comprised the dominant share of ingredients from UPFs and nearly the entire share of ingredients from UPBs. Caloric sweeteners made up approximately two-thirds of all ingredients supplied from UPFs and beverages combined, with volumes of 25.8, 9.2 and 2.2 kg/capita in HICs, UMICs and LMICs, respectively, in 2019. Total caloric sweeteners declined in HICs with a CAGR of −0.3% over the 2009–2019 period but increased by 1.6% and 3.9% in UMICs and LMICs, respectively. However, the decline in HICs was mainly attributable to a −1.2% CAGR in caloric sweeteners from UPBs, while caloric sweeteners from UPFs increased by 0.4%. Caloric sweeteners from UPFs and beverages increased in all regions, with the exception of small declines from UPBs in Australasia and North America, Latin America and Caribbean and Western Europe. Total LCNCS volumes were 0.4, <0.1 and <0.1 kg/capita in HICs, UMICs and LMICs, respectively, in 2019 and had CAGRs of 0.4%, 2.3% and 4.2% for the 2009–2019 period. In HICs, UPFs were the primary source of LCNCS at 0.4 kg/capita versus <0.1 kg from UPBs, although the latter category grew much more with CAGRs of 0.2% and 4%, respectively. Volumes of LCNCs supplied in Australasian and North America and Western Europe were between 2- to 40-fold higher than in other regions.

Vegetables oils made up a large share of the ingredients supplied exclusively from UPFs, at 6.3, 1.5 and 0.5 kg/capita in HICs, UMICs and LMICs, respectively, in 2019, with CAGRs of 2.0%, 3.8% and 8.0%. Vegetable oils from UPFs increased in all regions. Solid vegetable fats, which we used as a proxy for trans-fats, were supplied almost exclusively from UPFs and were markedly higher in HICs at 2.6 kg/capita compared with 0.7 and 0.2 kg/capita in UMICs and LMICs, respectively. Vegetable fat volumes declined in all country income groups, with CAGRs of −2.3%, −0.8% and −1.3% in HICs, UMICs and LMICs, respectively. Vegetable fats declined in all regions except North Africa and the Middle East. Reductions were most prominent in Australasia and North America and Western Europe.

Sodium was supplied from salt or salted ingredients added to UPF, at 1.2, 1.1 and 0.3 kg/capita in HICs, UMICs and LMICs, respectively, in 2019 and increased with CAGRs of 0.4%, 1.7% and 1.8%. Sodium volumes increased in all regions. Australasia and North America, Central and East Asia and Western Europe had markedly higher sodium volumes of 1.3, 1.4 and 0.9 kg/capita in 2019. The supply of cosmetic additives increased everywhere, mostly from UPFs. Total cosmetic additives supplied from UPFs and UPBs combined was 3.3- and 11.5-fold higher in HICs than in UMICs and LMICs at 2.3, 0.7 and

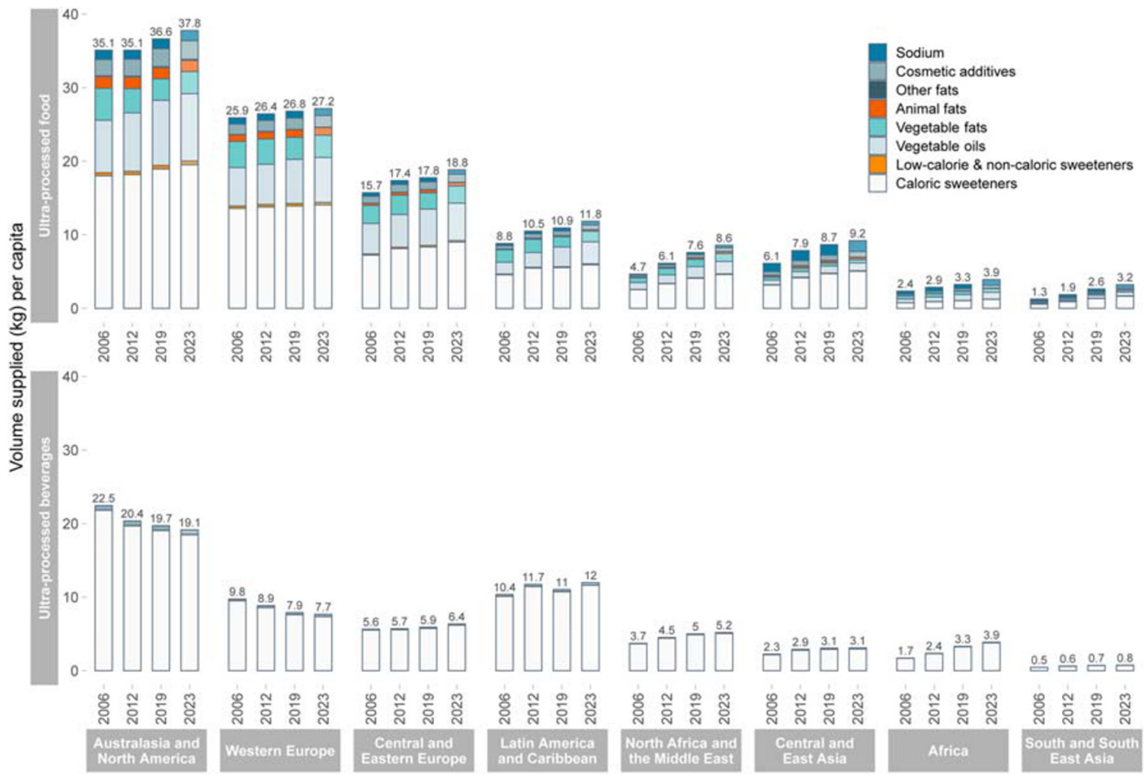

FIGURE 5 Volumes of sweeteners, fats, sodium and cosmetic additives supplied (kg) per capita from ultra-processed foods (top) and beverages (bottom) by region, 2006–2019 with projections to 2023

0.2 kg/capita, respectively. Volumes were markedly higher in Australasia and North America and Western Europe than in other regions, with volumes of 3.1 and 1.8 kg/capita, respectively, in 2019. Furthermore, cosmetic additives increased with CAGRs of 0.7%, 2.9% and 4.8% in HICs, UMICs and LMICs, exceeding growth in total UPF and beverage sales.

