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How Does the Ultra-Processed Food Industry Drive Consumption Through Product Design and Marketing? Mapping a Complex Commercial System According to Expert Mental Models and Evidence Review

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ABSTRACT

The corporations that produce and profit from ultra-processed foods (UPFs), and the regulatory conditions under which they operate, have been major contributors to the global rise of obesity and noncommunicable diseases. The aim was to map the drivers and feedback systems of the product design and marketing domains of the UPF system and to consider the implications for potential intervention strategies designed to improve population diets. A systems dynamics methodology, underpinned by a narrative literature review, was used to develop causal loop diagrams of the product design and marketing domains, through an iterative refinement process. Both domains contain multiple key drivers, alongside seven reinforcing feedback loops in the product design diagram and five in the marketing diagram. These loops predominantly focused on generating perceived value for the products, driving sales, and collecting data and information to further optimize product design and marketing strategies, serving the purpose of growing profits for UPF corporations. At many points, elements of human physiology and behavior are embedded in these feedback loops and are being manipulated or exploited by UPF corporations for this purpose. The research highlights multiple areas for intervention that, if implemented concurrently, can alter the dynamics of the current system such that power and control shift towards other types of food producers, communities, and citizens rather than UPF corporations.

1 | Introduction

The corporations that produce and profit from ultra-processed foods (UPFs), and the regulatory conditions under which they operate, have been major contributors to the global rise of obesity and noncommunicable diseases [1, 2]. According to the NOVA classification system, UPFs are food products created by combining ingredients and additives, many of which are only used in industrial food settings, through industrial processes that could not be performed in a standard home kitchen or in the kitchen of a standard small-scale food business [3]. Their ingredients may include substances that have been derived from whole foods, though the final products have few, if any, recognizable remnants of these foods, as well as cosmetic additives intended to optimize the smell, taste, mouthfeel, and visual appeal of products [3]. Some common examples of UPFs include packaged snack foods, such as chips or chocolate, sugar-sweetened beverages, reconstituted

meat products or meat analogues, and many ready-to-heat or ready-to-eat dishes [4]. Most UPFs contain high amounts of macronutrients and micronutrients of dietary concern, such as sugar, salt, and fats, with low amounts of dietary fiber and beneficial nutrients [4]. Here and throughout this article, UPF refers to both food and nonalcoholic beverages unless otherwise specified.

Globally, most UPFs are produced by large transnational corporations [5]. These corporations invest billions of dollars into production, design, marketing, and other activities to mass produce UPFs, at relatively low marginal cost, with the aim of selling high volumes to maximize profits and shareholder returns [4]. UPFs are usually branded and intensively marketed, with attractive packaging [4, 6]. These corporations may also produce, market, and sell products that are not ultra-processed and may use some of the same product design and marketing strategies for these, though many are unique to UPFs. However, the focus of this research is on UPFs, given the increasingly understood harm to population health and the environment related to their production and consumption [7, 8]. Most food systems around the world, and particularly in high-income countries (HICs), are now dominated by UPFs and the system that profits from them, facilitated by regulations that have enabled corporations focused on UPF sales to flourish [6]. The UPF system is theorized to be a complex system with the purpose of generating wealth for food corporations and their executives and investors primarily by manufacturing and maintaining high levels of demand for their products and displacing other foods in diets [3, 4]. A negative consequence of high levels of UPFs in human diets is an increased risk of obesity and other noncommunicable diseases, which are leading contributors to the global burden of ill health [1, 2, 7].

In many countries, UPFs have displaced or are displacing fresh fruits and vegetables, and other unprocessed and minimally processed foods from people's diets, including meals and dishes made from these foods [3, 4]. UPFs now make up a large proportion of the energy intake in people's diets in HICs around the world [3, 4]. For example, UPFs represent over half of people's dietary energy intake in the United States, Canada, and the United Kingdom, with this proportion being relatively stable over the last decade [3, 4]. In low- and middle-income countries (LMICs) like Mexico and Brazil, the dietary share of UPFs is rapidly increasing and currently sits at around 20%–30% [3, 4].

The public health implications of diets high in UPFs are substantial. Many observational studies link diets high in UPFs to obesity, and a randomized controlled trial showed the powerful influence of a high UPF diet on unintentional weight gain [7, 9]. Many studies have also demonstrated relationships between high consumption of UPFs and increased rates of metabolic syndrome, high blood pressure, high cholesterol, cardiovascular disease, breast cancer, and cancer overall [10]. In addition to the significant human health impacts outlined above, a growing body of evidence illustrates the harmful environmental and climate impacts of the UPF system [8, 11].

Systems dynamics is a methodology based on the premise that understanding the feedback loops within a system explains patterns of behaviors over time [12]. The behavior over time of interest to this work is the high or increasing consumption of UPFs in almost all countries, despite the negative impacts on population health and the environment from these dietary patterns. The benefit of taking a systems thinking approach to this research is that it provides a broad understanding of the complex drivers and interconnected dynamics of the system as a whole, allows for behaviors within the system to be explained and anticipated, and can identify potential leverage points for generating system-wide change [13].

Our approach to the research was informed by the observation that the business model for UPF corporations relies on (1) low-cost production inputs and processes that reduce production costs, (2) designing products that give a perception of value to consumers (e.g., through taste, convenience, status, affordability), and (3) emphatic branding and intensive marketing to drive high UPF consumption [2, 6, 14]. Our hypothesis was that the success of this model for the UPF industry from a profitability perspective incentivizes further production and replication of the UPF business model. Underlying this assumption was that the purpose of UPF corporations is to maximize shareholder wealth [6]. It was expected that this system would have numerous interconnected feedback loops driving and maintaining it, which were broadly categorized into the four major domains of product design, marketing, food supply chain, and political economy [15].

This study focused on the product design and marketing domains of the UPF system. The aim was to map the drivers and feedback systems of these domains, with a particular focus on positive or reinforcing feedback loops, because these are most likely the drivers of high and increasing UPF consumption. A second aim was to identify where human vulnerabilities may be embedded in or exploited by the system. Our goal was to inform potential intervention strategies designed to improve population diets, reduce the burden of obesity and noncommunicable disease, and improve overall population health.

2 | Methods

2.1 | Research Design

This research utilized a system dynamics methodology [13], informed by a narrative literature review and expert input on the current evidence around the product design and marketing aspects of the UPF system, to identify pertinent variables and causal relationships. We analyzed the data from this review to generate prototype causal loop diagrams (CLDs), which were then refined and further developed through an iterative and collaborative process, as described further below. CLDs are a way of explaining a theory of how the UPF system works, particularly through highlighting feedback loops that drive or stabilize the system [16]. We developed these diagrams as hypotheses through a narrative review of published literature and evidence, but they have not been converted into quantitative models or further validated through that process. Finally, we used a leverage points framework for sustainable system transformation [17] to consider how this understanding of the UPF system identifies certain intervention strategies to improve population health.

