

Commentary

Astrofood, Priorities and Pandemics: Reflections of an Ultra-Processed Breakfast Program and Contemporary Dysbiotic Drift

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Abstract: Recognizing the importance of nutrition as part of the grand challenges faced by humanity—the current epidemic of non-communicable diseases (NCDs), sustainability and maintenance of Planetary Health—the United Nations (UN) has declared 2016–2025 the Decade of Nutrition. Research continues to underscore the extent to which ultra-processed foods dominate the contemporary nutritional landscape. Moreover, the dual role played by food technology and marketing in the expansion of ultra-processed foods is under increased scrutiny. As public health experts and clinicians contend with a crisis of NCDs, attempting to untangle a knotted assortment of interrelated strands of causation, an examination of the early origins of highly-marketed ultra-processed foods can provide valuable lessons. Here, we illuminate a little-known piece of history in the annals of ultra-processed nutritional science and childhood welfare. Astrofood was a commercially-marketed, collaborative government-industry effort that brought soy protein-enriched Twinkies as a nutritive breakfast cake to disadvantaged children; its concept and delivery demonstrated an unwillingness to deal with root-cause challenges. Although its official tenure was only about 7 years, we argue that Astrofood and its total food engineering still resonate throughout the global ultra-processed nutritional landscape. New scientific advances in nutritional psychiatry and the microbiome are on a collision course with the profits, marketing and intellectual dishonesty of the ultra-processed food industry. Solutions to the grand challenges of the Decade of Nutrition may be found in lessons from Astrofood. They provide clues to undoing the tangled knots which otherwise maintain an untenable status quo.

Keywords: anthropocene; societies; social justice; ecology; microbiome; prevention; health policy; equity; mental health; non-communicable diseases; lifestyle medicine; nutrition

1. Introduction

“We achieve what nature could not do.” Robert H. Cotton, International Telephone and Telegraph Corporation [1].

In the spring of 1971, 12,000 financially disadvantaged American children in schools and day care centres were provided with a unique, federally-funded breakfast cake. Its manufacturer, the mega-multinational International Telephone and Telegraph Corporation (ITT) and its subsidiary Continental Baking Company, touted the breakfast cake as a breakthrough in food engineering. In a nationwide marketing campaign, ITT claimed (as it did to Congress) that when combined with milk, the fortified cake—known as Astrofood—was the nutritional equivalent of *“four ounces of orange juice, two strips of bacon, an egg, and a piece of buttered toast”* [2]. The following year ITT was churning out

more than half-a-million Astrofood cakes per month, and by 1974—at the cajoling of ITT and over the objection of select nutrition advocates—the inclusion of fortified, ultra-processed cakes became a formal part of the United States Department of Agriculture (USDA) Federal School Breakfast Program [3].

The Astrofood concept was a collaboration between ITT's Vice President at Continental Bakery, Robert H. Cotton, and USDA Deputy Director Ed Koenig. In his own words, Koenig describes the origins in clear terms: *"We wanted to devise a food that was cheap and easy to handle. We got a brainstorm. ITT's biggest seller with kids is Hostess Twinkies. We figured if we make something as appealing as a Twinkie, yet as nutritious as fruit and cereal...we needed something fast and ITT had a product that was ready to go"* [4]. Furthermore, Koenig also described the ease with which the brainstorm could be put into action: *"A truck can back up to the school door, dump hundreds of cartons of milk and cakes in the hallway if need be, the kids can grab them and eat them. No forks or spoons, none of this bowls or glasses of juice spilling over"* [5]. With a tweak of the USDA language concerning the definition of breakfast, the idea moved forward; Food and Nutrition Service, Child Nutrition Notice 180 of 19 October 1970, included a "Fortified Cake Product with Creamed Filling for Use in Breakfasts" [6].