3.3 | Food systems transformations linked with changing UPF and beverage markets

Our results so far indicate that UPF and beverage markets are growing nearly everywhere, indicating a global convergence towards a more highly processed diet. However, there are also important divergences in the volumes and types of products sold and ingredients supplied at regional and country levels.[14,92] In the following sections, our objective is to understand how contemporary transformations in food systems might explain this convergent-divergent pattern. This considers food supply chains, food environments and consumer behaviour as core food system elements and a range of external food system drivers (social, economic, technological, institutional and political) and knowledge systems, policies and regulatory frameworks shaping those systems.[112,114] We adopt a combined food systems and political economy approach, acknowledging in particular the power of TFBCs—including producers, processors, manufacturers, fast food chains and retailers—to shape food systems in ways that alter the availability, price, nutritional quality, desirability and ultimately consumption of UPFs and beverages.[95,96,100,114,115]

From the literature, we identified strong incentives for TFBCs to expand transnationally, including market saturation in their home countries, their large market capitalizations and profits (providing finance to grow), global brand recognition, knowledge capital (intellectual property, organizational practices, manufacturing and logistical technologies) and their capacity to adapt global brands to local cultures and regulatory contexts.[96,116,117] Since the establishment of the World Trade Organization in the mid-1990s, the number and depth of trade and investment agreements have increased substantially. Many countries have also unilaterally liberalized their economics, becoming more integrated into the global economy and deregulating markets.[118,119] This has accelerated the globalization of food systems by reducing barriers to the movement of finance, technologies, production capacity, raw materials and final products across borders, enabling TFBCs to more easily enter and drive consumption in emerging markets and connect these markets to their global sourcing and production networks.[91,92,118,120] Through greater investments, more intensive marketing and the introduction of new technologies and business practices, such companies, have also spurred competition and bolstered the development of domestic (or home-grown) UPF and beverage industries.[91,96]

3.3.1 | Basic economic, demographic and socio-cultural drivers

At the most basic level, TFBCs have pursued growth opportunities in emerging markets in response to factors that drive demand for UPFs and beverages, including those generally associated with economic development. These include income growth, urbanization, changing workforce structures and demographics. Total UPF and beverage sales have increased rapidly in Central and East Asia, North Africa and the Middle East and South and South-East Asia, where per capita *income* has grown rapidly in recent decades.[14,118] As economies grow, consumer incomes rise, resulting in higher household expenditure on food alongside a decline in the proportion of total expenditure on food relative to non-food items. This tends to result in increased diversification of the diet and expenditure on more expensive products, including animal-sourced and highly processed foods,[88,94,100,121] and purchasing of non-food items that facilitate greater access and utilization of these foods, such as cars, microwave ovens and refrigerators.[11,122] Our results reflect this, showing higher volumes of a wider variety of UPFs and beverages and a greater share of animal-sourced foods at higher country incomes. This is also reflected in, for example, the higher volumes of refrigerated products (e.g., ice cream and frozen desserts) in HICs and less perishable ones in UMICs and LMICs (e.g., vegetable oils, baked goods and sauces).

Within countries, the above processes appear to play out in socially stratified and dynamic ways, whereby UPF consumption increases first among higher-income groups[19,20] and then shifts to lower socio-economic groups as countries grow richer.[16–18] This same pattern is observed with the 'social transition' in obesity prevalence.[21,123] There are, however, significant variations in UPF and beverage sales between countries at the same level of per capita income. Income appears to be more strongly associated with UPF sales in countries that are more integrated into the global economy and hence more highly penetrated by TFBCs.[97,100] Food *prices* are also a key determinant of affordability and consumption. Price per calorie of different types of ultra-processed and ready-to-eat foods vary markedly across country incomes and regions, as do prices relative to less processed foods.[124,125] In 2011, for example, vegetable oils and sugar were relatively cheap almost everywhere; soft drinks relatively inexpensive in HICs and very cheap in North America and Australasia, moderately so in UMICs and expensive in LMICs; and potato chips very inexpensive in HICs, moderately so in UMICs and LMICs and inexpensive in India, China and elsewhere in East Asia.[124]

Urbanization is also a key driver. This facilitates greater physical proximity to more diverse and cheaper foods, including UPFs and beverages, exposure to commercial marketing and ready-to-eat foods and occupations and lifestyles less conducive to home food preparation.[11,126,127] This may partly explain differences in sales and growth rates between the highly urbanized regions of Western Europe, Australasia and North America and rapidly urbanizing Asia, North Africa and the Middle-East, Latin America and Africa. However, with the increased penetration of UPF and beverage supply chains into rural areas, the importance of urbanization may be diminishing.[94,100] In 2010, Reardon et al., for example, found highly processed foods comprised between 13% and 22% of total food expenditure in rural households of four low- and middle-income Asian countries, comparable with (although still lower than) urban households with between 17.7% and 36.7%.[94]

Another key factor is the growing number of women participating in formal work and the associated shift to dual worker households, without an equitable re-distribution of household work between women and men. In the United States, this has meant an approximate halving of the time woman spend preparing food and a small increase for men.[128] This increases the *time opportunity cost* of sourcing and preparing food and consequently the demand for semi-prepared and ready-to-heat convenience foods and for food eaten outside the home.[11,88,129] This may explain the higher proportions of convenient ready meals and snack foods in the HICs of Australasia and North America and Western Europe relative to the higher proportions of categories used in meal preparation, such as vegetable oils, sauces, dressings and condiments sold in UMICs and LMICs. Such demand may also closely link with a *culinary skills transition* involving significant changes in the patterns and kind of skills required and the time spent procuring, preparing and consuming food.[130–132] This can involve the adoption of 'technological skills' required to prepare convenience foods, as in using a microwave oven, opening cereal boxes or assembling processed ingredients (e.g., making sandwiches).[130] *Population age structure* is another relevant demographic factor. The younger populations of middle-income countries may be more likely than their elders to forego traditional foods for newer ones.[12]

3.3.2 | Supply chain transformations

Growing but highly variable worldwide UPF and beverage sales are not only driven by changing demand alone. Changes in global, regional and national supply chains are also important, involving the actors and processes that take products from the production of raw ingredients through to manufacturing, marketing, retail and consumption.