A necessity of system dynamics mapping is to create boundaries around the studied system, to be able to keep the work within a relevant scope and feasible size. For this reason, we have considered the UPF system as the actors, structures, and dynamics that drive and sustain the production and consumption of UPFs, with a particular interest in the interactions with and effects on consumers. We did not consider the differential effects of the system within different geographical locations or at different socioeconomic levels beyond price considerations and targeted marketing techniques, but rather maintained a general perspective on the system in an attempt to keep the diagrams broadly applicable.

The system has been divided into the domains of product design, marketing, food supply chain, and political economy. The scope of the product design domain is the mechanisms that are used by UPF corporations to create or alter the products themselves, as opposed to factors like the packaging, branding, and advertising of products. The scope of the marketing domain is defined as the activities undertaken by UPF corporations to brand and promote their products to consumers through marketing strategies (e.g., packaging, pricing and promotion in various media). Other aspects of the UPF system, such as elements of the political economy and food supply chain, were simultaneously researched and analyzed by other members of the research group [18], and so were not considered in this study. These domains overlap at various points and are not the only way of conceptualizing or dividing the system, but this framework groups together variables and concepts in a way that aims to be quickly understandable to a broad range of audiences and represents significant bodies of literature on UPF. Many technical terms from the field of system dynamics are used in this paper, and Table 1 provides definitions for these.

TABLE 1 | Definitions of technical terms from system dynamics research, adapted from Ford [19].

Technical term	Definition
Domain	A defined portion of the system that represents an overarching concept or goal within the wider system. The boundaries of these domains are one of many ways to divide the system and these domains overlap at various points.
Causal loop diagram (CLD)	A map that shows closed loops of relationships to capture how variables interrelate and interact, facilitating understanding of the drivers, stabilizers, and purpose of a system.
Variable/factor	A single element of the system that can increase or decrease depending on its relationship with other elements.
Relationship/driver	A causal link from one variable to another, represented by an arrow in a causal loop diagram. These can be positive (+) where an increase in the first variable increases the second variable or negative (–) where an increase in the first variable leads to a decrease in the second variable.
Pathway	A continuous set of variables and relationships that connect two variables across a causal loop diagram.
Feedback loop/ feedback system/ feedback mechanism	A sequence of variables and relationships that form a closed ring, where the causal influence of a variable comes back through a pathway to influence that same variable.
Positive/reinforcing feedback loop	A feedback loop in which the resulting effect over time is to increase change to the variables in a given direction. These loops either contain zero or an even number of negative relationships.
Negative/balancing feedback loop	A feedback loop in which the resulting effect over time is to limit change to the variables and stabilize the system. These loops contain an odd number of negative relationships.

2.2 | Narrative Literature Review

The first stage of this research was a narrative review of literature aiming to identify and collate evidence of important variables and causal relationships that describe and explain elements of the product design and marketing domains of the UPF system for inclusion in the prototype CLDs. This review was conducted between November 2022 and March 2023. It focused on research articles and reviews published in peer-reviewed journals over the years 2013–2023 in English, including both qualitative and quantitative research of any design. For further information on the search strategy used, see Supplemental Material 1. Titles and abstracts of all search results were screened for relevance. Articles were excluded if they did not focus on aspects of the UPF product design or marketing domains of the system, that is, other aspects of the political economy or food supply chain, or if they focused on a specific area of the system that was not generalizable to the UPF system overall, for example, vending machines. A full-text review was undertaken of the retained articles using purposive text analysis to identify important variables (e.g., elements that can increase or decrease sales and consumption) and causal relationships between these relevant to the product design and marketing aspects of the UPF system.

2.3 | Causal Loop Diagram Generation

The gathered list of variables and causal relationships for both domains that were identified through the narrative review was then used to inform the creation of prototype CLDs by the lead author. All diagrams were created using the Vensim PLE software. First, the identified variables were drawn out on screen,

and then, the causal relationships were used to draw arrows between these, with a "+" or "−" marking a positive or negative relationship, respectively. Finally, feedback loops that had been created through this process were identified as reinforcing or balancing [20].

The CLDs were then refined and developed through an iterative and collaborative process, involving numerous group meetings and a 2-day workshop including three external experts in addition to the core authorship team. These experts included an Associate Professor in Sensory and Consumer Science with previous experience as a researcher and project leader for a corporation that produces UPF, a Professor of Marketing with experience in anti-consumption and consumer resistance research, and a Research Fellow and founding partner of a research organization that specializes in systems dynamics methodologies. In addition, the core authorship team also holds expertise on the public health and environmental impacts of UPFs, the political economy of UPFs, and applying systems dynamics methodologies to food systems. This process identified several gaps in the CLDs, where the narrative review had not provided evidence, which were then filled either by articles from the authors' knowledge of relevant research or by specific secondary searches of the literature to evaluate whether there was adequate evidence to fill these gaps.

We then created simplified CLDs by aggregating similar variables into broader themes, while maintaining all feedback loops and highlighting elements of human physiology and behavior that were embedded in the system. These simplified versions of the CLDs are displayed in the following sections, with the expanded versions included in the supporting information to retain the detail and show the complexity of the system.

3 | Results

3.1 | Narrative Review

The literature search returned 275 records, including 141 from the product design search and 134 from the marketing search (Figure 1). Alongside these, 15 articles were included that were identified during the diagram generation process: seven that were provided through the authors' knowledge of relevant research and eight that were intentionally sought to provide evidence for gaps in the prototype CLDs that were identified through the iterative process of their refinement and development. After screening by title and abstract, 62 were retrieved for full-text review, of which 45 articles were included. The causal relationships identified from this literature review were collated and used as the basis for generating the structure of prototype CLDs.

3.2 | Core Reinforcing Loop

The CLDs displayed in Figures 2, 3, and 4 demonstrate the feedback systems that exist within the product design and marketing domains of the UPF system.

Figure 2 shows the core reinforcing loop (R1) that we describe as the overarching mechanism that drives the growth of UPFs. The loop demonstrates the continuous cycle from *production and advancement*, encapsulating the capability and investment of UPF corporations in the advancement (development, improvement and optimization) of product design and marketing, driving the *volume of sales* through supply- and marketing-induced demand for UPFs by consumers. If these advancements also allow the *price* to be adjusted or maintained relative to production *costs*, the price margin may be maintained or increased, generating *revenue*, gross profit margins and absolute *profits*, and incentivizing further investment in and *advancement of product design and marketing strategies*. In parallel with this feedback loop is another pathway, acknowledging that increased *production* comes with *costs* of money, time, and other resources, and if these increase at a higher rate than corresponding sales *revenue*, this reduces subsequent *profits*.

