Dissecting the ultra-processed food phenomenon: Dietary patterns and public health perspectives.

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Abstract

Ultra-processed foods have become a big part of modern diets, raising concerns about their health implications. This paper explores the definition, classification, and historical evolution of UPFs with regard to their pervasive presence in current diets and the complexity involved in their classification. This article uses the NOVA system to distinguish the features of UPFs from minimally and processed foods, on the one hand, and high industrial processing with added additives on the other. Based on previous studies of the health effects of UPFs, the review related their rising consumption to adverse health outcomes like obesity, metabolic syndrome, and cardiovascular diseases. It also identifies sociocultural and economic factors behind UPF consumption, considering the role of global food systems in shaping dietary patterns. This article provides a critical review of available literature and brings on board a spectrum of viewpoints to once more stress the need for better regulatory regimes and public health actions against the negative health effects of UPFs. The following are some very critical insights for policymakers, health professionals, and researchers struggling to improve the global nutritional health of populations.

Keywords: Dietary patterns, Health implication, Metabolic syndrome, NOVA classification, Ultra-Processed Foods (UPFs).

Abbreviations: FAO: Food and Agriculture Organization of the United Nation; GHGE: Green House Gas Emission; LCA: Life Cycle Assessment; UPFs: Ultra-Processed Foods; WHO: World Health Organization

Introduction

The processing of foods is very important for ensuring food security and safety. For a long time, the security and safety of food have been ensured by salting, drying, smoking, sugaring, pasteurizing, or fermenting. At present, numerous additives, namely, preservatives and antioxidants, are also used. Their use makes it possible to preserve foods during long periods of transport in trucks or boats from a production site to supply megalopolises worldwide and to help typical consumers cover, for example, seasonal gaps or if food storage at the household level is poorly managed [1]. Therefore, to feed humanity, food processing is essential. In addition, some foods require processing to be palatable (e.g., grains), safe (e.g., pasteurized milk), or available year-round (e.g., canned, dried, and frozen fruits and vegetables) [1,2].

The ever-evolving dietary approach to reducing the prevalence of metabolically related and degenerative diseases has long been focused on identifying macro and micro-nutrients, foods and, most recently, dietary patterns with relevant and well-defined health effects, whose adoption should then be promoted to the population. Special attention must also be paid to energy intake, to minimize imbalance between calorie intake and expenditure, because excess energy intake is likely to be the primary cause of weight gain and obesity irrespective of other dietary considerations [3].

However, recently, excessive consumption of highly processed or Ultra-Processed Food (UPF) has been gaining significant attention as an alternative explanation for the rates of high BMI/ obesity and poor health. There are several proposals that promote classification schemes for UPF, but the NOVA system is probably the most commonly cited and allocates foods into one of four categories, in terms of degree of processing:

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- Unprocessed or minimally processed foods.
- Processed culinary ingredients.
- Processed foods.
- Ultra-processed foods.

Materials and Methods

The UPF category is quite large, encompassing the vast majority of foods and beverages produced by the food industry, and specifically singles out 'products obtained from formulations of several ingredients like salt, sugar, oils, and fats, and substances like flavors, colors, sweeteners, emulsifiers', which are often highly calorie dense [4-6].

The preferential use of foods from the first categories and the reduction (or even banning) of foods from the fourth one is presented as an effective tool in preventing weight gain or obesity, and preserving health. Given the growth in the use of the concept of ultra-processed foods, it is reasonable to explore the definition of this term as it currently stands and how it has evolved over time. Moreover, because such foods constitute more than half of the energy intake in the United States and because the policy of NOVA is to recommend avoidance of this food category in their proposed dietary guidelines, the total elimination of ultra-processed foods from the national diet could have profound and uncertain consequences [7].