In its nationwide marketing campaign, with dominant ads in media outlets ranging from the *Los Angeles Times* to *Ebony* and *Black Enterprise*, ITT told a more nuanced story of the intellectual wellspring for Astrofood [7–9]. They claimed the product was in response to the challenges set forth at the White House Conference on Food, Nutrition and Health which was held 2–4 December 1969. Attended by some 3000 interested parties from science, medicine, academia and industry, the White House Conference focused on, among other subjects, the prevalence of childhood hunger in the US. The conference included several "New Food" panels geared toward food engineering and assembling novel dietary items from isolated macro/micro nutrients, both natural and synthetic. The conclusion of the corporate-led panel was immediate food fortification program to relieve malnutrition. Robert H. Cotton of ITT was on the panel devoted to systems of delivery for food, which recommended *"research on new foods, especially nutritional snacks, which could be introduced through the schools but which might have an impact on the whole population"* [10].

1.1. Roadmap to the Current Review

Here in our perspective review, we will discuss the nutritional formulation of Astrofood and place its historical development and continued legacy in the contemporary context of a nutritional landscape dominated by highly-processed foods, corporate-public health campaigns intertwined with profits, and an epidemic of non-communicable diseases (NCDs). We argue that Astrofood, once brought to disadvantaged American schoolchildren by the makers of Twinkies, is a symbol of modern-day dysbiotic drift; from its Greek root, dysbiosis translates as "life in distress". The term is also used in the microbial context where it is defined by loss of beneficial microorganisms, and/or the expansion of potentially harmful microbes, and/or the loss of overall microbial diversity. We will underscore the ways in which ITT's Astrofood endures, that in many ways the westernized diet is Astrofood-like, potentially contributing to life in distress for both commensal microbes and the psyche of the human host.

Finally, we will open up discourse on societal priorities. The idea for Astrofood began in the midst of the Apollo lunar missions and the Vietnam War. Today, the sophisticated science of food engineering (not only taste, but positioning on shelf and advertisements for sales) as a contributor to NCDs is set within growing health inequalities and massive gaps in socioeconomic status (SES). Such engineering, now a large-scale Astrofood-effort, is currently set within enduring wars and a zest for human Mars exploration. We will return to some of the less-publicized ideas presented at the 1969 White House Conference on Food, Nutrition and Health.

We underscore at the outset that food technology and the processing of food provides untold value to human health and well-being. So, too, has individual nutrient fortification proven its value in public health. Our commentary isn't a "back to nature" effort. However, in the context of environmental justice, we ask, what are the societal costs of ignoring or providing only minimal investments toward

exploring the science of nutrition for mental health, and to what extent inequalities—nutritional and otherwise—are actually engineered? To what extent (to borrow terms from Rene Dubos [11]) does intellectual dishonesty and escapism burden the channels of food technology as it pertains to the defense of ultra-processed foods? Answers to such questions are a critical part of the grand challenge set forth by the United Nations in its recently declared Decade of Action on Nutrition (2016–2025) [12].

1.2. Helping Out—Development of H-11

Astrofood was developed under its laboratory name of H-11. The backbone of H-11 was ITT's Twinkies which the company described as a "fun-food". ITT had purchased the Continental Baking Company in 1968; although Twinkies enjoyed popularity when ITT assumed control, they used powerful marketing and manufacturing strategies to elevate the sales of Twinkies to lofty heights and facilitate their place in American cultural folklore. By the mid-1970s, American consumers purchased 700 million of the snack cakes [13]. Although sugar remained the dominant ingredient, the composition of Twinkies differed from its simple, short-shelf-life origins when they debuted in 1930; the ingredient list and shelf-life grew steadily under the watch of ITT (1968–1984).