This diagram represents a high-level overview of the system that the subsequent domain CLDs shown in Figures 3 and 4 operate within. This is not a feedback loop that is unique to the UPF system; rather, it is relatively common to many corporate industries that produce and sell products. However, corporations producing UPFs have much greater power to manipulate, differentiate, and brand these products through industrial processing and integrated marketing [4, 6], as well as significant influence over global political and economic systems [18]. For many of these corporations, centering their business models on UPFs has been a successful way to maximize profits and shareholder value [21]. The factors in the core loop are colored green to create a link between these factors and their counterparts in the domain diagrams. For example, *profits* in the core loop correlate with *profits* in the domain diagrams, connecting both to the core loop.

3.3 | Product Design Domain

Figure 3 is the simplified CLD created to represent the key pathways and feedback loops within the product design domain. The description of the results related to this diagram will start at the left-most variable, the *capability to advance product design*, while noting that this system is not linear but works in a continuous cycle. While some of these product design strategies could be used in the production of products that are not ultra-processed, many of the industrial processes, mechanisms, and additives are unique to UPFs due to the greater capacity to control and manipulate the characteristics of these products.

3.3.1 | Key Pathways From Capability to Advance Product Design

Four key pathways were highlighted that stem from the *capability of UPF corporations to advance product design*.

First, UPFs are altered through multiple *ultra-processing methods intended to minimize production costs* and create appeal for *distributors and retailers*, as well as increase *desirability among consumers*. These reduce storage and transportation costs for distributors and retailers [22–25]. Many processing methods can

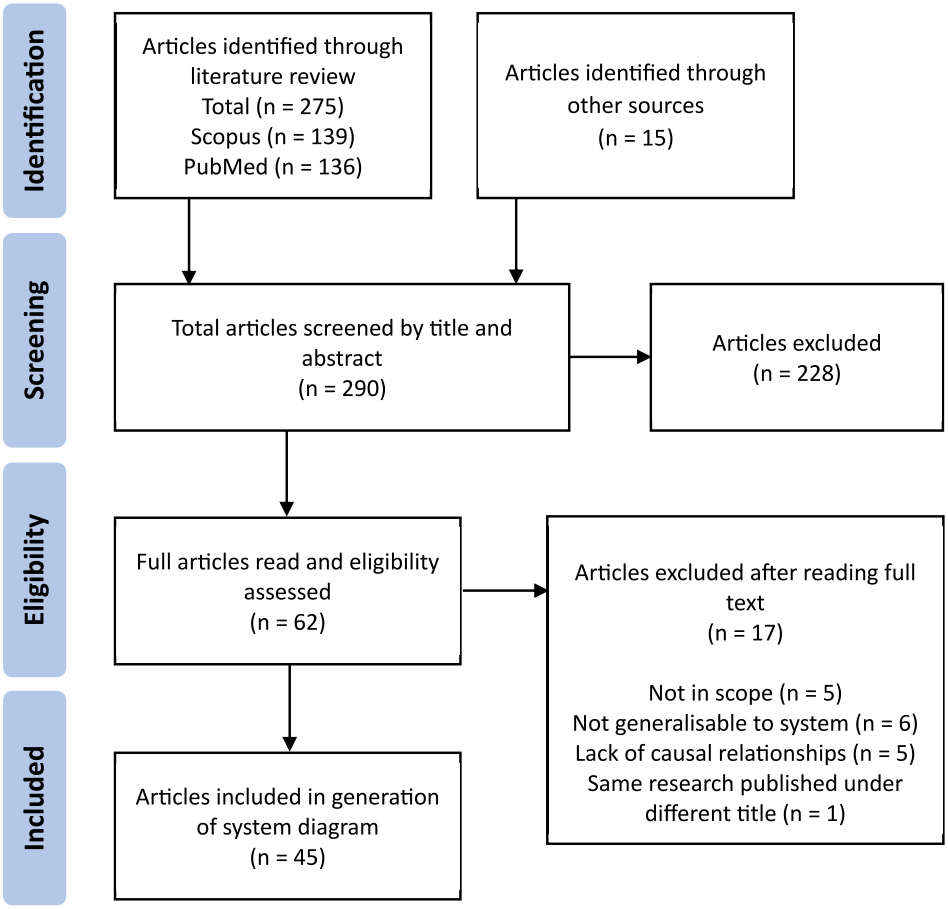

FIGURE 1 | PRISMA diagram of the narrative review process.

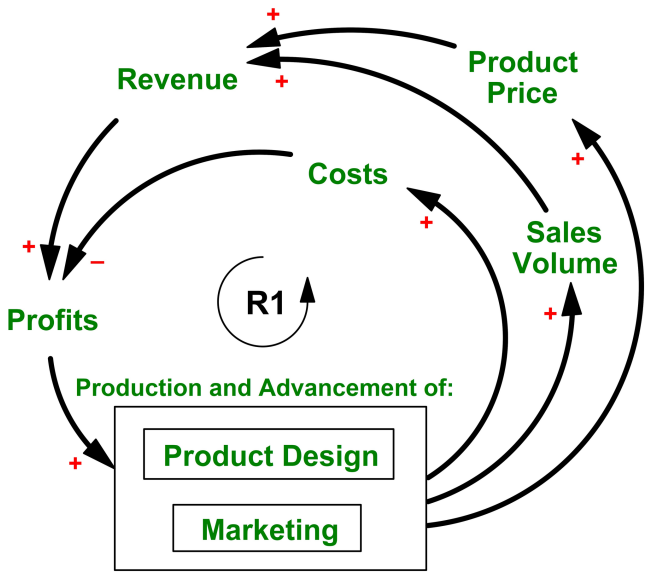

FIGURE 2 | Core reinforcing feedback loop of the UPF system (R1).

also increase the efficiency of production and reduce marginal production costs, which may enable reductions in the price of products for consumers while maintaining or even increasing profit margins [24]. Further, *large-scale commodity* trading allows UPF corporations to *use relatively cheap ingredients and crops*, which can lower the *price of products* [1]. Lower prices are often attractive for consumers [26]. The increased *perception of value among consumers, distributors, and retailers* leads to increased UPF *sales* [22–26].

Second, the ingredients and design elements of UPFs are altered to *increase their desirability*, and thus their *perceived value*, among consumers. Products are designed to be more convenient for consumers, including easy preparation and consumption [24, 27, 28]. Portion and packaging sizes of UPFs can also be designed to alter perceptions of quantity and value-for-money [1]. Some UPFs are designed to benefit from the "health halo effect," leading to an overestimation of the nutritional quality of the product [29–31]. Although consumers may view these products as healthier, they often contain high levels of nutrients of concern [29–32]. The resulting increase in the *perceived value of UPF among consumers* also leads to increased *sales* [1, 27, 28, 30].