This begins with market consolidation, technological change and growth in the *production*, *processing and global trade* in basic agricultural commodities and additives used as ingredients in manufacturing.[92,113,118] A small number of corporations control this sector. These include the four so-called 'ABCD' agribusinesses Archer Daniels Midland (USA), Bunge (USA), Cargill (USA) and Louis Dreyfus (France), who together controlled an estimated 70–90% of global grain trade by the mid-2000s.[113,133] Others include Dow Dupont (USA), Associated British Foods (UK), Royal DSM (Netherlands), Bunge (USA), China National Cereals, Oils and Foodstuffs (China) and Wilmar (Singapore) and a number of specialized ingredients suppliers spanning the food, pharmaceutical and nutraceutical sectors.[133,134] As shown in Figure 6, world production of the four major processed vegetable oil crops expanded 19-fold from 7.5 to 144.8 million tonnes between 1961 and 2014, mainly from government-supported expansion of palm oil production in Indonesia and Malaysia; soybean oil in China, the United States, Brazil and Argentina; and canola/rapeseed in

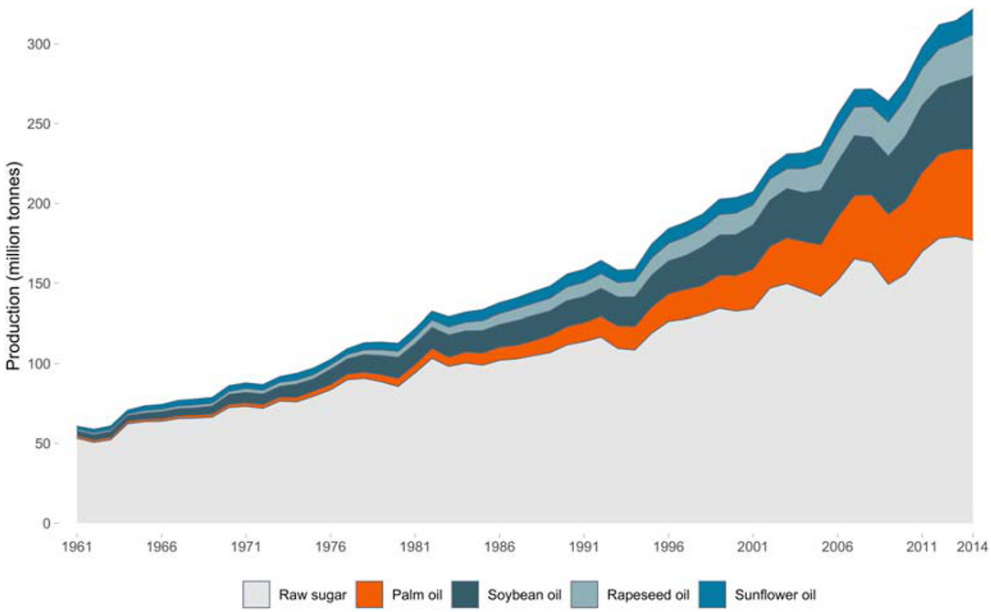

FIGURE 6 World production of raw sugar and major vegetable oil crops, 1961–2013. Data from FAOSTAT database

Canada and China.[92,118,135] Palm oil is now the world's most significant vegetable oil,[136] with food manufacturing using an estimated ~70% of production and half of all packaged and processed foods containing this oil or its derivatives.[133]

World raw sugar production expanded 3.3-fold from 53.2 to 176.9 million tonnes over the same period, mainly from sugar cane in Brazil, India and China and beet sugar in the European Union and the United States. In the United States, the production of high-fructose corn syrup (HFCS) also increased, with a subsequent 10-fold rise in consumption between 1970 and 1990 to represent >40% and ~100% of caloric sweeteners added to foods and beverages, respectively.[49] In 1994, tariff reductions mandated under the North American Free Trade Agreement then led to increasing volumes of HFCS in the food supplies of Mexico and Canada.[137,138] Relative to rice, wheat production has also increased given its use in producing noodles, baked goods and similar products, for example, in Asia and West Africa.[126,139] Increased production of oil and cereal crops has also provided cheap inputs for expanded livestock production and hence the supply of meat and other animal sourced foods used in UPF manufacturing.[140]

In the food *manufacturing sector*, companies have utilized these low-cost and readily available ingredients to develop diverse product portfolios, often using variations of the same ingredients for multiple branded products in the same market.[113] In 2019, 10 companies controlled 47.5% of the market share of the world's top-100 food manufacturers, with sales ranging from US$61.5 to US$17.6 billion.[105] These included Nestle (Switzerland), PepsiCo (USA), Coca Cola (USA), Mondelez (USA), Danone (France), Kraft Heinz (USA), Unilever (UK/Netherlands), Mars (USA), Kelloggs (USA) and Ferrero (Italy).[113] However, when considering the market in its entirety, the top 10 controlled just 14.7% of world market share in 2019,[105] indicating the importance of other large, as well as small- and medium-sized companies, in this sector.[141] Market concentration is much higher at the product category level, including beverages, snack foods and biscuits. For example, Coca Cola and PepsiCo alone controlled 19.3% and 8.3% of the world's beverage market in 2018, with 37 and 19 brands, respectively. The carbonated beverages category is even more concentrated, with these two companies controlling 45.6% and 17.5% of world market share.[105]