Ultra-processed foods history

It is well known that wars provoke technological advances, and there is little doubt that World War II accelerated the development and distribution of processed foods. In the acute crisis of war, these advances in food technology and packaging prevented starvation and saved untold numbers of lives. After the war, when the acute crisis had passed, highly-processed foods were introduced into the American diet with vigor. In 1947, N. Philip Norman, a nutritionally-oriented physician, expressed concern with what he thought was the beginning of a national dietary experiment, one "without regard to the effect which these 'processed food' fractions will exert, ultimately, upon the health of the people" [8]. In their 1947 book 'Tomorrow's Food', [9] Norman and co-author James Rorty, the latter a well-known critic of the power of the American Medical Association, took aim at the tandem of the advertising industry and the purveyors of highly-processed foods. The authors concluded that this toxic union was ushering in a 'food fad' on the grandest scale. In their view, the sudden influx of highly-processed foods was faddish in the context of human history; they argued that highly-processed foods weren't really foods at all, they were substances that were "kicked around, doped and puffed up by hucksters". Rorty and Norman's claim that the highly-processed food industry was fueling a monumental fad didn't stick; it was they who were labeled as 'food faddists'. Norman argued that fellow clinicians should be urging patients to choose foods rich in nutrients and avoid "highly-processed food commodities low in nutrients." Furthermore, he proposed that health practitioners of all stripes should align together to promote "an effective consumer boycott" of highly-processed foods. Over the next few decades, terms like 'junk food', 'convenience food', 'highly-processed food', and 'fast-food', were used interchangeably to describe foods that were, by-and-large, dense in calories, low in nutrients, low in fiber, high in sugar and/or fat and/or sodium, and inclusive of emulsifiers, flavor enhancers, various synthetic additives. By the 1980's, the term 'ultra-processed food' entered this fold in a 1982 Esquire article entitled The Universal Salesman, author Laurence Shames called out the marketing executives who peddled "ultra-processed foodstuffs whose labels read like a chem text"; in 1989, integrative medicine pioneer, Leo D. Galland, referred to the 1970's-80's as the "era of ultra-processed foods".

Processed foods classification according NOVA

Almost all foods are processed to some extent, if only by preservation, and it is therefore unhelpful to criticize foods as being 'processed'. A number of food classifications have been devised that pay special attention to types of processing. A systematic review has shown that, of these, NOVA is the most specific, coherent, clear, comprehensive and workable. NOVA classifies all foods and food products into four groups according to the extent and purpose of the industrial processing they undergo. It considers all physical, biological and chemical methods used during the food manufacturing process, including the use of additives.

Minimally processed foods, that together with unprocessed foods make up NOVA group 1, are unprocessed foods altered by industrial processes such as removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, roasting, boiling, pasteurization, refrigeration, freezing, placing in containers, vacuum packaging or non-alcoholic fermentation. None of these processes add salt, sugar, oils or fats, or other food substances to the original food. Their main aim is to extend the life of grains (cereals), legumes (pulses), vegetables, fruits, nuts, milk, meat and other foods, enabling their storage for longer use, and often to make their preparation easier or more diverse.

NOVA group 2 is of processed culinary ingredients. These are substances obtained directly from group 1 foods or from nature, like oils and fats, sugar and salt. They are created by industrial processes such as pressing, centrifuging, refining, extracting or mining, and their use is in the preparation, seasoning and cooking of group 1 foods.

NOVA group 3 is of processed foods. These are industrial products made by adding salt, sugar or other substance found in group 2 to group 1 foods, using preservation methods such as canning and bottling, and, in the case of breads and cheeses, using non-alcoholic fermentation. Food processing here aims to increase the durability of group 1 foods and make them more enjoyable by modifying or enhancing their sensory qualities.

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The ultra-processed foods group in NOVA classification

Ultra-processed foods are formulations of ingredients, mostly of exclusive industrial use, that result from a series of industrial processes (hence 'ultra-processed'). Processes enabling the manufacture of ultra-processed foods involve several steps and different industries. It starts with the fractioning of whole foods into substances that include sugars, oils and fats, proteins, starches and fiber. These substances are often obtained from a few high-yield plant foods (corn, wheat, soya, cane or beet) and from puréeing or grinding animal carcasses, usually from intensive livestock farming. Some of these substances are then submitted to hydrolysis, or hydrogenation, or other chemical modifications. Subsequent processes involve the assembly of unmodified and modified food substances with little if any whole food using industrial techniques such as extrusion, molding and pre-frying. Colors, flavors, emulsifiers and other additives are frequently added to make the final product palatable or hyper-palatable. Processes end with sophisticated packaging usually with synthetic materials.