UPFs tend to contain high levels of ingredients like *salt, fat, sugar, and other sensory-related industrial additives* that give the products attractive sensory properties, such as taste, smell, or feel [32]. These increase the *palatability* of UPFs, which has been linked to increased *activation of pleasure and reward pathways* in the brain, particularly those that involve dopamine [27]. This generates a reward response that is out of proportion to the UPF's nutrient content, which is theorized to encourage overconsumption [33].

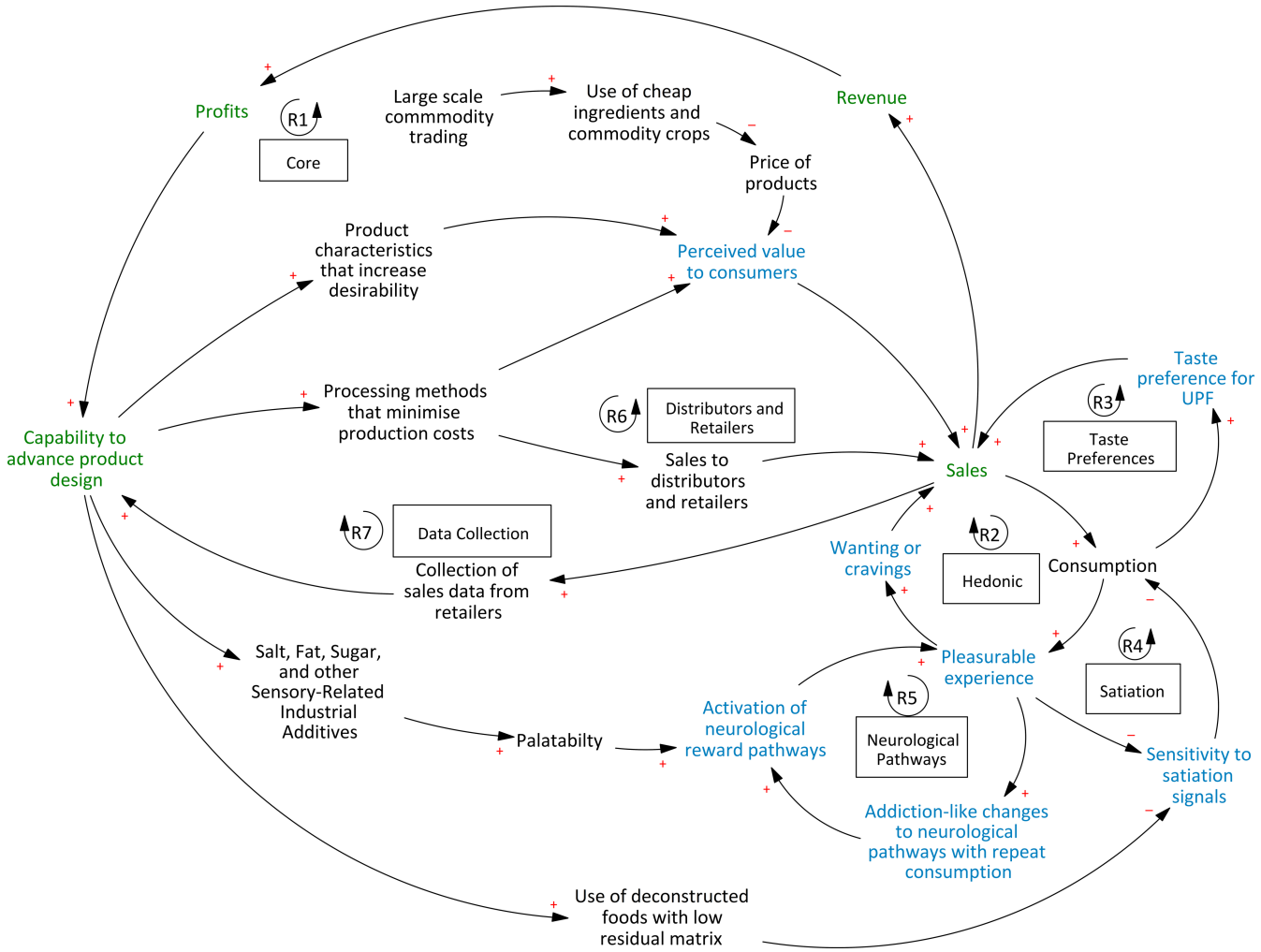

FIGURE 3 | Product design domain causal loop diagram. Green factors are those included in the core loop (Figure 2). Blue factors are those that represent an element of human vulnerability. "R#" signifies a reinforcing feedback system.

UPF corporations use industrial processes in manufacturing their products, which deconstruct and reduce the *structural matrix of foods* [34]. Many UPFs can be eaten quickly and easily, partly due to their low residual food matrix and thus softer texture [32, 34]. Along with increased *palatability*, these effects can delay the onset of and reduce the *sensitivity to neurological satiation signals*, which lead to increased *consumption* of UPFs [32, 34].

3.3.2 | Feedback Loops in the Product Design Domain

The product design domain contains multiple feedback systems that are driven by and partly made up by these key initial pathways, and in turn, reinforce the *capability to advance product design* by generating *profits* and *collecting market data and information*. The first of these feedback systems is the *Core Loop, R1*, described above.

The second feedback system is the *Hedonic Loop, R2*. This reinforcing loop shows that the *consumption* of UPFs, particularly with added flavors and other sensory-related industrial additives that increase *palatability*, produces a *pleasurable or hedonic eating experience* for the consumer [27, 33]. This pleasurable eating experience can cause *wanting or cravings* for UPFs, leading to consumers purchasing and *consuming* more UPFs [27]. This feedback system creates a cycle of repeat sales and consumption, driven by the *pleasurable eating experience* and *cravings*. This exploits the biology and psychology of humans to increase sales and profits.

The *Taste Preference Loop, R3*, exhibits a feedback system by which increased *consumption* of hyperpalatable and nutrient-poor foods can lead to consumers having an increased *preference for the taste* of these foods [35, 36]. Research has shown that regular consumption of products like UPFs can alter taste preferences [36]. Consumers preferring the taste of products has been found to be a driver of repurchase and *consumption* [37], demonstrating another cycle in which human biology, through the nature of taste preferences, is embedded and vulnerable to exploitation.