Many of these manufacturers have been at the vanguard of economic globalization.[96] However, they have expanded with renewed vigour from the 1980s onwards. This is evident in the rapid growth in foreign direct investment in this sector throughout the Global South, with manufacturers establishing new (often 'mega') manufacturing plants and distribution centres through 'greenfield investments.'[91,118,119] This has led to the establishment of vast manufacturing capabilities serving domestic and regional markets. For example, Nestle reported having 403 factories spanning 84 countries in 2019, with 16 in Brazil, 13 in Mexico and 31 in the Greater China Region.[142] Growth has also been achieved through the acquisition of domestic competitors. For example, in 1993, Coca Cola became the market leader in India by acquiring the domestic Parle Products company and its cola brand Thums Up and in 1999 became the market leader in Peru by acquiring the Lindley Corporation and its Inca Kola brand.[118,119] Some countries have seen the emergence of large domestic companies prior to transnational market entry, for example, IndoFoods in Indonesia and in China the state-owned China National Cereals, Oils and Foodstuffs.[96,139] Japan's market is dominated by domestic manufacturers, with foreign companies having limited market share.[96,143]

New *production and processing technologies* have increased production efficiencies, lengthened shelf-life, enabled long-distance transportability and enhanced the hedonistic properties of UPFs. This includes the development of new varieties of high-yielding oilseed crops and processing techniques (e.g., extraction, refining and hydrogenation) that have enabled the development of novel ingredients and reduced the costs of baking and frying fats, margarines and cooking oils.[144] New processing techniques of automation, extrusion and frozen dough production and additives such as new yeast varieties, enzymes and emulsifiers have enabled the mass production of breads, noodles and other baked goods.[88,145] Other manufacturing techniques and technologies have included high temperature processing, extraction, fractionation and hydrogenation.[146] New packaging technologies have enabled entirely new product categories, for example, microwaveable popcorn.[147] Manufacturers have invested heavily in their technological capabilities to enhance the organoleptic properties of their products including structure, mouth feel, taste, aroma and flavour. Fortification, functionalization and reformulation techniques have been used to alter the nutritional properties of products.[148] They have also adapted (or 'glocalized') global brands and menu offerings to meet local tastes, cultural preferences and regulatory environments.[146,149] This is enabled through the establishment of food and nutrition science research capabilities, coordinated on a global scale. Nestle, for example, has 'the world's largest private nutrition research capability' spanning a Research Centre for basic research, seven research and development centres, and nine product technology centres, with nutritional expertise in every market.[150]

Developments in the *retail sector* have also contributed in important ways to growing and diversifying UPF and beverage markets, especially the growth of modern food retail throughout the Global South. This sector is highly concentrated (and moderately to strongly oligopolistic) in many countries, often dominated by transnational grocery retailers including Walmart (USA), Aldi (Germany), Carrefour (France), Tesco (UK) and 7-Eleven (Japan) or other regional and national players.[96,113,151] Figure 7 presents data on processed food distribution channels by country income level. Distribution occurs predominately through 'modern grocery retailers' in HICs (supermarkets, hypermarkets and convenience stores), in LMICs through 'traditional grocery retailers' (mostly small, independent, owner-operated stores and wet markets) and in UMICs through a mix of modern and traditional channels. Modern grocery retailers originated in the United States and other HICs in the mid-1950s, with several companies achieving considerable market power in some countries. Supermarkets then spread into South America, East Asia (excluding China) and South Africa in the 1990s, followed by Mexico, Central America and most of South-East Asia in the mid- to late-1990s and then China, India and Vietnam in the early 2000s.[152,153] This expansion has closely followed the timing of countries' accession to the World Trade Organization and its General Agreement on Trade in Services, which liberalized foreign investment in the food retail sector.[92,122] Within countries, supermarkets tend to spread from major cities to intermediate and smaller localities, reflecting an initial targeting of wealthier middle-class consumer segments before targeting poorer urban and rural segments.[154,155]

In contrast to traditional grocery retailers, supermarkets shape UPF and beverage sales in a powerful way by facilitating market segmentation through the development of new products, or the re-development of existing ones, to target consumer groups differentiated by income, age, gender, geography and lifestyle-status or other. Supermarkets also provide a platform for facilitating market segmentation by stocking a wide variety of foods and accepting the risk of introducing new foods, as well as regularly updating their stock in response to demand. Because consumer purchasing behaviour shapes their procurement activities, supermarkets also send market signals to manufacturers about what and what not to produce.[151] This may explain the greater variety of UPFs and beverages sold in HICs relative to UMIC and LMICs, because as this analysis has demonstrated, a

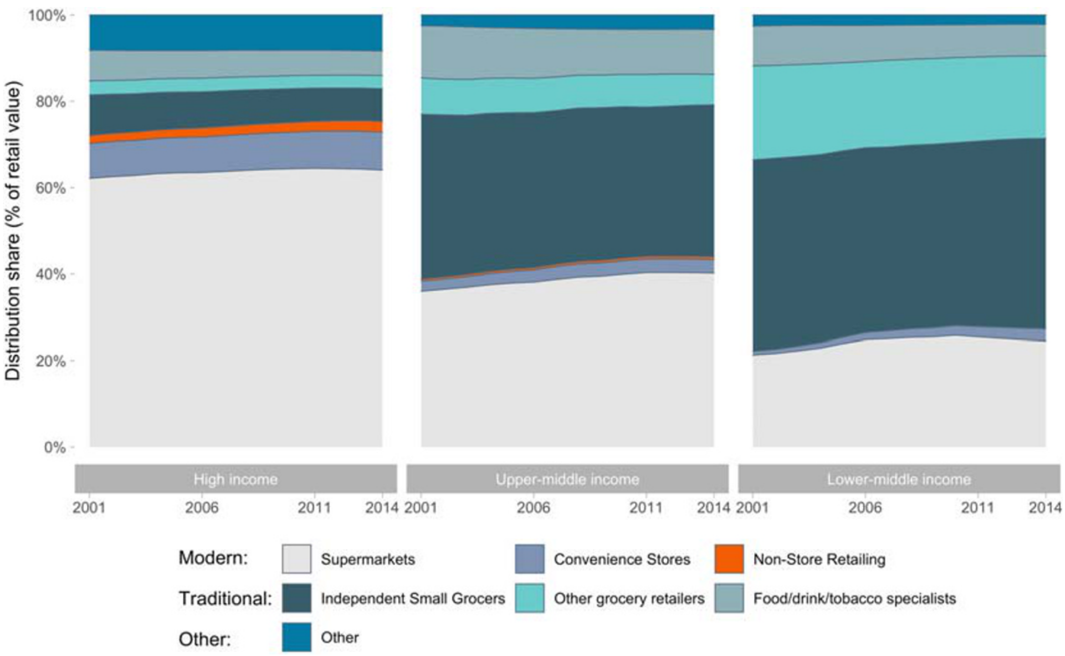

FIGURE 7 Processed food distribution (calculated as % of total retail value) by modern versus traditional retail channels by country income, 2001–2014. Data from Euromonitor International Passport database