The challenge for ITT's modified-Twinkie breakfast was twofold—get some protein and vitamins into H-11, and do it cheaply. The pledge to defeating hunger at breakfast was heavy on rhetoric and light on funding. But ITT was committed to delivering a breakfast on a 15¢ federal budget, of which 7¢ had to be devoted to the carton of milk. Cotton described the Astrofood formulation process and final product in the journal *Cereal Science* [14] and the *Journal of the American Oil Chemists Society* [15]. Emulsification, the addition of vegetable oil rich in the omega-6 fatty acid linoleic acid and synthetic vitamins (heat-sensitive vitamin C and B1 added into the vegetable oil solids-based "cream" after the baking process) facilitated formulation. Inexpensive soy protein helped provide the minimum of 5 g of protein. Since the USDA set no restrictions on total carbohydrate or sugar content of the breakfast supplement (but they did set a *maximum* fiber content of 0.8%), the product, much like the Twinkies backbone, was dominated by sugar.

ITT knew there were concerns that a high-sugar cake-like product could promote dental caries but these were speculatively tempered by Cotton: "We have reason to suspect that highly emulsified, fat-containing cake with creamed filling will clear the mouth faster, leaving less compacted food matter than, say, a dry cracker. Because the cake is taken with milk, we believe the mouth should clear quickly". The company proceeded to test H-11 as a pilot project in several schools within the Northeastern US. Cotton touted anecdotal reports that children were more likely to be present at school, and while there, more attentive and less sleepy [1]. These claims were never substantiated.

Nevertheless, during the week of 22 March 1971, the Chairman of the Board of ITT Continental Bakery, R. Newton Laughlin, and President, M. Cabell Woodward Jr., blanketed big-market newspapers with an identical advertisement, near-full-page, titled with bold block letters: "An Important Message to Every Mother in America". The message concerned ITT's commitment to nutritional wellbeing:

"Our Hostess Cakes provide sound nutrients as well as good taste. As a mother, you know how important this is. As a further step in our efforts to contribute as much as we can to America's nutritional wellbeing, we developed "Astrofood". This specialized breakfast food is designed to help provide children with the nutrients they need for greater attentiveness and learning capacity. Especially important to children in underprivileged areas, Astrofood is being made available to schools across the nation. ITT Continental baking worked with the US Department of Agriculture on this project" [16,17].

H-11, an ultra-processed mix of sugar, omega-6-rich vegetable oil, soy flour, soy protein isolate and emulsifiers officially became Astrofood, a government-approved breakfast. The name appealed to children; ITT had worked with NASA on many ventures in the Apollo program. It was a watershed moment, the era of highly-processed foods had begun in earnest, and mothers were being reassured that multinational corporations such as ITT were collaborating with trusted public agencies to promote health, especially in society's most vulnerable, through optimal nutrition. Although Astrofood was by no means the first ultra-processed food developed [6,18], it maintains a notable place in history as

exemplifying superficial attempts to address complex societal problems with the motivation of the lowest common denominator—profit.

1.3. Processing the Legacy of Astrofood

Through pressure from nutrition groups concerned about sugar intake, and public advocates of whole food nutrition, the fortified-baked goods supplemental breakfast program was due to expire on 30 June 1978. However, after immense industry pressure, the Chair of the House Agriculture Subcommittee, Representative Jamie Whitten, held an unusual closed-door meeting on Astrofood; the result of the meeting was maintenance of the rules that allowed for Astrofood. When asked, Whitten could provide no explanation for why the Committee meeting was held outside the public eye, other than to say “so we could thrash these things out”. His explanation for maintaining the breakfast cake loophole was that “no one in Washington should say what is best for everyone in the country” [19].

Over time Astrofood as a specific product would be phased out; however, the legacy of engineered, ultra-processed foods remains, and the contribution of such foods to chronic NCDs and other pressing issues of our time looms large. In order to emphasize the historical importance of Astrofood in the annals of nutrition transition history, it may be helpful to distinguish between food processing and ultra-processed foods.