The next feedback system is the *Satiation Loop, R4*, which shows the relationship between the *pleasurable experience* of eating UPFs and a decrease in consumer *sensitivity to satiation signals* [33, 38]. Along with the previously discussed aspect of UPFs having a *low residual food matrix* [32, 34], overconsumption of UPFs

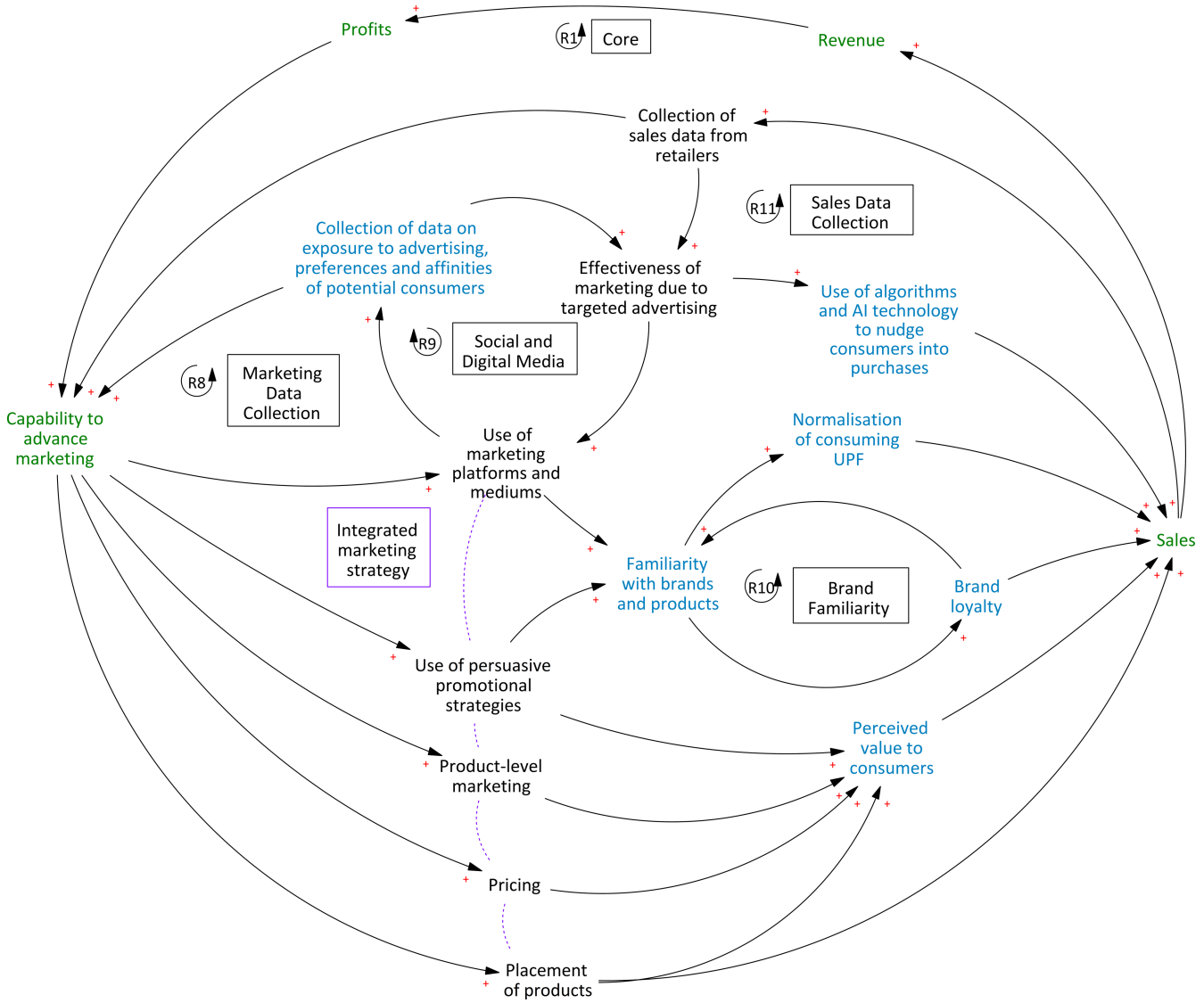

FIGURE 4 | Marketing domain causal loop diagram. Green factors are those included in the core loop (Figure 2). Blue factors are those that represent an element of human vulnerability. Purple dashed lines indicate the interrelated aspects of an integrated marketing strategy (purple box). "R#" signifies a reinforcing feedback system.

may decrease the *sensitivity to satiation signals*, that is, those that make you feel full and stop eating [33, 38]. This decreased *sensitivity to satiation signals* may lead to overeating and increased UPF *consumption* through circumventing homeostatic systems, though this is an area requiring further research [33, 38].

The *Neurological Pathways Loop, R5*, expands on the link between the *activation of neurological reward pathways* and a *pleasurable eating experience*, demonstrating the *changes to these reward pathways through repeat consumption* of UPFs. Research has shown that repeated or high consumption of UPFs can induce changes in the reward pathways of the brain that are similar to those seen in substance addiction [37, 39–41]. These addiction-like changes lead to increased motivation to consume UPFs and overeating behaviors [39]. The theory that consumption of UPF can lead to food addiction is particularly concerning as this signifies an exploitation of human biology and behavior in which it may be very difficult to intervene [39, 41].

The *Distributors and Retailers Loop, R6*, shows that the factors that reduce storage and transportation costs, including extended shelf-life and decreased product weight [22–24], can incentivize food distributors and retailers to increase the availability and promotion of UPFs, thereby leading to an increase in UPF *sales* [25].

Finally, the *Data Collection Loop, R7*, shows how the *collection of data and information on sales* also enables UPF corporations to *advance product design* [42]. Increasingly, digital technology and artificial intelligence are used by UPF corporations to collect and process even larger amounts of data and information [42], including what products are sold, when they are sold, and by what types of retailers [43]. These data can inform corporate strategies to optimize marketing, product design, and cost of products to meet ever-more-specific consumer groups. These digital data uses are further discussed below in Section 3.4.2.

3.4 | Marketing Domain

Figure 4 is the simplified CLD created to represent the key pathways and feedback loops within the marketing domain. The description of the results related to this diagram will start with the left-most factor, the *capability to advance marketing*, but noting that the system is cyclical and not linear. It is important to note that, while a number of these marketing strategies and mediums are available to producers of all food and beverages, there is a corporate incentive and financial capacity to utilize these strategies and heavily market UPFs because of their relatively high profitability, as well as the degree of brand and product differentiation possible through product design strategies [4, 6].

3.4.1 | Key Pathways From Capability to Advance Marketing

Five key pathways were highlighted that stem from the *capability of UPF corporations to advance marketing strategies*, again linking through to either *sales* or one of the feedback loops that will be discussed in the next section.