greater proportion of such foods are distributed through supermarket channels in the former.

Supermarkets act predominantly as new distribution channels for durable processed foods in the early stages of market growth, before offering a wider variety including fresh foods (and out-competing traditional wet markets) in later stages.[12,154,156,157] As a result, supermarket distribution shares in categories such as grains, noodles and dairy products have increased more rapidly than in fresh food categories.[158] This reflects not only the greater economies of scale in sourcing processed foods[91,156] but also because 'cultures of consumption' change over time, from the daily purchasing of fresh foods in traditional markets to less frequent purchasing from modern retailers and refrigerator storage.[159,160] Supermarkets often use price discounting, prominent displays at the end of aisles and place snack food lines close to cash registers to stimulate impulsive purchasing.[161,162] By leveraging their market power to negotiate large-scale acquisition contracts, supermarket chains can drive down sourcing costs to supply customers with prices well below those charged by traditional retailers.[162,163] For example, a Brazilian study found that the share of UPFs as a proportion of total food purchased was 25% higher at supermarkets, and supermarket prices were 37% lower for these products, compared with other food retail stores.[161]

In the absence of modern retail formats in emerging markets, UPF and beverage manufacturers have also developed novel strategies to target poorer and rural consumers. In China and India, for example, companies have offered smaller package sizes and affordable pricing points more appealing to low-income and rural consumers.[164,165] Others have developed 'last mile' strategies to reach the 'base' of the consumer pyramid. In Mexico, for example, Coca Cola developed an extensive distribution network of *tiendas* (small stores), providing free incentives such as refrigerators and point-of-sale advertising materials in return for exclusivity agreements.[92] In Brazil, Nestle has used 'floating supermarkets' to sell more than 300 products to small towns throughout the Amazon basin and through its door-to-door salesforce reaches more than 250 000 households with more than 800 products every fortnight, in the country's favelas.[95,166]

In LMICs and UMICs, the consumer food service sector tends to be dominated by thousands of small, independent restaurants or street food operators, often selling local dishes at very low prices and operating entirely in the informal sector.[96,126] However, growth in transnational fast food chains has been rapid, presenting more outlets for UPF and beverage distribution.[88,126] Five 'fast food' corporations have led this transnational expansion: Seven & I Holdings (Japan/South Korea; 7-Eleven), Yum! Brands (USA; KFC, Pizza Hut, Taco Bell), McDonalds (USA), Doctor's Associates (USA; Subway) and Starbucks (USA). In China alone, the number of fast food chain outlets expanded 6.4-fold from 25 984 in 2004 to 167 560 in 2018, beginning in major cities before spreading to smaller cities and towns. Yum! Brands has been at the forefront of this expansion, given the preference of Chinese consumers for chicken over beef.[96] Franchising has been a key growth strategy, allowing firms to acquire local knowledge about consumer preferences and business practices and to 'glocalize' their menu offerings. For example, McDonalds offered vegetarian options in India, rice porridge with chicken and pork in Thailand and rice-based wraps, bowls and 'bubble tea' in China.[96] Local restaurants and street food vendors often develop similar products, mimicking the fast food brands.[126] The rapid uptake of online food delivery platforms such as Uber Eats in many countries has provided a new distribution channel, reducing the time cost of sourcing fast food for consumption at work or home.[167,168]

Growing but highly variable UPF and beverage markets also reflect more intensive food *marketing*, enabled by the globalization of marketing agencies and new media technologies.[92] Food companies and the marketing agencies that work for them have used increasingly sophisticated techniques to reach consumers segmented by age, income, location, lifestyle and cultural preference. Extensive mass media advertising targeting children and adolescents via television, film and media franchising has been reported in many countries.[149] The globalization of digital technologies including social media, mobile phones, gaming platforms and others has enabled new ways to reach younger audiences, including gamification, peer-to-peer and user-generated messaging, cross-device tracking, in-store surveillance and prompting and demographic- and location-based targeting.[88,169,170] These technologies are harnessed in powerful ways by using 'Big Data' processing and analytics platforms to collate, analyse and use data, including the profiling and predictive targeting of individual consumers.[169] Sophisticated packaged-based marketing techniques are also used to promote purchasing. This includes making health and nutritional claims to imbue products with 'health halos' and packaging designs (e.g., shapes, cues and sizes) that skew perceptions of quantity and increase preferences for supersized portions and packages.[171] Some have suggested that the net effect of these changes is the increased desirability of ultra-processed relative to unprocessed and minimally processed foods,[91,92] the decline of traditional food cultures (e.g., commensal eating) and a shift towards those more conducive to UPF and beverage consumption (e.g., snacking).[95,172,173]

3.3.3 | Policy, regulatory and political economy drivers

Finally, growing but variable worldwide UPF and beverage markets also reflect differences in the strength of policy and regulatory frameworks targeting unhealthy diets and the power of different actors and interests to enable or hinder policy action.

