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COMMENT

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A toxic relationship: ultra-processed foods & plastics

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Abstract

Background Among the crises engulfing the world is the symbiotic rise of ultra-processed foods (UPFs) and plastics. Together, this co-dependent duo generates substantial profits for agri-food and petrochemical industries at high costs for people and planet. Cheap, lightweight and highly functional, plastics have ideal properties that enable business models to create demand for low-cost, mass-produced and hyper-palatable UPFs among populations worldwide, hungry, or not.

Evidence linking UPF consumption to deterioration in diet quality and higher risk of chronic diseases is well-established and growing rapidly. At the same time, the issue of plastic food contact chemicals (FCCs) is receiving increasing attention among the human health community, as is the generation and dispersion of micro- and nanoplastics.

Main body In this commentary, we explore how the lifecycles and shared economic benefits of UPFs and plastics interact to co-produce a range of direct and indirect harms. We caution that the chemical dimension of these harms is underappreciated, with thousands of plastic FCCs known to migrate into foodstuffs. Some of these are hazardous and have been detected in humans and the broader environment, while many are yet to be adequately tested.

We question whether policies on both UPF and plastic chemicals are fit for purpose when production and consumption of these products is adding to the chronic chemical exposures that plausibly contribute to the increasing global burden of non-communicable diseases.

Conclusions In the context of ongoing negotiations for a legally binding global treaty to end plastics pollution, and rapidly growing concern about the burgeoning share of UPFs in diets worldwide, we ask: What steps are needed to call time on this toxic relationship?

Keywords Ultra-processed foods, Plastics, Industry, Commercial determinants, Climate change

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Background

Ultra-processed foods

Unhealthy diets are responsible for one in five deaths globally [1, 2]. Ultra processed foods (UPFs) are a major contributor to this multifaceted problem [3–5]. Defined by the Nova system as formulations of food-derived substances and additives industrially processed and designed to displace whole foods and freshly-prepared dishes[6], UPFs form a high share of diets in many high-income countries and are rapidly expanding across low- and middle-income country (LMIC) populations [5, 7–9].

Most UPFs are designed to generate sustained short-term profits for multinational food corporations [10]. These profits are driven by manufacturing portion-sized, easy to consume and highly appealing 'foods' with cheap ingredients [11, 12], and by extending supply chains, evading or even combatting government regulation [13, 14]. As such, UPFs are ubiquitously available, affordable and convenient even among the poorest of consumers. Through these strategies, UPF manufacturers have secured a growing market throughout food environments worldwide while shielding their harms from public attention [10]. That is, until recent years, during which evidence has accumulated with more than 75 prospective cohort studies worldwide consistently showing associations between UPF consumption and dozens of adverse health outcomes including premature all-cause mortality, cancer, and mental, respiratory, cardiovascular, gastrointestinal, and metabolic ill health [15]. In addition to the well-established harms associated with the typical high fat, sugar and salt content in UPFs, evidence is mounting on the addictive properties of these products [16, 17], the neo-formed contaminants created during processing (e.g. acrylamide, acrolein, trans fatty acids) and the additives commonly used in their manufacture including colours, emulsifiers, preservatives, and sweeteners [18], some of which have been linked by experimental and epidemiological evidence to imbalances in gut microbiota, systemic inflammation, cancer risk, cardio-vascular disease, diabetes and obesity [5, 6, 18–20].

While these pathways are gaining attention among public health and consumer groups, another factor integral to UPF business models may also be making these foods harmful to human and planetary health: plastics.

Plastics and the UPF supply chain

The plastics industry is worth over $700 billion annually [21] with continued growth forecasted for decades ahead, tripling from 460 million metric tons in 2019 to 1.2 billion metric tons in 2060 [22]. Plastics have revolutionised the global economy, including food systems, through myriad applications [23]. Given their cheap cost and functional properties, plastics are deeply intertwined with UPFs, enabling these highly profitable business models, from farm to fork.

On the farm, they support industrial agriculture to produce a handful of low-cost crops and animal-sourced ingredients such as maize, soya, sugar cane, livestock and poultry. Agricultural plastic applications include encapsulating fertilisers and pesticides, mulching, row covers, greenhouses and feeding equipment. At the farm gate, an array of plastic food contact materials (FCMs) – "materials and articles intended to come into contact with food" [24] – such as storage sacks, crates and containers, support the handling of produce towards factories where UPFs are produced. In the factory, UPFs are manufactured through processes such as "fractioning, puréeing, hydrolysis, or hydrogenation, chemical modifications, extrusion, moulding and pre-frying […], adding colours, flavours, emulsifiers" [25]. Here, plastic FCMs serve a variety of functions including in-packaging pasteurisation and high-pressure processing. At the end of production, plastic FCMs support the transportation, preservation and marketing of UPFs to consumers. As lightweight barriers against bacterial contamination, plastic packaging allows UPFs to travel great distances without jeopardising form or flavour, extending shelf life and supply chains [26, 27]. Their versatility as printing substrates, a blank canvas for compelling marketing motifs, colours and characters used to promote UPFs, makes them the optimal 'skin of commerce' [28].