Ingredients that are characteristic of ultra-processed foods can be divided into food substances of no or rare culinary use and classes of additives whose function is to make the final product palatable or often hyper-palatable ('cosmetic additives'). Food substances of no or rare culinary use, and used only in the manufacture of ultra-processed foods, include varieties of sugars (fructose, high-fructose corn syrup, 'fruit juice concentrates', invert sugar, maltodextrin, dextrose, lactose), modified oils (hydrogenated or interesterified oils) and protein sources (hydrolyzed proteins, soya protein isolate, gluten, casein, whey protein and 'mechanically separated meat'). Cosmetic additives, also used only in the manufacture of ultra-processed foods, are flavors, flavor enhancers, colors, emulsifiers, emulsifying salts, sweeteners, thickeners, and anti-foaming, bulking, carbonating, foaming, gelling and glazing agents. These classes of additives disguise undesirable sensory properties created by ingredients, processes or packaging used in the manufacture of ultra-processed foods, or else give the final product sensory properties especially attractive to see, taste, smell and/or touch.

Processes and ingredients used for the manufacture of ultra-processed foods are designed to create highly profitable products (low-cost ingredients, long shelf-life, branded products) which are liable to displace all other NOVA food groups. Their convenience (imperishable, ready-to-consume), hyper-palatability, branding and ownership by transnational corporations, and aggressive marketing give ultra-processed foods enormous market advantages over all other NOVA food groups. Marketing strategies used worldwide include vivid packaging, health claims, special deals with retailers to secure prime shelf space, establishment of franchised catering outlets, and campaigns using social, electronic, broadcast and print media, including to children and in schools, often with vast budgets. All this explains why ultra-processed foods have been successful in displacing unprocessed or minimally processed foods and freshly prepared dishes and meals – or 'real food' in most parts of the world.

Definitions of ultra-processed foods

These are made up from group 2 substance (Group 2 is of substance extracted from whole foods) to which either no or relatively small amounts of minimally processed foods (Group 1) are added, plus salt, and other preservatives, and often also cosmetic additives.

This group is defined as a process that mixes group 2 ingredients (processed culinary or food industry ingredients) and group 1 foodstuffs (unprocessed or minimally processed foods) to create durable, accessible, convenient, and palatable ready-to-eat or ready-to-heat food product liable to be consumed as snacks or desserts or to replace home-prepared dishes.

These are formulated mostly or entirely from ingredients and typically contain no whole foods. The purpose is to devise durable, convenient, high or ultra-palatable, and profitable products. They typically are not recognized as versions of foods. Most are designed to be consumed by themselves or in combination snacks or drinks. Most of the ingredients used by manufacturers are not available in supermarkets or other retail outlets. Although some are directly derived from constituents. Numerically, the great majority of ingredients of ultra-processed products are additives of various types that include among others, bulkers, sweeteners, sensory enhancers, flavors, and colors.

Formulated mostly or entirely from substances derived from foods. Typically contain little or no whole foods. Durable, convenient, accessible, highly or ultra-palatable, often habit-forming. Typically, not recognizable as versions of foods, although may imitate the appearance, shape, and sensory qualities of foods. Many ingredients not available in retail outlets. Some ingredients directly derived from foods, such as oils, fats, flours, starches, and sugar. Others obtained by further processing of food constituents. Numerically the majority of ingredients are preservatives; stabilizers, emulsifier, solvents, binders, bulkers; sweeteners, sensory enhancers, colors and flavors; processing aids and other additives. Bulk may come from added air or water. Micronutrients may "fortify" the products. Most are designed to be consumed by themselves or in combination as snacks. They displace food-based freshly prepared dishes, meals. Processes include hydrogenation, hydrolysis, extruding, molding, reshaping; preprocessing by frying, baking. The third group (ultra-processed foods) is composed of industrial products that are made entirely or mostly made from substance that have been extracted from food (oils, fats, sugar, starch, proteins), those that are derived from food constituents (hydrogenated fats, modified starches), or foods synthesized in a laboratory based on organic materials such as oil and cola (colorants, flavorings, flavor enhancer, and other additives used to give the products attractive sensory properties).

The fourth NOVA group is of ultra-processed food and drink products. These are industrial formulations typically with 5 or

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more and usually many ingredients. Such ingredients often include those also used in processed foods, such as sugar, oils, fats, salt, antioxidants, stabilizers, and preservatives. Ingredients only found in ultra-processed products include substances not commonly used in culinary preparations, and additives whose purpose is to imitate sensory qualities of group 1 foods or of culinary preparations of these foods, or to disguise undesirable sensory qualities of the final product.

Formulations of several ingredients that, besides salt, sugar, oils and fats, include food substances not used in culinary preparations, in particular, flavors, colors, sweeteners, emulsifiers, and other additives used to imitate sensorial qualities of unprocessed or minimally processed foods and their culinary preparations or to disguise undesirable qualities of the final product.