As our findings so far demonstrate, the drivers of UPF and beverage markets are multifactorial and dynamic, reflecting transformational changes in food systems underway. Therefore, an ecological approach to policy intervention, targeting multiple components of food systems simultaneously, is needed to drawdown consumption and minimize harm.[112,114,174] Various frameworks exist for guiding such action,[112,174,175] requiring a strong role for government legislation and regulation.[176,177] These include actions targeting food supplies (e.g., removing sugar subsidies, reformulation and public procurement standards), food environments (e.g., restrictions on advertising and promotion, taxes and import tariffs, food and menu labelling and school food standards) and communications to encourage behaviour change (e.g., food-based dietary guidelines, mass-media campaigns, nutrition education in school curricula and counselling in health care settings).[174,176] It also requires cross-cutting actions. These include bottom-up civil society mobilization, top-down political commitment, protections against conflicts of interest in policy development and well-resourced monitoring, accountability and enforcement mechanisms.[178–180]

However, worldwide policy responses are currently inadequate in both scope and strength.[181–183] According to the latest WHO monitoring reports, the large majority of reporting governments have implemented education and counselling (75%) and media campaigns (61%) targeting lifestyle-behavioural change. Far fewer have implemented more upstream actions targeting food supplies and food environments including, among others, taxes on SSBs (38%) and unhealthy foods (6%), front-of-pack labelling schemes (25%; with just over half being mandatory), elimination of industrially produced trans-fats (37%), portion-size controls (16%) and school food standards (43%).[184,185] The majority of these actions have been taken in HICs in Europe,[183] although UMICs with high obesity and diet-related NCD burdens in Latin America and the Pacific Islands are world leaders.[88,186,187] Weak worldwide policy responses and the skew towards lifestyle-behavioural interventions at least partly reflect the nature of food regulatory paradigms in many countries. For example, 'cutting red-tape' agendas have emerged in many HICs, with potential to impede new UPF regulations.[188] Drawing from behavioural economics, 'nudge' approaches to policy intervention, involving minor modifications to consumer environments, have also come into vogue. This approach shows mixed results, small at best, for modifying consumer choices.[189,190] It focuses on the 'immediate choice architecture' of consumers but fails to address many of the structural and commercial determinants of consumption we describe.[191]

Policy actions in many countries are informed by reductionist approaches, including nutrient-profiling models, to assess the healthiness of foods.[192,193] Such models have an important role to play. However, in focussing on the amount of certain nutrients in foods, this approach does not address other harms associated with food processing or how foods fit within an overall healthy diet. It has led to an over-reliance on 'nutrients-to-limit' reformulation initiatives in some countries,[194,195] with potentially counter-productive outcomes. This includes the replacement of certain highly processed ingredients with other such ingredients, for example, unhealthy fats with added sugars, or with additives, for example, added sugars with artificial sweeteners, rather than whole or minimally processed foods. Nutrient-centric approaches can also stimulate the production and promotion of UPFs. For example, between 2014 and 2019, the Australian nutrient-based Health Star Rating (HSR) system approved between 73% and 77% of UPFs using the system to display a 'pass mark' of 2.5 stars or more (out of a possible 5) on labels.[196,197] Food-based dietary guidelines (FBDGs) adopted in most countries are a foundation for nutrition policy and guidance.[193,198] Yet, a large majority of FBDGs adopt a nutrient-centric approach, recommending to limit foods high in certain risk nutrients or 'energy-dense and nutrient-poor' foods. The term 'discretionary foods' is also used, a framing that implies consumer rather than producer responsibility.[85] Only Brazil, Peru, Uruguay, Ecuador and Canada have dietary guidelines that differentiate foods by the degree of processing, recommending to favour unprocessed and minimally processed foods, limit processed foods and avoid UPFs altogether.[4,85,195]

Weak worldwide responses also reflect the power of the food industry to undermine political commitment for action.[199,200] The food industry, including predominantly transnational food corporations and the peak industry groups that represent them, has strongly resisted policy responses using standard 'playbook' tactics.[97,199] These have included *inter alia* lobbying policymakers, making political donations, framing policy debates, adopting self-regulation to pre-empt and delay government action (policy substitution), public relations campaigns portraying business as 'part of the solution', and partnerships with community and sporting associations.[148,199,201,202] This has occurred at multiple levels, often focusing in battleground jurisdictions, as shown in the intensive lobbying, media campaigns and establishment of front groups to resist the adoption of SSB taxes in U.S. counties and throughout Latin America.[203–205] At the international level, the Codex Alimentarius Commission, the UN food standard-setting body, has faced intensive lobbying as it often functions as the de facto benchmark for food regulatory agencies in low- and middle-income countries, as well as the reference standard used in WTO trade disputes.[206] Companies and industry groups have skewed the production of knowledge and evidence informing policy and regulatory debates. This includes financing academic research, sponsoring scientific organizations to produce favourable messaging (e.g., International Life Sciences Institute) and producing in-house research that minimizes the harms and supports the health benefits of their products.[207,208]

More broadly, food industry power has been enhanced in the context of growing preferences for hybrid governance arrangements, including public–private partnerships (PPPs), that expand corporate influence in policy decision-making.[97,115,148] At both national and international levels, this includes a variety of PPP types involving various combinations of government, industry and civil society actors and activities spanning food reformulation and fortification, consumer education, labelling, direct food provision and research.[209,210] By procuring in-house nutritional expertise, food companies have expanded their capacity to engage in these activities and thereby influence food policy and regulation-setting processes.[148] As a result, PPPs involving food manufacturers have focused more on nutrient-based responses, such as reformulation. This depoliticizes food environments by deflecting attention away from the structural determinants of unhealthy diets, including the wide availability and intensive marketing of UPFs.[148] Trade liberalization further enhances food industry power by restricting the 'policy space' of governments through limiting the scope of regulatory actions allowed under trade rules and by imposing 'regulatory chill' or a reluctance to adopt regulations through the fear of a trade dispute.[118,211] This chilling effect is enhanced when HIC governments representing the interests of TFBCs (mainly the United States and European Union) have used WTO trade dispute mechanisms to challenge food regulations adopted by other countries.[118,212] Furthermore, as suppliers of jobs and tax revenue, the food industry has gained 'productivist power' through its importance in national economies, and greater international capital mobility as trade liberalization enables TFBCs to punish or reward governments for their policy decisions, by shifting or threatening to re-locate jobs and investments.[14,92,199]