The modification of nourishing substances has been part of the human experience since time immemorial. Scientific endeavors at ancient sites reveal the extent to which humans have used fire, grinding stones, fermentation and other modification techniques to extract and preserve nutrients over the millennia [20,21]. Modern freezing, canning and various forms of packaging have provided immeasurable value to public health as they facilitate the widespread distribution of safe, healthy and nutritious foods. Today, multinational corporations within the food industry (and industry-supported scientists) remind both academic and lay readers that most foods are “processed” in the aforementioned ways. However, conflating ancestral fermentation, canned salmon and frozen spinach with Twinkies and carrageenan-rich, textured meat patties in the context of being processed (that is, avoiding criticism of contemporary industrial food processing) is, in our opinion, an act of intellectual escapism, if not intellectual dishonesty.

To cut through this noise and define food processing in the forms where it might present a threat to human and ecological health, the World Health Organization and leading public health scientists now refer to “ultra-processed” foods. These are not the modified foods used by our ancestors or the cheeses and pressed olive oil of the Mediterranean diet; rather they are “formulations” made mostly or entirely from substances (originally derived from whole or minimally-modified foods) and additives, reassembled but with little, if any, intact whole food within the formulation [22]. These foods mostly include ingredients not usually used in a domestic kitchen—hydrogenated fats, modified starches, protein isolates, emulsifiers, artificial sweeteners and flavorings et al. [23]. Whereas traditional cheeses might have 3 or 4 ingredients, the ultra-processed variety destined for ‘macaroni and cheese’ might have 2 dozen. Despite what industry front groups might suggest, most consumers are well aware of the differences between ultra-processed foods and traditional food processing [24].

Public health experts underscore the ability of ultra-processed foods to dominate and displace healthier, minimally-modified foods: “The nature of the ingredients, the various processing techniques and the sequences of stages used by the industry to manufacture ultra-processed foods are designed to create durable, accessible, convenient, hyper-palatable, highly profitable ready-to-eat, ready-to-drink or ready-to-heat products liable to displace all other...food groups” [22]. Available evidence shows that ultra-processed foods do indeed displace their healthier whole-food and minimally-modified counterparts, with greater consumption of ultra-processed foods linked with high consumption of free sugars and total, saturated and trans fats, and with low consumption of protein, dietary fiber, and various vitamins and minerals [25–27]. Moreover, research indicates that ultra-processed foods contribute to the physiological changes (e.g., elevated blood glucose, blood lipid alterations, adiposity) which link these foods to risk of NCDs and mortality [28–33]. Even in children, early-life exposure to ultra-processed

foods is associated with blood lipid alterations which may place the individual on a trajectory to subsequent risk of NCDs [34].

Today, consumer packaged (ready-to-heat, ready-to-eat) foods with a high degree of industrial processing [35], and ultra-processed foods in particular, have become a major part of the diet in westernized nations, aboriginal peoples within such countries, and increasingly so in developing nations. For example, in North America, ultra-processed foods represent 50% or more of energy intake [27,36], while in transitioning nations, such as Brazil and Chile, they represent approximately 30% of energy intake [37,38]. Across Europe, household availability of ultra-processed foods varies widely, on average they represent 26%, but in the United Kingdom the household purchases are over 50% [30]. Among First Nations people in Canadian Provinces, ultra-processed foods now provide 54% of daily energy intake [39]. Food technology has brought inexpensive “instant” noodles to the table, and only recently are scientists catching up with the health-related consequences of their encroachment into traditional dietary patterns in Asia and beyond [40–42].

The Framingham Heart study began in the U.S. about the same time H-11 was transitioning to Astrofood. Recently researchers examined whether or not the residential food environment among the subjects of the study (in four distinct geographic areas of the Northeast, U.S.) had changed. Today the average number of fast-food outlets in proximity to the home and work of each subject has increased 5-fold [43]. In a nationwide study of U.S. veterans, it was reported that they have an average of 8 fast-food outlets within a one-mile radius of home [44]. Fast-food expansion in China—hundreds of McDonald’s and Kentucky Fried Chicken outlets are opening annually, far faster than their expansion in the continental U.S.—is a surrogate marker for alterations to the global nutritional environment [45]. Highly-recognizable, branded fast-food outlets are not alone; they are part of food swamps that include take-away shops, unbranded or local fast-food outlets, convenience stores, and the expansion of gasoline/petrol stations as purveyors of sugar-added drinks, snacks and main ready-to-eat meals [46–48]. Ultra-processed foods often find a dominant place in vending machines within academic settings [49–51].