As revolutionary as these materials may have been however, they are far from benign.

Main text

The toxic relationship

Derived almost exclusively from fossil feedstocks, conventional plastics generate pollution across their lifecycles, compounding the harmful effects of the UPFs that they facilitate. Plastic production requires extraction of oil and gas, followed by industrial refining and processing that together emit 1.1 Gt of greenhouse gases annually, before a product comes into use [29]. Compounding these climate risks, the production of plastics uses, generates and emits persistent problematic chemicals detrimental to the environment and human health [30, 31].

Over a third of global plastics are used in packaging, including single-use products for food and beverages [32]. Approximately 83% of flexible food packaging and 45% of all rigid food packaging is made from plastics, with UPFs commonly encased in these materials [33]. Plastic FCMs contain many chemicals, both intentionally used and non-intentionally added, as well as those from glues, printing inks, and other materials included in finished FCMs. The chemical constituents of FCMs – the food contact chemicals (FCCs) – can migrate into

foodstuffs from food processing equipment and packaging [34]. Migration can increase under higher temperatures, fat content and acidic conditions, as well as long storage and transportation times and smaller packaging sizes which increases surface-to-food volume packaging ratio [35, 36]. Each of these characteristics are common to UPFs.

Many of these FCCs are already known to be hazardous to human health [34, 37], including bisphenol A (BPA), ortho-phthalates and per- and polyfluoroalkyl substances (PFAS) [38]. Several FCCs are classified as endocrine disrupting chemicals (EDCs) that interfere with hormone signalling and have been associated with multiple adverse health outcomes [39], while hundreds of others are known to be mutagenic, carcinogenic, or toxic to reproduction [38]. Many other FCCs are of unknown toxicity but relevant because of ubiquitous human exposure, such as oligomers and antioxidants [40, 41].

Based on this, it is unsurprising that UPF consumption is associated with higher levels of urinary phthalates, bisphenols and other chemicals, including among children [42–44]; as well as increased levels of PFAS in the umbilical cords of pregnant women [45]. While this emerging evidence is of significant concern, thousands of chemicals migrating from plastic FCMs into food have not been comprehensively tested, thus their hazard properties and potential health effects are unknown [46]. This issue is further complicated by a lack of transparency, because food and plastics industries are not obliged to share, and seldom disclose, information about the chemical constituents of their plastic products, even within their supply chains. According to a recent report which identified over 16,000 plastic chemicals, almost 60% (over 9,000) "lack specific information on their use or have not been analyzed in plastics, based on industry or scientific sources" [46].

Plastic FCMs used in UPF manufacturing, packaging and supply chains also leads to micro- and nanoplastic (MNP) contamination, with evidence suggesting that highly processed foods may contain more than minimally processed foods [47]. Growing UPF consumption may also explain emerging evidence for MNPs in human blood [48]. While evidence of health effects of MNPs is not yet conclusive, animal data suggest MNPs may pose risks for reproductive, digestive and respiratory health, with links to colon cancer [49].

Consequences of linear business models

Recovering and recycling post-consumer plastics, of which UPFs are a major contributor, is a resource-intensive and highly industrialised process shown to (re)-introduce hazardous chemicals into the food chain and ecosystems [50]. Not only does plastics recycling lead to higher levels of known hazardous chemicals in recycled materials, but it generates new environmental MNP emissions [51, 52]. Many plastic products, like multilayer flexible packaging, are difficult if not impossible to recycle. Only 9% of the world's plastics have been successfully recycled and recycling will never be feasibly sufficient to manage current and growing levels of plastic production [22]; something the petrochemical industry has known for decades [53, 54]. In light of this, (open) burning of plastics has proliferated globally, contributing to CO_2 emissions and climate change, air pollution and severe, transnational toxicity [55].

Major UPF producers, including Coca Cola, PepsiCo, Unilever and Nestlé are among the leading plastic polluters worldwide, selling around 5.5 billion products every day, with large markets in LMICs where waste management systems are often inadequate, thus driving open burning [56, 57]. Perhaps less visible, but no less impactful, are the companies that produce the petrochemicals, primary plastics, additives and ingredients integral to the supply of UPFs, such as BASF, Chemours, Cargill and DSM.

The true cost of the combined impacts of UPFs, their plastic FCMs and FCCs is not yet fully quantified. However, some clues exist in recent modelling from different fields. For instance, the Food and Agriculture Organization of the United Nations (FAO) calculates that the annual public health costs and productivity losses of consuming unhealthy diets, in which UPFs play a significant role, exceed $9 trillion globally [58]. While just four chemical groups used in plastics have an attributable disease burden of $249 billion in 2018 in the United States alone – equivalent to 1.2% of the country's gross domestic product [59].