Industrial formulations typically with 5 or more and usually many ingredients. Besides salt, sugar, oils, and fats, ingredients of ultra-processed foods include food substances not commonly used in culinary preparations, such as hydrolyzed protein, modified starches, and hydrogenated or interesterified oils, and additives whose purpose is to imitate sensorial qualities of unprocessed or minimally processed foods and their culinary preparations or to disguise undesirable qualities of the final product, such as colorants, flavorings, non-sugar sweeteners, emulsifiers, humectants, sequestrants, and firming, bulking, de-foaming, anticaking, and glazing agents.

Results and Discussion

Key ingredients and additives in ultra-processed foods

UPFs are made from many recombined ingredients and/or additives, and we suggested that the link between UPF and food system sustainability is first driven by the massive production of these compounds. This question is addressed by identifying the ingredients/additives characteristic of ultra-processing within the list of UPF ingredients used in these products. Based on the UPF definition by NOVA, Figure 1 schematically represents the way in which a UPF is generally constructed, *i.e.,* through the cracking of raw foods into isolated ingredients that are then recombined in artificial matrices with the addition of industrial 'cosmetic' additives that are not commonly used in the kitchen. Depending on food products, e.g., ready-to-eat dishes, UPFs may also contain more or less real foods. The processes used to create these markers of ultra-processing include refining, extraction, purification, hydrolysis, and/or chemical modification. Such ingredients include processed carbohydrates such as sugar syrups, maltodextrins, dextrose, malt extracts and polyols, mainly extracted from maize, and wheat, rice, and potato; processed lipids such as refined and/or hydrogenated and inter-esterified oils; and processed proteins such as isolates from soy, milk, pea, egg, and meat, derived hydrolysates, and gluten. In addition to these ingredients, UPFs also contain "cosmetic" additives extracted directly from natural ingredients or chemically synthesized; there are more than 316 authorized at the European level and more than 2500 at the world level, as evaluated by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The 690,499 foods referenced in the French open food facts database make it possible to determine an initial approximation of the frequency of these main ingredients/additives in UPFs (Tables 1 and 2). This database is today the most comprehensive one about packaged foods, and that gives the list of ingredients for most registered foods. Notably, this database has been previously used for retrieving lists of additives from approximatively 126,000 foods.

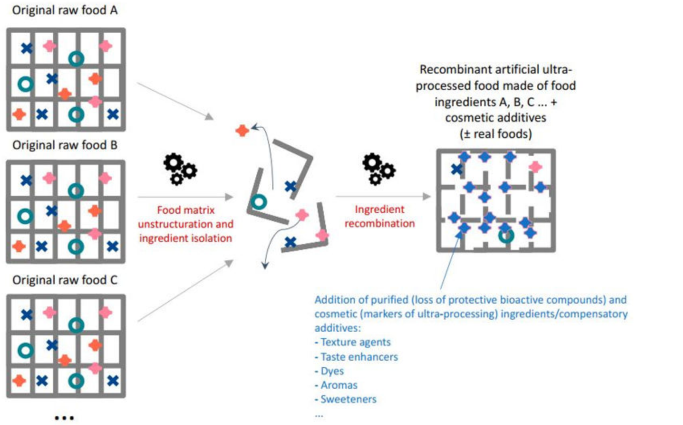

Figure 1. *Schematic representation of UPFs through fractionation of original raw foods and ingredient recombination with 'cosmetic' additives. Figure was originally supplied by the Siga Society©.*

Starches and glucose-fructose/glucose syrup are by far the most commonly used carbohydrate-based ingredients in UPFs, being found in at least 7.6% and 3.2% of all referenced products, respectively. Ranking third are dextrose (>3.1%) and lactose (>1.6%), followed by malt extract (>1.2%), dextrin/maltodextrins (>1.1%), and invert sugar (>0.6%). For lipids, refined oils are extensively used and are found in at least 9.4% of referenced products, while hydrogenated oils are less commonly used (0.01%). In addition, for proteins, gluten (>1.7%) and milk protein isolates (>3.7%) are the most commonly used, while egg white proteins, gelatine, as well as pea and soy protein are less commonly used, falling in the range of 0.01–0.6%, and protein hydrolysates are used in a minimum of 0.04% of referenced products. Aromas are much more commonly used, being found in at least 10.5% of all referenced products (Table 1).