The harsh reality is that ultra-processed foods are on the global menu. Astrofood was designed, at least superficially, as a cheap way to help undo nutritional problems associated with poverty and disadvantage in children. Hunger and malnutrition remains a global problem; however, inexpensive, nutrient-poor, calorie-dense, ultra-processed foods and drinks are now consumed in the greatest amounts by the most vulnerable in society. This is not exclusively a problem in wealthy, developed, westernized nations. In one of the largest studies of its kind, collaborators of the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) reported that around the world, at various levels of national development, unhealthy dietary patterns are strongly related to SES—children in lower income groups consistently have unhealthy dietary patterns [52].

1.4. Nutrition for Mental, Cognitive Health

At the 1969 White House Conference on Food, Nutrition and Health, there was broad agreement that the provision of quality nutrition (and undoing hunger) was an essential prerequisite to cognitive development, attention, and academic performance. However, outside of gross nutrient deficiencies, there was little in the way of research at that time to substantiate the effects of specific dietary patterns and nutrient combinations in relation to brain, behavior and emotional health. The idea that dietary quality and modest nutrient inadequacies might play an important role in mental health was an outlier in medical discourse [53].

Nearly half-a-century on, international research indicates that breakfast quality (both in school programs and in general) can support normal mood, behavior and cognitive performance in children [54–57]. Indeed, a breakfast with lower glycemic load (that is, one opposite to Astrofood) has been specifically shown to support mood and cognition in children in the two to three hours following a meal [58–60]. Moreover, in a 2017 breakfast study, researchers reported that a high-fat/high sugar “toasted sandwich” and chocolate milk-type beverage caused reductions in hippocampal-dependent

learning and memory in healthy young adults after only four days [61]. Skipping breakfast has also been linked to depression, anxiety and high levels of stress throughout the life course, and this is pronounced in association with socioeconomic disadvantage [62–64].

However, our discourse isn't about breakfast per se; rather, we underscore the increasingly robust research in the realm of "nutritional psychiatry" to highlight that the widespread encroachment of ultra-processed foods, fast-food, and energy-dense-nutrient-poor foods is a barrier to the fulfillment of human potential. Traditional, dietary patterns (exemplified by the Mediterranean diet) have been associated with good emotional and cognitive health, as well as lowered risk of depression and attention deficit hyperactivity disorder [65–67]. On the other hand, greater adherence to the westernized diet is associated with a smaller hippocampus, the area of the brain crucial to aspects of memory [68]. Short-term intervention studies based on such traditional or low-glycemic dietary patterns have shown benefit for individuals with depression, as well promoting positive mental outlook, benefits in memory and alleviation of fatigue [69–73].

1.5. Deconstructing Astrofood

From a biological perspective, Astrofood was built on the assumption that the delivery format of macro/micro nutrients was largely irrelevant and "new food" combinations (pieces of nature mixed in with additives) could easily replace the old foods; that is, the old delivery "format" in the form of whole foods—to which the genus *Homo* was accustomed for nearly 3 million years—was outdated. However, ancestral nutritional experience didn't prepare consumers of Astrofood (and the ultra-processed foods it represents) for the ways in which its parts were assembled into the whole cake.