While these data paint a partial picture, they indicate that significant costs have not been borne by the businesses producing UPFs and plastics. This has allowed this toxic relationship to grow. Should the companies profiting from UPF products be held accountable to these costs, rather than the societies exposed to them – the whole business model could become unviable.

Box 1 The global plastics treaty

The Global Plastics Treaty will be the outcome of a series of ongoing intergovernmental negotiations to develop a legally binding global agreement on plastics pollution. Set in motion through a resolution among United Nations member states in 2022, negotiations toward this multilateral environmental agreement reflect international recognition of plastic pollution as a system level threat to Earth and humankind Given the hazards that plastics and their associated chemicals of concern pose to humans, including through their role in supporting UPFs, the treaty negotiations represent a valuable opportunity to protect and promote human health globally [60]. Yet, there is a risk that its scope may be narrowed with a disproportionate focus on 'downstream' measures, such as recycling. A more ambitious treaty would take a life cycle approach to plastic pollution, with an emphasis on reducing and simplifying plastics and chemical production according to clear safety, sustainability, transparency, and essentiality criteria [61]

Industry co-dependence and power

With plastics projected to represent 20% of global oil consumption by 2050 [62] the petrochemical industry, under pressure on climate change, needs a plastic future. This is reflected by the vast presence of industry lobbyists at the fourth session of the Global Plastics Treaty negotiations, in numbers greater than the smallest 87 country delegations combined [63].

If plastics and petrochemical industries need one another, then the food system is their lifebuoy [27]. Indicative of this is the global food packaging market, worth $456 billion and projected to increase by over 60% in the next six years [64]. However, food systems are in transition. The corporate concentration and vertical integration that has driven the rise of mass-produced, low-cost UPFs has come at the cost of sustainability and resilience, leaving the food system vulnerable to shocks [65]. As such, food system 'transformation' agendas increasingly recognise the need for more sustainable production and consumption, including of fresh and minimally/non-processed foods that may require shorter supply chains and potentially less packaging [66]. Redesigning food systems to meet these goals will not be simple. It will take time and struggle to dismantle the economic, ideological and physical machinery driving current food production systems. Untangling entrenched co-dependencies and technological lock-ins is complex and will require behavioural change, major capital investments and innovation. For example, many filling lines that are used for packaging UPFs, such as 'vertical form fill seal' or 'horizontal flow wrapping for snacks and confectionaries', are designed to work for a specific type of plastic packaging only and may have long-term (often 20 + year) amortisation time spans.

Perhaps the biggest challenge, though, is the pushback from the industries whose interests are at stake, and who have been shown to deploy a range of strategies to protect their operations – from intimidating scientists and funding questionable studies, to financing professional associations, front groups and collaborations [67–70]. The power of these actors is often exercised through discourse and framing, including to propagate oversimplified or misleading narratives. Where plastics and UPFs are concerned there is no shortage of such activity. Among these are the claims that plastics promote food security and reduce food waste [71, 72] including, for example by using so called 'active and intelligent packaging' designed to release substances into foodstuffs; and that recycling and bio-based technologies can make plastics (and thus, current production and consumption levels) sustainable [73, 74]. While powerful and enduring, partly due to their simplicity and the coordinated resources perpetuating them, these narratives do not withstand scrutiny [75]. For example, a largescale review in 2021 found no independent scientific studies demonstrating that plastic packaging measurably increases or promotes food security or reduces food waste [23]. Similarly, contrary to industry narratives, a growing body of evidence highlights hazards associated with both recycled and bio-based plastics [51, 76, 77].

Conclusions

Implications

In this commentary we have expressed caution about the relationship between plastics and UPFs, illustrating the harms they present to people and planet. We propose that this relationship has succeeded in part due to a lack of interdisciplinary evidence, industry transparency, and multisectoral binding policy action. To conclude, we offer four propositions:

First, we advocate for more systems thinking in agenda setting, embracing complexity and avoiding siloed reductive thinking to realise the co-benefits of tackling the common drivers of climate change, UPF diet-related illness, plastics and chemical pollution. It took decades for agri-food systems to find prominence in climate agendas, gaining eventual recognition at COP28. Unified action to halt the dual health and environmental harms of UPFs and plastics cannot wait this long. The Global Plastics Treaty represents a major opportunity in this respect. At the same time, governments, research funders and civil society need to strengthen efforts to build bridges across communities of research, practice and policy.