Concerning additives, the most commonly used are texturing agents such as lecithins (>3.4%), modified starches (>2.4%), xanthan gum (>1.7%), mono and diglycerides of fatty acids (>1.7%), pectins (>1.5%), diphosphates/pyrophosphates (>1.5%), guar gum (>1.3%), and carraghenans (>1.2%); coloring agents such as capsanthin (>0.7%), carotenes (>0.6%), carmines (>0.5%), and plain caramel (>0.5%); and taste modifiers such as monosodium glutamate (>0.5%), sucralose (>0.4%), acesulfame potassium (>0.3%), aspartame (>0.2%), and steviol glycosides (>0.1%) (Table 2).

Mass production of ultra-processed non-additive ingredients, and of numerous additives processed from the cracking of raw

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foods, mainly comes from intensive monocultures or livestock of only a few plant/animal varieties. At minimum, their percentage use in foods varies from 0.03 to 12.6 of all foods (Tables 1 and 2), suggesting a high level of consumption, notably due to the rapid increase in worldwide UPF consumption, especially in Latin America. In the following section, we will therefore analyze how the agricultural system at the basis of these ingredients is linked with sustainability or not, and the impacts of UPF-like product consumption on environmental indicators such as Greenhouse Gas Emissions (GHGEs).

Table 1. *Number of food products for the different non-additive ingredients 'characteristic of ultra-processing[1].*

Ingredients	Number of food products[2]	Percentage of all products in the open food facts database[2]
Ultra-processed carbohydrates	>52,154	>7.6
Glucose-fructose syrup/glucose syrup/(oligo)fructose	>22,389	>3.2
Starch	>21,340	>3.1
Dextrose	>11,232	>1.6
Malt (extract)	>8292	>1.2
Maltodextrins/dextrins	>7756	>1.1
Invert sugar	>4349	>0.6
Ultra-processed lipids		
Refined plant-based oils and fats[3]	>64,811	>9.4
Hydrogenated oils	>99	>0.01
Ultra-processed proteins		
Milk/whey/casein protein	>11,789	>1.7
Gluten	>11,428	>1.7
Gelatine	>3970	>0.6
Soy protein	>1953	>0.3
Pea protein	>1289	>0.2
Pea protein	>307	>0.04
Egg white and protein	>62	>0.01
Aroma[4]	>72,348	>10.5

Note: [1]Collected from the French Open Food Fact database, which contains 690,499 products (on 20 June 2020, as described previously, [2]Ingredient lists are not given for all products in the Open Food Facts database: Therefore, given values are only minimum values, [3]Refined oils are not strictly characteristic of UPFs in NOVA classification; however, due to the high level of processing that refined oils undergo, they were considered in this analysis, as in the Siga score methodology, [4]Includes artificial and natural aromas.

Table 2. *Number of food products for the different 'cosmetic' additives 'characteristic of ultra-processing[1].*

Additives	Number of food products[2]	Percentage of all products in the open food facts database[2]
Texture		
E322: Lecithins	>23,640	>3.4
E14XX: Modified starches	>16,405	>2.4
E415: Xanthan gum	>12,015	>1.7
E471: Mono and diglycerides of fatty acids	>11,828	>1.7
E440: Pectin	>10,172	>1.5
E450: Diphosphates, pyrophosphates	>10,644	>1.5

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E412: Guar gum	>9177	>1.3
E407: Carraghenans	>8616	>1.2
E420: Sorbitol	>4285	>0.6
E406: Agar-agar	>842	>0.1
E1200: Polydextrose	>375	>0.1
E421: Mannitol	>235	>0.03
Color		
E160c: Paprika extract, capsanthin, capsorubin	>5101	>0.7
E160a: Carotenes	>4347	>0.6
E120: Cochineal, carmines, carminic acid	>3560	>0.5
E150a: Plain caramel	>3097	>0.5
E133: Brilliant blue FCF	>1450	>0.2
Flavor/taste		
E621: Monosodium glutamate	>3710	>0.5
E955: Sucralose	>2436	>0.4
E950: Acesulfame potassium	>2329	>0.3
E951: Aspartame	>1249	>0.2
E960: Steviol glycosides	>880	>0.1
E953: Isomalt	>443	>0.06
E967: Xylitol	>394	>0.06
E954: Saccharine	>238	>0.03
Note: [1]Collected from the French Open Food Fact database, which contains 690,499 products (on 20 June 2020, as described previously, [2]Ingredient lists are not given for all products in the open food facts database; therefore, given values are only minimum values.		