First, the ratio of omega-6 to omega-3 fatty acid in ancestral nutritional experience was very close to 1:1. With the mass introduction of linoleic-acid-rich vegetable oils, such as that in Astrofood, the omega-6 to omega-3 ratio in the westernized diet is now around 16:1, and in some transitioning nations is as high as 50:1 [74]. Dominance of omega-6 relative to omega-3 has been linked to obesity, depression and childhood learning and behavioral disorders [75–78]; Second, added sugars, also foreign to ancestral experiences, have been linked with depression and behavioral disorders in human and animal research; mechanisms by which sugar could provoke mood, cognitive or behavioral disturbances include diminished levels of brain derived neurotrophic factor (BDNF) that otherwise supports stability and growth of nerves even past middle-age, elevation of inflammatory immune proteins such as cytokines (the elevation of which can compromise mood, disturb cognitive focus and increase anxiety), changes in blood-glucose-insulin control (which can effect subsequent mood), and addiction-like effects of sugar and sugar-fat combinations working through dopamine-mediated reward centers in the brain [79–81]. The effects of highly-palatable sugar or sugar-fat combinations may be especially disruptive to brain and behavior when encountered early in life [82].

Although soybeans have been a staple in Asia, the historical dietary intake was through fermented pastes, tofu and milks. Soybeans contain isoflavones which are natural chemicals with estrogen-like properties. In the Astrofood era, North American food engineers found "new food" applications for highly-processed isolated soy proteins and textured vegetable proteins, including soy [83,84]. These new food forms of soy are particularly rich in phytoestrogens. For example, textured soy protein contains over 8 times more phytoestrogens than soy milk [85]. Since new food soy was allowed to be mixed into a wide variety of meat products at levels up to 30% (meat labeled as patties, sausage, meatballs et al) including school lunches and multitudes of processed foods [86], it is nearly impossible to get a realistic idea of soy intake in North America (for example, a "meat" consumer who refrains from tofu and soymilk may not realize they are a soy consumer when asked on dietary recall studies). From our perspective of mental health, it is worth noting that several animal studies have shown soy isoflavones to increase anxiety-like behavior in males [87,88]. In humans, a J-shape curve has been reported wherein higher levels of soy intake have been associated with depression [89].

Since Astrofood was a combination of sugar and protein baked at high temperatures, we speculate that it would have been high in advanced glycation end-products (AGEs). These are highly oxidant

compounds formed through the non-enzymatic reaction between reducing sugars and free amino acids. AGEs are particularly abundant in westernized foods prepared with high heat in the absence of water (i.e., oven-baked goods). For example, a biscotti, with its oven-baked combination of protein and sugar, is extraordinarily high in AGEs—over 35 times higher than a poached egg [90]. This is of relevance because foods high in pre-formed AGEs have been linked to inflammation, oxidative stress and enhanced allergenicity of foods [91–93]; on the other hand, dietary interventions to lower exogenous AGE intake can significantly reduce systemic inflammation and oxidative stress [94].

The unspecified emulsifiers and synthetic additives will be addressed further in the dysbiosis section below. It is unclear if Astrofood was inclusive of artificial food colorants; Twinkies did include synthetic colors and flavors in the 1970s. Levels of artificial food dyes available in many markets have witnessed exponential growth—since 1968 the upper range of synthetic food dye in cereals has risen by almost 3-fold, and the amount in baked goods by over 3.5-fold—with early life intake far higher than previously estimated [95]. Synthetic food additives, especially colorants and preservatives, are under increased scrutiny; biologically they have been linked with inflammation [96], and behavioral problems which may not be exclusive to ADHD [97–99]. Many questions surround carrageenan, a seaweed derivative added to numerous foods for texture, binding and thickening (for example, carrageenan can be added to meat products in levels over one gram per patty [100]); it has been linked with inflammation in numerous experimental studies [101].

1.6. *Dysbiosis-Life in Distress*

The term microbiome refers to microbes and their collective functional genomes operating within an ecological niche [102]. When Astrofood was formulated there was only limited appreciation for the important role played by gut microbes in human health, and their interaction with diet and stress [103,104]. Today we know that the microbiome plays a functional role in nutrient absorption, manufacture of beneficial bioactive chemicals (e.g., short chain fatty acids and transformed phytochemicals), protection against pathogens, maintaining gut/skin and other barriers to the outside environment, reducing the burden of potentially-harmful environmental chemicals (xenobiotics). Microbes also “educate” the immune system in early life such that it can make appropriate, adaptive responses to the environment. Put simply, humans have evolved with microbes with mutual benefit.