The first key pathway is through the *use of persuasive promotional strategies* to market UPFs. Various strategies are used to increase *consumers' perception of the product's value* or *familiarity with brands and products*, such as through celebrity endorsements or influencers, associating products with popular and well-known people to increase *consumer perceptions of value* [44, 45]. A similar method is using cartoon characters and mascots to promote products to children [46]. Corporate social responsibility (CSR) activities can improve a corporation's reputation, increase *familiarity*, and generate *brand loyalty* [27, 47]. Packaging design is another important element, promoting products through recognizable branding and eye-catching imagery, communicating about features that may be perceived as valuable or desirable [1].

These strategies need to be communicated through a *marketing platform or medium*. The large *profits* of UPF corporations allow them greater access to various mediums and lead to the dominance of UPFs among advertised products [4]. Digital and social media platforms allow advertising to be much more sophisticated, through the *collection of online data* and targeting of advertisements to consumers [42]. All mediums provide opportunities for UPF corporations to expose consumers to their brands and products [44, 48, 49], increasing *familiarity* and *normalizing the consumption of UPF*, driving *sales* [44, 48, 49].

Product-level marketing is an aspect of this domain that overlaps with elements of the product design domain, designing products and packaging to create a perception of desirability and *value among customers*. This includes the alteration of fundamental properties of products such as flavor, color, and texture [4]; the shape and size of products and packages that skew perceptions of quantity [1]; and the use of the "health halo effect" or front-of-package labelling schemes to give the perception of healthy products [30, 50, 51].

While there is significant variation in the *pricing* strategies of UPF corporations, UPFs are often more affordable than foods from other NOVA Groups [52, 53]. Further, price discounts applied to UPFs tend to be bigger than those applied to other foods [54]. The capability for UPFs to be sold at a low price partly relies on the ability to use cheap inputs, as well as on the improvement of technology and processing methods to increase production efficiency [52]. The comparatively low price of UPFs is an attractive feature for consumers, generating *sales* [52–54].

The final pathway is the *placement of products*, both in stores and geographically. Within stores, a common strategy is allocating a large amount of prominent shelf space to displaying UPF, such as at the end of aisles or near checkouts [55]. Further, UPF corporations loan or gift branded equipment to retailers to increase the visual presence of their brands [56]. These factors can impact *perceptions of value* and *sales*, such as through impulsive purchasing [1, 55]. A higher number of convenience stores or supermarkets within a geographical area increases the availability and access to UPFs, which tends to lead to increased *sales* and *consumption* among those living nearby [53, 57, 58].

Each of these key aspects is aligned with an *integrated marketing strategy* [59], represented in Figure 4 by dashed purple lines connecting these interrelated aspects of the marketing domain. This details the approaches and techniques that a corporation will use to design and advertise its products, providing consistency and efficiency at an international level, while also allowing adaptation to the differences at local levels [59]. The purple dotted lines in Figure 4 represent *integrated marketing strategies*.

3.4.2 | Feedback Loops in the Marketing Domain

There are several feedback systems within the marketing domain, many driven by the *use of persuasive promotional strategies* and the *marketing platforms and mediums* through which these are distributed. These feedback loops act to either reinforce marketing strategies that are effective in increasing *sales* or cycle resources and information back into the UPF corporations' *capability to advance marketing*. As was the case for the product design CLD, the first feedback system is the *Core loop, R1*, described above.

The next two feedback systems are the *Marketing Data Collection Loop, R8*, and the *Social and Digital Media Loop, R9*. These reinforcing loops involve the *collection of large and complex sets of data* from the platforms and mediums through which corporations advertise [42, 60]. This is particularly pertinent to digital and social media platforms, which can convert people's social lives into data and information that can be used by corporations to hone and personalize their promotions [60]. The information collected from these platforms goes beyond sale and market data to understand people's preferences, affinities, and behavioral patterns [60]. This immense amount of intelligence is a valuable resource for UPF corporations to *advance their capability* to design an optimized *integrated marketing strategy* [42, 60]. Further, the capacity to convert online social life into data and the interactive nature of social media allow corporations to manipulate and navigate social media algorithms to target users who are more

likely to purchase and *consume* their products and use unique marketing techniques that capture user attention, increasing *effectiveness* [44, 60]. Another key element related to digital platforms is the role of emerging technologies, such as artificial intelligence [42]. Using this technology, UPF corporations can create programmes to read and respond to consumer behavior, online and in physical settings such as drive-throughs and in stores, to deliver individualized *nudges to upsell products* [42]. Humans are inherently embedded in and exploited by these systems, as it is information about us and our use of these media, which has become ingrained in our daily social lives, that drives them.

The *Brand Familiarity Loop, R10*, is the next feedback system. This loop involves the reinforcing factors of *familiarity with brands and products* and *brand loyalty* of consumers [27, 61]. High exposure to advertising across platforms is a vital way for UPF corporations to familiarize consumers with their brands and products [44, 48, 49]. This familiarity, along with other marketing techniques, creates *brand loyalty*, an allegiance to a brand or product that can border on becoming part of a person's identity [27, 61]. The degree to which UPF can be branded is a significant factor that differentiates them from less processed products [6], further facilitating these effects. *Brand loyalty* can influence and drive the purchasing decisions of consumers [27]. The other effect of *brand familiarity* is that it can *normalize the consumption of UPFs*, creating a sense that it is normal and appropriate to consume UPFs, even at a high rate [49]. These aspects of familiarity with, loyalty to, and normalization of UPF products play on human social behaviors for the purpose of increasing *sales* and *profits*.

Lastly, the *Sales Data Collection Loop*, *R11*, is a similar feedback system to the product design domain's *Data Collection Loop, R7*. This loop demonstrates that this same *collection of data and information* on what sort of products are popular, where they are sold, when they are sold, and in what context can be used to enhance the *capability of UPF corporations to improve marketing strategies* [42, 43]. The collection and use of this information is a key contribution to the effectiveness of *integrated marketing strategies*, allowing advertisement and promotion of UPFs to be targeted and personalized to consumers [60].

4 | Discussion

4.1 | Summary

The CLDs inform several key findings. First, both the product design and marketing domains of the UPF system contain multiple reinforcing feedback loops, driving the core feedback loop shown in Figure 2. These feedback loops provide some explanation for the persistent high (in HICs) and increasing (in many LMICs) consumption of UPF [3, 4, 62, 63]. Furthermore, the CLDs highlight various social and biological elements of human behavior that are embedded in and exploited by the workings of the UPF system (colored blue in Figures 3 and 4), with the effect of driving consumption of UPF and profits for UPF corporations. This theory of the UPF system explains part of how these products have developed and maintained dominance within the food system over recent decades [64].