Market concentration is another key mechanism enabling the food industry's power across all sectors, whereby increasing market share, and hence market power, is held by a declining number of firms.[91,154,213] This increases the buying and selling power of corporations, allowing them to dictate terms of trade, set prices, control consumer product offerings and cut costs.[91,117,214] Market power reinforces political power as accumulating financial resources and economic importance in national economies can be used for greater political influence.[113,115] Mergers and acquisitions have become the main mechanism by which this concentration occurs and through which corporations grow.[91,154] The home markets of the United States and European food and beverage corporations are now highly concentrated, especially in the processing and retail sectors.[143,151,214,215] Markets are also concentrating regionally as in the Asia-Pacific and Latin America, as well as globally.[96,143,214] In the manufacturing sector, concentration is the highest in ultra-processed segments such as soft drinks, biscuits and snack foods.[216,217]

Through establishing transnational networks of affiliated firms and contractual suppliers, this market power can be coordinated across global value chains (GVCs) incorporating multiple supply chain components including research and development, production, processing, manufacturing and distribution.[96,113] This enables the sourcing of raw ingredients, labour and other production inputs from wherever costs are lowest and regulatory environments most favourable, distancing consumers and regulators from the harms associated with production (e.g., deforestation associated with palm oil production).[116,218] Financialization of the global economy, involving the emergence of a liberal financial regime characterized by rapid growth in marketized securities and monetary exchange freedoms has facilitated GVC integration. This enables food and beverage corporations to use financial derivatives to offset risks associated with sourcing large volumes of agricultural commodities from volatile global markets.[116] Processes of transnationalization and market concentration are also closely linked with the financialization of food systems. A small number of private equity firms—mainly Blackrock, Vanguard, State Street, Capital Group and Fidelity—have funnelled vast amounts of equity into publicly listed food and beverage corporations, providing them with access to finance for accelerated global expansion.[219]

4 | DISCUSSION

Our findings have important implications for global public health and policy responses targeting unhealthy diets, obesity and diet-related NCDs.

First, UPF and beverage sales are growing in all regions and in the large majority of countries but most rapidly in UMICs and LMICs, although with wide variations in the volumes and types of products sold. Given the well-established evidence linking UPFs with adverse health outcomes, and because growth is most apparent in highly populated regions and countries, the consequences for global health are likely to be substantial. We also find important changes in the nature of the transition to diets higher in UPFs and beverages. A wider variety of products are sold in richer countries. Cosmetic additives are supplied from UPFs in markedly higher volumes in HICs, but are increasing almost everywhere, and have approximately doubled in UMICs and LMICs. The vegetable oils and sauces, dressings and condiments categories used in food preparation make up a greater share of total food sales in UMICs and LMICs relative to HICs. Together, these results indicate a shift in the global diet towards higher consumption of UPFs and beverages, and that populations purchase a wider variety of products, and more higher-value and convenience products, as countries grow richer. Although UPFs appear to contribute more to the 'sweetening' of the global diet, vegetable oil as a stand-alone product and as an ingredient used in UPFs has grown rapidly, especially in the UMICs and LMICs of Central and East Asia and South and South-East Asia. This is consistent with previous studies showing vegetable oils have contributed more than any other food category to the expanding world calorie supply—the 'fattening' of the global diet.[92] The rise of palm oil as a cooking oil in many transitioning countries, and as an ingredient or medium used in UPF manufacturing, raises concern, given the high levels of 'probable carcinogens' (certain fatty acid esters and glycidol), generated during the palm oil refining process.[220]

Second, important changes are underway in the beverage sector. Declines in carbonated beverages in HICs and certain regions have been offset by growth in sports, energy, RTD teas and juice drinks. This diversification may represent several dynamics underway in beverage markets. This includes rising health consciousness among consumers, substitution effects resulting from policy actions targeting SSBs,[182] and more intensive marketing of these categories as beverage companies diversify product portfolios to offset declines in revenue from carbonated beverages. Our results show that beverages contribute nearly as much caloric sweeteners as UPFs across all income levels, suggesting the continuing importance of policy actions to reduce SSB consumption. This may be particularly important in HICs and UMICs where SSBs are a relatively inexpensive source of calories.[124] The growth in energy drinks in particular presents an important challenge for food regulators, given the intensive marketing of these products to youth and the harms associated with excessive consumption.[221]

Third, our findings on ingredients raise several policy challenges. Caloric sweeteners from beverages are declining in HICs, suggesting that policy actions including SSB taxation, labelling and reformulation are having some effect.[182] However, caloric sweetener volumes from UPFs have increased or barely changed in HICs, indicating a need to broaden these policy actions beyond SSBs. Furthermore, volumes of caloric sweeteners from UPFs and beverages are growing rapidly in UMICs and LMICs. Policy actions to reduce added sugars from UPFs and beverages therefore remain crucial, given the well-established adverse health outcomes associated with high sugar intake.[109,222] Significant growth in cosmetic additives, and non-caloric and low-calorie sweeteners, raises further questions for public health, given the emerging evidence on the health effects of these ingredients. Hydrogenated vegetable fat, which was our proxy for industrial trans-fat in this analysis, is steadily declining across all country income levels. This possibly reflects successful policy actions to eliminate these fats from the food supply in many countries. Sodium levels are increasing nearly everywhere and are markedly higher in North America, East and South-East Asia and Western Europe. The world's highest sodium levels, reported in Central and East Asia, may reflect the use of sodium-rich sauces, dressings and condiments used in food preparation, given home-cooked foods are the main dietary source of sodium in China.[223]