Functional roles played by the microbiome are often discovered by observations following dysbiosis. Translating from its Greek root as “life in distress”, it is defined in the context of microbiology as disruptions to the structure of complex commensal microbial communities, involving one or more of the following: loss of beneficial microorganisms, and/or the expansion of potentially harmful microbes, and/or the loss of overall microbial diversity [105]. Dysbiosis can be induced by stress, antibiotic administration, and is of high relevance to Astrofood, high-sugar/high-fat ultra-processed foods. Clues suggesting that dysbiotic microbes play a functional role in depression, anxiety, obesity and other NCDs can be found in fecal transfer studies. That is, when fecal material from either healthy adults or those with NCDs (e.g., obesity or depression) is transplanted into healthy rodents, there are clearly observable metabolic and behavioral disturbances in animals that were the recipients of dysbiotic donor stool [106–108].

While an “ideal” healthy gut microbiome remains elusive, it is generally accepted that gut microbiome diversity equates to healthy lifestyle habits, especially diet. This is illuminated through the examination of relatively isolated groups of people who still maintain their way of life in pre-Astrofood ways. Living in ways that closely resemble our hunter-gatherer and early subsistence ancestors—diets rich in minimally-processed foods, plants, fiber and devoid of ultra-processed fare—these groups seem particularly resistant to NCDs. With a good degree of consistency, researchers have shown general losses in microbial diversity in association with westernization and industrialization [109,110]. The loss of microbial diversity as a result of what Astrofood represents—that is, an ultra-processed, reassembled food supply deficient in fiber and phytochemicals—may have long-term consequences [111,112] and

even extend over generations [113]. As in the larger world of natural environments, loss of microbial diversity generally equates to a loss of functional benefits and threat to a healthy ecosystem.

Recalling the Astrofood deconstructed section above, we can now point out that beyond the high sugar content [114], the various components of this ultra-processed breakfast have now been associated with dysbiosis of gut microbiota. For example, animal studies have linked AGEs [115], emulsifiers [116–118], excess omega-6 oil [119] and soy protein [120] with dysbiosis and inflammation. In recent animal research, carrageenan has been shown to reduce levels of an intestinal microbe which otherwise protects the intestinal lining and prevents inflammation [121]. Thus, ultra-processed foods are, as an ingredient collective, a potential threat to normal cognition, mood and behavior by virtue of their macronutrient profile, additives, and their missing parts.

In agreement with the minimally-processed, whole foods (Mediterranean style) diet interventions shown to improve mood and cognition (as mentioned above), emerging research is demonstrating, at least over the short-term, that such foods provide neuro-emotional benefit via the microbiome [122,123]. While still in its infancy, a small but growing list of controlled human studies indicates that oral microbial products (probiotics or nutritional substrates that confer benefit via microbial activity) can improve aspects of mood, cognition, stress and/or anxiety [124–127]. The mechanisms by which microbes can influence brain development, cognition and behavior include, but are not limited to: direct and indirect microbial interactions with the immune system, enhancement of nutrient bioavailability and neurotransmitter precursors, maintenance of the gastrointestinal lining, reduction of oxidative stress, direct gut microbe-to-brain communication via the vagus nerve which connects the intestinal tract to the emotional centers of the brain, and transformation of dietary phytochemicals into bioactive compounds which subsequently influence mood [21,128]. But as we will explore in more detail below concerning the cost of diets, the application of probiotics and specialized fermented products are expensive and unlikely to represent a primary solution to the nutritional drivers of NCDs [129]. In other words, Astrofood wouldn't have been complete if it had a probiotic in its cream-like filling.