Second, to bridge these policy agendas across human health and environment will require interdisciplinary research collaboration. As such, we echo calls for food production and consumption to be assessed together more frequently [78]; for UPF value chains to be scrutinized on their so-called 'sustainable' practices, including plastic use and disposal; and for plastics and their related chemicals of concern to be fully recognised as problems *both of and for* food systems [75, 79]. This will necessitate standardised indicators, data sharing and surveillance on food system plastics as well as their associated chemicals and microplastics which are absent in food systems transformation agendas [80]. These kinds of cross-cutting data – produced, for example among disciplines and topics as broad as (eco)toxicology, material sciences, public health nutrition and commercial determinants of health – could equip policymakers to better centre health and the environment in national policies, international negotiations, and trade decision-making. Consumers do not have the power to solve a problem of this scale, and thus it is the responsibility of policymakers to ensure that transitions away from unhealthy, unsustainable foods are accompanied by structural measures that support demand and access to healthy foods [5, 27, 81].

Third, we need clear safety, sustainability, transparency and essentiality criteria for plastics [61]. The definition of "safety" and "sustainability", and the regulations and standards that draw on these concepts (i.e. EU Regulation 1935/2004[1]*), should be firmly centred in a precautionary, hazard-based approach that addresses groups of chemicals of concern, as opposed to industry positing "safe levels" of hazardous chemical use that rely on poorly defined exposure thresholds that do not account for chronic exposures to multiple chemicals of concern [82, 83]. New safety testing approaches must be developed that utilise current science to assess hazards of intentionally used and non-intentionally added plastic chemicals, accounting for the contribution of chemical mixtures migrating from plastic FCMs to non-communicable diseases. Alongside this, a new generation of epidemiological studies based on innovative exposure assessment tools must be conducted to provide adequate information on long-term health effects in humans. Enforcing transparency criteria (i.e. what should be reported and by whom) across plastic and food industry alike is critical for ensuring that these safety and sustainability criteria are being met, in turn these data will facilitate scientific research in identifying and eliminating emerging risks and finding suitable alternatives. The 'essential use' concept and criteria [84] can support systematic decision-making to determine which plastics could be removed altogether, which can be substituted for other materials or systems and which plastic chemicals, polymers and products are truly playing essential roles for the safety or functioning of society, and in which contexts. If the role of plastic packaging is to protect UPFs, can we really say they are serving the safety of society?

Fourth, we add to growing calls to scrutinise and address commercial determinants of health. Unhealthy commodity industries are shrewd and innovative: for example, tobacco-owned food companies successfully applied their knowledge about manufacturing and marketing tobacco addiction towards hyper-palatable unhealthy food products [17, 85]. Given the intersecting interests and strategies of Big Food, Petrochemical and Plastic industries, complementary and coherent government-led statutory regulations are to be strongly encouraged to limit the power of commercial actors profiting from health-harming and environmentally damaging products. These could include provisions in food legislation such as requirements to list the chemical constituents of packaging, as well as obligations for reporting chemical presence under substance law regarding the use of plastic materials, thereby enabling traceability of chemicals in plastic products; for which the latter may result from an ambitious UN Plastics Treaty. Self-regulation is shown to be ineffective [86] and is a well-known corporate political activity to delay stricter regulations. Where private sector actors – from small-scale to transnational – are committed to contributing to healthy and sustainable food systems, we propose that they should be supported to innovate. However, science-policy interfaces must be guarded against conflicts of interests [87] – and food systems policy processes, such as the Committee on World Food Security and the UN Food Systems Summits need to acknowledge and tackle the role of Big Food, Petrochemical and Plastics industries in commercially determining poor diets and health.

There is no simple way out of the toxic relationship between plastics and UPFs, but momentum is mounting among groups – including shareholders – seeking accountability from health-harming industries [88]. Few challenges offer such significant potential to deliver cross-cutting benefits for people and planet.

[1] * *Including for example, to revisit the definition of "safety" in regulations such as in the European Union's FCM Framework Regulation, EU 1935/2004, Art. 3, in which "safe" should mean that FCMs contain no known hazardous chemicals (as defined by the EU Chemicals Strategy for Sustainability and EU Farm to Fork strategy) and no untested chemicals.*

Abbreviations

UPF	Ultra-processed foods
LMIC	Low- and middle-income countries
FCC	Food contact chemicals
FCM	Food contact materials
FAO	Food and Agriculture Organization of the United Nations
BPA	Bisphenol A
PFAS	Per- and polyfluoroalkyl substances
EDC	Endocrine disrupting chemicals

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Data availability
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Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
OM is a member of the Food Packaging Forum Scientific Advisory Board and a member of the OECD Plastics Expert Group.

JM is an employee of the Food Packaging Forum (FPF), a charitable foundation dedicated to science communication and research on chemicals in all types of food contact materials and articles. FPF's funding relies on unconditional donations and project-related grants, including from corporations in the glass packaging industry and foundations involved in the prevention of plastic pollution.

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