Evaluation the environmental and social consequences of ultra-processed foods

Authors distinguished processing at the household, village and factory levels with different impacts on the environment, with the main risk of the factory level being "the community as a whole does not often share the profit, which is the main drawback of shifting towards factory food processing. This is "why Clarke demands that 'factories need to be well planned and should be not too big as otherwise massive investments may be lost and local lifestyles, cultures and traditions can be seriously and often irretrievably affected'. An alternative approach for factory processing might be village processing. More generally, in a presentation given at the International Sustainability Conference in 2005 entitled "Nutrition ecological assessment of processed foods", Riegel et al. gave a framework to rate the impact of processed foods not only on health but also on the other different dimension of sustainability, additionally including social, economic and environmental impacts. Concerning the environmental impact, authors proposed to consider agriculture (*i.e.,* favoring low input and organic agriculture), transport (*i.e.,* means of transport and miles per output unit), energy (*i.e.,* consumption per output unit), and water (*i.e.,* consumption per output unit and pollution).

Ultra-processed foods vs. Discretionary foods

Discretionary foods are very similar to UPFs, as they are defined as energy-dense foods and drinks that are high in saturated fats, sugars, salt and/or alcohol and are not necessary to provide the nutrients that the body needs. At first glance, eating too many calories favors more GHGEs. Therefore, UPFs, which lead to consume more calories than minimally processed foods, indirectly generate more GHGEs. Under this assumption, the study by Hendrie et al. is particularly interesting. These authors showed that the overconsumption of energy and excessive discretionary foods contributes 29.4% to the total GHGEs of the Australian population. However, other food groups probably containing UPFs may contribute even more than 30% of the GHGEs of the overall diet. Furthermore, their study shows that reducing discretionary food intake would allow for small increases in emissions from core foods (particularly vegetables, dairy and grains), thereby providing a nutritional benefit at little environmental expense. However, the GHGE calculations in this study are derived from typical LCA and misrepresent less intensive agro-ecological systems.

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Altogether, a first strategy for reducing GHGEs and to simply fulfil recommended energy needs would be to limit caloric intake from UPFs, *i.e.,* at a level of 15% of recommended ≈2000 kcal/day. Beyond GHGEs, water use is another indicator of the environmental impact of foods. In a recent study about core and discretionary foods consumed daily by a large (>9000) population of self-selected adults, a potential association between a healthier diet and lower environmental impacts was emphasized. Indeed, this study concluded that "excessive consumption of discretionary foods *i.e.,* energy-dense and nutrient-poor foods high in saturated fat, added sugars and salt, and alcohol-contributes up to 36% of the water-scarcity impacts and is the primary factor differentiating healthier diets with lower water-scarcity footprint from poorer quality diets with higher water-scarcity footprint". The authors added that very large reductions in the dietary water-scarcity footprint are therefore possible, notably through technological change, product reformulation, and procurement strategies in the agricultural and food industries.

Ultra-processed foods and plastic pollution

Overall, the consumption of UPFs is high in Western countries, especially Anglo-Saxon countries, with 307 kg/year per capita in the USA, followed by Canada (230 kg), Germany (219 kg), Mexico (214 kg), Belgium (210 kg), Australia, Norway and the UK (>200 kg/year). Conversely, it is still low in India (7 kg) and some African, South America and Asian countries (<100 kg). However, the growth rate of sales is very large in emerging countries, with a 115% increase in sales between 2000 and 2013 for Asian and Pacific regions, 71% in the Middle East and Africa, and 73% in Eastern Europe. Overall, world growth was 44% during this period. Finally, the market share of UPFs is the highest in Asian and Pacific countries, with 29.2%. Therefore, our massive consumption of over-packaged UPFs worldwide is very likely to generate massive plastic pollution without neglecting plastic bags to bring products from market to home.