The aims of this research have been to investigate and explain the mechanisms of the UPF system's product design and marketing domains, with a particular focus on the positive feedback loops, which continue to drive high or increasing consumption of UPFs around the world [7], and to explore the ways that the vulnerabilities of consumers are embedded in and exploited by this system. Figures 2, 3, and 4 demonstrate an evidence-based representation of these mechanisms.

4.2 | Interpretations

The main purpose of the UPF system is to maximize profits for UPF corporations and their shareholders [4], represented by the core reinforcing feedback loop, *R1* (Figure 2). Central to fulfilling this purpose are the domains of product design and marketing. Defining this purpose of UPF systems and articulating the dynamics of these product design and marketing domains, as well as the political economy and food supply domains [18], endeavor to explain why the consumption of UPFs is high or increasing in almost all countries [1], despite the substantial amount of evidence demonstrating that these products are major determinants of obesity and many noncommunicable diseases.

Further, within countries, the UPF system is seen to have differential effects on communities and people with low income and low socioeconomic status [65, 66]. Though we have not explicitly included this influence in the CLDs, there are certainly factors such as pricing and affordability, geographical accessibility, or social normalization that are likely to have a greater influence on communities experiencing socioeconomic deprivation. The work of Sawyer et al. [65], mapping the complexity of unhealthy food systems for low-income populations, found that increased accessibility, availability, affordability, and acceptability of unhealthy foods led to poorer dietary intake, emerging from a system paradigm focused on economic growth rather than population health. The findings from our research strongly align with this conclusion, supporting a view that the UPF system interacts with other existing inequitable social systems to perpetuate social and health inequities.

While global food systems are ultimately interlinked, there are a number of important factors that facilitate the dominance of UPF in food systems, compared with the systems that produce whole, minimally processed or processed foods (NOVA Groups 1 and 3). First is the scale of the UPF businesses, which are dominated by large transnational corporations with enormous financial capacity and profit generation, and all operate within the wider industrial food system [1, 6]. Second is the considerable degree of product design manipulation that ultra-processing provides to manufacturers. For example, a UPF manufacturer using a potato base to make crisps has a vast array of processes and additives to choose from when designing products, which are not available to potato growers (NOVA 1) or takeaway shops selling French fries (NOVA 3), and these can be constructed to target specific consumer segments and marketed to create an apparent diversity of “new and exciting” products. Third is the large number of ways that human vulnerabilities can be captured and exploited with the UPF system, as highlighted in the CLDs.

Both the product design and marketing domains reach this goal of creating profits through several important pathways and reinforcing feedback systems, and the biology or psychology of people is embedded in all of these. Berridge [67] proposes a framework for understanding how products such as UPFs can elicit two different biological and psychological phenomena: "wanting" and "liking." In the context of UPF, "liking" is the pleasure or enjoyment derived from consuming a product, whereas "wanting" is the appetite or motivation to consume a product [67]. While these two motivational mechanisms often converge (people tend to want the products that they like), they are distinct from each other, both philosophically and neurobiologically, and may occur without the other [67, 68]. For example, a consumer may enjoy eating a new flavor of potato chips once, but not want to buy that flavor again. Alternatively, they may be motivated to buy and eat an ultra-processed "ready-to-eat" meal that they do not necessarily like, because of other factors such as time or money constraints. For UPF corporations with the purpose of creating profits, "wanting" is arguably the more important factor, as this is what drives people to purchase their products [69].

As a strategy for product design and marketing, it makes sense to develop products that people like and want, such as by making them hyperpalatable, convenient, visually attractive, and affordable. These ideas are reflected in the domain diagrams in many areas, including *palatability* and the *Neurological Pathways Loop* that are important factors in consumers liking UPFs, as well as the *perception of value* and the *Hedonic*, *Social and Digital Media* and *Brand Familiarity Loops* that may all drive consumers to want UPFs. Designing, manipulating, and marketing products to optimally appeal to our motivational mechanisms enable sales maximization and profits [66]. This central driver of the system can be framed in two ways, either as "responding to consumer demand," emphasizing a reactionary response of UPF corporations to consumer decisions, or as "exploiting human vulnerabilities," highlighting the significant and intentional influence of UPF corporations over the decisions of consumers. The consequence is that the system is also driving the overconsumption seen at the individual, national and international levels, creating the burden of obesity and noncommunicable disease and other harms caused by the high consumption of UPFs [7, 63]. Because of this, these elements of the UPF system that utilize human biology or psychology to increase the "liking" of and "wanting" for UPFs should not just be seen as effective product design and marketing. Instead, they should be seen as the system manipulating and exploiting people's vulnerabilities to drive and maintain high consumption despite the health harms associated with high consumption [66].

As an extension of these motivational mechanisms, an important area of research around UPFs is the question of whether these products can or should be considered addictive, though this is an area where the evidence is still developing. Gearhardt et al. [27] apply to UPF the four primary criteria by which the addictiveness of tobacco smoking was scientifically evidenced. The UPF system feedback structures identified in this study provide further support of this stance. The first criterion of compulsive use may be shown through people continuing to have a high intake of UPFs despite facing health consequences [27, 70–72]. The consumption of UPFs that are highly palatable may trigger and alter neurological reward pathways among some people, affecting both pleasure and mood, supporting the second criterion of psychoactivity [37, 39, 40]. The overconsumption of UPFs driven by the activation of reward pathways and the decreased sensitivity to satiation signals, mediated by intentional design elements like palatability and deconstructive processing, supports both the first criterion of compulsive use and the third criterion of reinforcing properties [33, 34, 38, 39, 41]. The development of strong urges or cravings in response to eating some UPFs supports these products meeting the fourth criterion [27]. If some UPFs can be considered to have addictive potential, even only among a minority of people, this would be a serious reason for concern and may represent a contributory cause for their dominance within the food system and their continued and increasing consumption.

4.3 | Implications for Policy and Practice

The conclusion that UPFs could be considered addictive has implications for the potential framing of legal cases against the corporations who intentionally design and produce these products that promote overconsumption. One such case, considered to be the first of its kind, has already been filed in the United States against a set of major UPF corporations [73]. A significant aspect of the plaintiff's argument is that these corporations should be held legally accountable for the individual and public health issues caused by the marketing and product design strategies that they use [73]. The intentional engineering of addictive products that trigger cravings and compulsive consumption and the use of aggressive marketing tactics are particularly highlighted by the plaintiff [73], indicating the central importance of evidence for these elements in taking action to address the harms of the UPF system. A similar framing of the exploitative strategies used by UPF corporations, which manipulate human biology and psychology, may also serve to raise awareness and increase public support for other political, regulatory and systemic interventions [66].