Fourth, we have shown how changing global markets for UPF and beverages reflect transformations underway in all food systems sectors, including those linked with the expansion and growing market and political power of TFBCs. Variations in sales across countries are likely to reflect differences in these food systems factors and dynamics and support the importance of adopting a combined food systems and political economy approach to understanding global dietary change.[114,115] A recent review on the political economy of nutrition reported industry interference as the most important barrier to achieving strong regulatory actions on unhealthy diets, obesity and diet-related NCDs in HICs and UMICs.[199] This emphasizes the importance of further understanding, monitoring and acting on the commercial determinants of health.[97] A growing literature on this topic is emerging, including monitoring food industry corporate political activity in multiple countries.[224,225] Scholars are also paying increasing attention to the political economy of food systems, placing actors and their relations of power at the centre of analysis.[115,226] This includes emerging research on the financialization of food systems and the way new investment patterns by private equity firms and food corporations are transforming market and political relations in their favour.[116,219]

Finally, reducing UPF and beverage consumption and associated harms involves implementing synergistic policy actions targeting multiple food system sectors simultaneously. Several factors have enabled policy progress in some jurisdictions, especially the accelerated adoption of SSB taxes. These include the mobilization of broad-based civil society coalitions, the strategic development and use of evidence and concerted advocacy during key policy windows, for example, during fiscal reform.[178,187,204] Expanding financial support for mobilizing civil society coalitions and 'social lobbying,' as provided by Bloomberg Philanthropies in Mexico,[204] presents an important opportunity for accelerating worldwide policy change. Some of the key challenges to sustaining policy actions in the long-term include maintaining political commitment, countering ongoing industry resistance and ensuring adequate capacity to design, implement and monitor policy actions.[199,201,227] This highlights the importance of continuing technical guidance and country-level support provided by WHO, FAO, UNICEF, the World Bank and others. Classifying foods and beverages by degree of processing (as in the NOVA classification) in dietary guidelines, and not just nutrient content alone, can help policymakers and the public to better identify foods associated with adverse health outcomes.[228] Such 'food-based profiling' is now guiding policy action. For example, the Brazilian Government recently included limits on UPFs in new school food programme legislation.[229] Developing guidance on food-based profiling, in combination with existing nutrient profiling work, may present an important new technical activity for WHO in particular. There are also potential strategies to develop less-processed packaged foods (whole-food reformulation) and to promote the consumption of home- and hand-prepared foods.[195]

There are several limitations of our analysis. We have not reported actual consumption and have instead used retail sales data. Our reliance on using Euromonitor sales and ingredients data reflects the absence of these food types in nationally comparable standardized dietary survey instruments, presenting an important data gap for the global nutrition community. We have not considered trends or patterns in the social stratification of UPF and UPB sales within countries. Although urban consumers tend to be more affluent than rural, some studies reveal the urban poor purchase higher levels of UPFs.[127] We have also reported only formal UPF and UPB sales. This may therefore under-represent true volumes as it does not capture sales via informal channels, which are more important in lower-income countries. We have not included commercial breast milk substitutes or commercial complementary foods, which are often the first types of UPFs consumed by children, although we have reported on these elsewhere.[98] We have considered the health impacts of UPFs but have largely ignored the environmental implications. Our understanding of the links between the degree of food processing and environmental degradation (or benefit) is emerging and presents an important topic of investigation as evident in recent studies focused on greenhouse gas emissions.[230,231] Although the large variety of UPF products on supermarkets shelves may be manufactured from a small number of primary agricultural commodities, the links between these products and agricultural biodiversity have barely been explored.

5 | CONCLUSION

The findings of this review supports our initial premise that there has been a substantial expansion in the types and quantities of UPFs and beverages available in the world's food supply, occurring first in HICs and increasingly in middle-income ones. This provides evidence that a transition towards a more highly processed global diet is not only underway but also continues apace. As countries grow richer, their populations appear to purchase a wider variety of higher value and convenience ultra-processed products, with the share of foods used mainly in food preparation declining. There are, however, wide variations at regional and country levels, suggesting that although there may be a singular global transition to a more highly processed diet, *transitions* are also playing out across regions and countries at different stages of economic and social development. This at least partly reflects differences in the underlying drivers, core elements and dynamics of food systems that influence purchasing behaviours and dietary change. Causes for concern include the failure to reduce caloric sweeteners from UPFs in HICs, the rising supply of caloric sweeteners from both UPFs and beverages in UMICs and LMICs and the rising supply of cosmetic additives and LCNCS nearly everywhere.

We have also shown that these transitions are closely linked with the industrialization of food systems, technological change and globalization, including growth in the commercial and political practices of TFBC, and the power these corporations have to shape food systems on a global scale. Growing UPF and beverage markets are closely linked with the mass production of primary agricultural commodities and the conversion of these commodities into a diverse range of cheap ingredients available for use in manufacturing. In the current era of trade and investment liberalization, these ingredients flow through globally integrated sourcing, production and distribution networks of corporations, making UPFs available on a truly global scale. These food processing transitions are also closely linked with transformative changes underway in food retailing, especially the growth of modern grocery retailers, as well as the intensive use of sophisticated marketing techniques. The rise of new digital marketing technologies, enabled by big data platforms, is a crucial topic for ongoing investigation.

Our results also suggest that these food processing transitions reflect variations in the strength of policy and regulatory frameworks targeting unhealthy diets and the power of different actors and interests to help or hinder policy action. Although there has been some recent progress, policy and regulatory actions in many countries are weak, with a skew towards lifestyle-behavioural interventions targeting individuals rather than more upstream ones targeting the commercial practices of the UPF industry. Substantial evidence now shows this industry has impeded political commitment for strong regulatory action. This power has been expanded by favourable governance arrangements, nutrient-based approaches to profiling the healthiness of foods and processes linked with trade and investment liberalization, market concentration and the financialization of food systems. This brings into question the role of the UPF industry in current food governance arrangements and 'as part of the solution' in policy responses to attenuate unhealthy diets.

Overall, these findings suggest that adopting an approach that combines food systems and political economy thinking is vital for understanding the determinants of global dietary change and to informing future nutrition policy responses. Given the rapidly emerging evidence on the adverse health outcomes associated with dietary exposure to UPFs and the scale of change underway, the implications for global nutrition and public health are crucial to consider.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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