Indeed, over-packaged UPFs are designed to be consumed while travelling, in isolated situations, and rapidly. Overall, the largest source of plastic production is packaging, driven by the pervasive commercial use of single-use containers destined for immediate disposal. Worldwide, primary plastic waste generation has grown from nearly 0 in 1950 to 300 million metric tons (Mt) in 2015, with approximately 42% being used for food packaging and approximately 79% being accumulated in landfills or the natural environment, with dramatic impacts on marine life. In supermarkets, UPFs constitute more than two-thirds of packaged foods in France, more than 70% in the USA, and even more than 83% in New Zealand. Therefore, it is very likely that returning to more fresh food should drastically alleviate plastic waste. Notably, marine animals are mostly affected through entanglement in and ingestion of plastic litter, and the absorption of polychlorinated biphenyls from ingested plastics is another threat. As reported recently, there is also growing evidence that many single-use materials in contact with food, including plastics, can pose health risks to consumers through chemical migration. It has been shown that harmful chemicals, such as endocrine disruptors, migrate not only in plastic packaging, but also in other materials, such as recycled paperboard.

Ultra-processed foods and health troubles

A major challenge in public health is confronting the multinational billion-dollar corporations that profit from selling products such as alcohol, tobacco/nicotine, and Ultra-Processed Foods (UPFs, e.g., soda, chips, snack cakes) known to accelerate poor health. Unfortunately, public regulatory and market intervention efforts typically rely on industry self-regulation (e.g., reformulating products to barely meet school lunch standards, such as 51% whole grain), an approach that has been ineffective in preventing the adverse health outcomes associated with these commodities.

One randomly controlled study in a metabolic ward setting found that increased consumption of UPF was associated with a rise in body weight while the control arm, fed a MP diet, showed no such trend. Because this trial involved ad libitum intakes of food, the range of foods offered to either arm of the study at each meal exceeded the predicted energy intake and the two arms of foods offered had identical mean energy densities. However, from the foods offered, those chosen by the subjects in the UPF arm had a higher energy density than the foods chosen on the MP diet. Energy density is a known driver of energy intake and thus should be controlled for in studies of UPF intake and obesity. Sadly, it has never been retained as a variable in any of the studies of UPF intake and obesity. A Dutch study has shown that whereas the mean energy density of UPF is higher that less processed foods, the within-category variability is also very high. Thus, MP foods can have a high energy density (avocados, peanuts, butter) while foods designated as highly processed can have a low energy density (breads, breakfast cereals, flavored low-fat yogurts). In the randomized controlled trial that found an association between the intake of UPF and obesity, a higher eating rate was also found on the UPF arm of the trial. A high eating rate is strongly associated with weight gain. Further gains in nutrient intake with bread and breakfast cereals can be achieved by promoting whole grain varieties and through reformulation. However, the NOVA recommendation that all UPF foods be avoided, including industrially prepared breads and breakfast cereals, does not make sense for public health nutrition policy. Moreover, NOVA opposes the concept of reformulation of foods on the grounds that one cannot make an unhealthy food (subjectively defined) healthy.

Some studies have found associations between UPFs and anxiety, but the weight of the evidence suggests a dose–response risk for depression but not anxiety. Large prospective studies have documented associations between increased UPF intake and higher incident depression after extensive adjustment for dietary patterns correlated to UPFs (e.g., physical activity, sleeping hours, television viewing) and other potential confounders (e.g., marital and employment status). These dose–response findings often emerge in adolescence, even after adjusting for factors such as self-perceived body image and bullying victimization. Higher UPF consumption also correlates with elevated internalizing symptoms such as boredom, crying, fear, worry, loneliness, unhappiness, poor sleep, and sadness.

Conclusion

The emerging field of food addiction is not without criticism and debate and the condition is not a formally recognized diagnosis. While the Yale Food Addiction Scale (now YFAS 2.0) asks about symptoms and behaviors related to foods that can be categorized as UPFs (e.g., sweets, packaged snacks, sweetened beverages), the NOVA classification system has substantiated a proposed rename of "food addiction" to the more specific term UPFA. Notably, over a decade of research has demonstrated that most UPFs elicit addiction-like biological and behavioral responses, whereas MPFs do not. Biological responses include striatal activation (*i.e.,* dopamine projection), whereas a more frequent consumption pattern reduces reward responsivity in this region. Such changes parallel the phenomenon of tolerance, which is associated with UPF seeking despite risk and negative consequences. While there is no single biomarker for addictions, neuroimaging research on functional connectivity that corresponds with behaviors associated with decreased executive functioning (e.g., impulsivity) around salient stimuli (*i.e.,* UPFs) will strengthen the UPFA construct. The role of early life adversity is emerging as an important predictor of altered reward network connectivity among those with UPFA.

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