Taking a systems-thinking approach to the issue of high UPF consumption allows the identification of potential strategies or interventions to address this. Abson et al. [17] propose a framework of leverage points, or potential target points for intervention within a system, that draws from and builds on the work of Meadows [74]. Their framework organizes Meadows' 12 leverage points of a system into four broader categories of system characteristics: *parameters*, *feedback*, *design*, and *intent*, from shallowest to deepest [17]. For instance, our analysis indicates that disrupting and intervening in the *feedback* loops of the UPF system that utilize and manipulate human biology may provide fruitful opportunities for regulation, such as by having stricter or more holistic regulations on the use of industrial additives in UPF manufacturing. Although Abson et al. posit that developing sustainable and transformative interventions requires engaging with the deeper groups of leverage points, targeting the system's *design and intent* [17], these deeper levers are more difficult to access and meet stronger system pushback. Further, an international analysis of current regulatory interventions relating to UPFs has found that these are predominantly skewed toward changing the decisions of consumers within food environments, with a relative paucity of interventions that address the broader structural drivers of the UPF system [75].

Fischer and Riechers [76] discuss the concept of chains of leverage, whereby interventions at various levels may synergize to have a greater impact across the system. The product design and marketing CLDs can be used to identify such leverage points, with several examples discussed here. Shallower interventions at the *parameters* level tend to be easier to achieve and so are more common, such as front-of-package labelling schemes. These have the aspiration of providing transparency and knowledge to consumers around the healthfulness of products, but have issues with UPF corporations gaming this to achieve higher ratings, such as adding beneficial nutrients like vitamins, without addressing other unhealthy ingredients such as high levels of sugar, salt or fat, applying a "health halo" effect to portray their products as healthier than they are [50].

A *feedback* level intervention would target the reinforcing loops of the system, such as targeting the loops in both domains that collect and utilize sales and advertising data (*R7*, *R8* and *R9*). This could be done by regulating and controlling the use of personal and private information, particularly data that are collected from digital and social media platforms about the affinities and preferences of consumers. The effect of this may be to reduce the capacity of UPF corporations to exploit these data to target products and advertisements at consumers.

At the *design* level, aiming to affect the rules and structure of the system, a suite of interventions that affect the marketing strategies could be used. This could include restrictions on discounts and promotions on UPFs, regulation of marketing that targets children, such as by banning the use of cartoon characters in advertising and on packages, and taxation of products for the quantity of nutrients of concern they contain, such as the sugar taxes that many countries have introduced [77]. These would restrict UPF corporations' ability to market products in certain ways, such as through low pricing or persuasive promotions, and aim to decrease their attractiveness to consumers.

Even though these interventions fit within different levels of the framework, they are synergistic in the way that they weaken different aspects of the integrated marketing and product design approaches of UPF corporations, limiting their capability to design and promote products attractively and influence the decision-making of consumers. Through synergistic chains of intervention that include deeper leverage points, genuinely sustainable and transformative change may be achieved [17, 76]. It is important to note that many potential interventions to address the parameters, feedback, and design levels of the UPF system would target elements of the political economy or food supply chain [18]. These include instituting robust legal frameworks that support diverse businesses producing food that is not ultra-processed, implementing policies that mandate increased transparency around corporate political activities, and instituting programs that protect and promote traditional or Indigenous food systems [18].

Finally, the deepest level of intervention is at the *intent* level, attempting to address the goals and paradigms of the system to enact fundamental change; however, interventions at this level are often met with significant resistance from the system overall. Within the product design and marketing domains of the UPF system, the goals are to design and manufacture products in a highly cost-effective way with properties that maximize their desirability and to market these products using integrated marketing strategies to increase sales and consumption. This is built on an economic paradigm where the maximization of profits for corporations and their shareholders is the system's primary goal. Shifting the intent of this system will require a change in mindset and collective action along with a broad range of policies and interventions that build on each other to reorient its goals toward public health, environmental sustainability, social equity and justice and to internalize the external costs to populations and the environment that UPF corporations and their products cause.

4.4 | Strengths and Limitations

This study is one of the first to conceptualize the behavioral drivers of high UPF consumption as part of a complex system, and as such, sheds new light on the exploitative nature of the UPF system and on the deeply embedded factors that work together to entice people to consume more UPFs. A systems approach allows the identification of leverage points, at different levels, with greater potential to disrupt the system.

There are several limitations to this research. The first limitation is that the CLDs represent a theory of how the system works, based on a narrative review of current literature, and are influenced by our interpretation of the literature and decisions in generating the diagrams. Thus, some variables or feedback loops may have been omitted and are inherently biased by the perspectives of those involved in the generation process. Also, the inclusion of a broad range of qualitative and quantitative studies in the literature review introduces a degree of uncertainty with regard to the strength and direction of causal relationships included.

A way that this research may have been strengthened is through the inclusion of further insights from a greater number and wider range of experts in the product design and marketing of UPF. This could refine the diagrams further and improve the validity and reliability of the findings, and the absence of this is a limitation of this work. This was not able to be undertaken due to restrictions in time and scope, but represents an opportunity for further research to build on these findings. If pursuing this, it would be extremely important to be cognizant of the conflicts of interest that current or former employees of UPF corporations may have, as well as restrictions on participation in research that may apply to these experts. However, if these conflicts were appropriately assessed and managed, then this would add significant value to the research.

Another limitation is the absence of balancing or negative feedback loops from the domain diagrams. In reality, the UPF system must contain some balancing loops because each of the reinforcing loops does not cycle unrestrained to the point that all people are eating UPF for the entirety of their diets. It would be valuable to make these balancing loops explicit; however, a focus of this study was to identify the reinforcing loops first because they represent the driving forces for increasing consumption in LMICs and persistent high consumption in HICs.

Many of the balancing feedback systems may exist within the political economy or food supply chain domains of the UPF system, which were outside the scope of this research, but certainly still interact and overlap with the product design and marketing domains.

Finally, it is common to attempt to convert a CLD into a quantitative model, which can then be run to assess how changes within the system may affect the behavior of interest. Unfortunately, some of the factors within the UPF system may be very difficult to convert into quantitative variables, such as the degree of normalization of consumption, making this a challenge. Nevertheless, these CLDs are a useful tool for understanding and explaining the UPF system and may be tested and validated through other methods such as expert interviews or group model building, which may also provide an opportunity to better identify the balancing mechanisms and present opportunities for future research.

5 | Conclusions

The persistently high and increasing consumption of UPFs globally can be more fully understood as the outcome of the complex UPF system within which human physiology and behaviors are exploited for the purpose of corporate profit maximization. This understanding provides an explanation of why the high consumption of UPFs, and the harm this causes, continues. For strategies to intervene in this system most effectively for public health benefit, they will need to challenge the goals and paradigms that underlie the system's purpose, synergistically act across multiple leverage points of the system, and shift power and control over the food system back to other types of food producers, citizens, and communities.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supporting information.