1.7. Extinction of Experience, Nature Relatedness

Changes in lifestyle in concert with screen-based technology has accelerated childhood disconnection from the natural environment, a phenomenon researchers have termed “extinction of experience” [130]. Childhood connections to nature can influence environmental attitudes and promote the psychological asset known as nature relatedness [131]; nature connection, as measured by Nature Relatedness or Nature Connectedness scales has been linked to mental well-being in a variety of studies [132,133]. We consider Astrofood—as a surrogate marker for a sugary, synthetic attempt to fill in the extinction of ancestral experience with minimally-processed, nutrient dense foods—to be part of the total disengagement, a fragmentation of nature wrapped in cellophane.

To appreciate how daily Astrofood would potentially cue a disconnect from nature, we can look to research in the realm of gardening in academic and community settings. Participation in gardening programs brings children in touch with food and nature at the same time [134]. Indeed, gardening increases nature-connectedness as an asset of health and well-being [135]. Among the many benefits noted by researchers, gardening promotes positive mental outlook and healthier behavior in general, including increased physical activity. Of special note here in our context, gardening has been linked with subsequent increases in fruit and vegetable intake, and reduced fast-food consumption [136–138]. Relationships between child and food along a continuum of whole foods to Astrofood in the context of nature relatedness warrants exploration.

1.8. Engineering Policy, Marketing Dysbiosis

The larger plan of ITT was to bring the Astrofood breakfast to supermarkets and shops, hence its nationwide ad campaign targeting “every mother in America”. Indeed, the ties between ITT and the USDA were so strong that the latter mandated that the former *must* bring the breakfast cakes to market.

In a 1972 nationally-syndicated opinion piece, noted science and policy journalist Daniel Zwerdling provided a nutritional forewarning:

“Under agriculture regulations, any food developed for the breakfast programs must eventually be sold commercially in neighborhood markets. ITT Continental is already test marketing Astrofood in a few cities. In a few years, all the protein and vitamin-packed puddings and candies and soft-drinks developed at government expense for the breakfast program will spill out onto the market shelves” [139].

Today, there is little doubt that marketing calorie and sugar-dense breakfast products (most notably, cereals) towards parents and their children is a multi-billion-dollar investment on the part of global corporations [140–142]. Marketing investments in sugary breakfasts pay off handsomely for manufacturers, with research showing clear lines between ad exposure and greater childhood consumption [143]. Similar relationships between ad exposure and greater childhood fast-food consumption have also been reported [144]. Indeed, there is enough research in place to move beyond mere associations, these ad-to-consumption patterns are now in the realm of causation [145]. Children from low-income urban areas in the U.S.—despite free access to better quality school breakfast programs—often skip the breakfast altogether, or opt instead for nutritionally-poor dietary breakfast choices made at local convenience shops [146].

As highlighted by scholar Selena Ortiz and colleagues in *Social Science and Medicine* (2016), food engineering in the contemporary environment goes beyond manipulations of sugar, fat, sodium and chemicals to enhance taste, texture, and palatability. This physiological form of engineering is accompanied by cognitive engineering in the form of effective marketing mentioned above—advertisements, celebrity endorsements, toy giveaways, “health-halo” label claims, and vague terminology such as “nutritious” which collectively appeal to the mind of the parent and/or child consumer. The third form of engineering is the manipulation of the total food environment via product placement and prominent shelf-space devoted to ultra-processed, energy-dense, low-nutrient foods [147].

We will address the burden of total food engineering on socioeconomically disadvantaged communities shortly, but for now we point out that these forms of food engineering proliferate because policy (or in many cases, lack of policy through lobbying efforts) is itself engineered. In other words, the westernized nutritional environment viewed in its totality is a product of neoliberal policies which allow the drivers of NCDs (including ultra-processed foods) to sit on-shelf with commercially available remedies (e.g., pharmaceuticals, supplements). Under neoliberalism, personal responsibility for a healthy lifestyle is heralded to be the sole road to fulfilling potential in life [148–150].

At the same time, the largest names in the food industry have increasingly partnered up with government—just as they did in the early days of Astrofood—in highly visible forms of so-called public-private partnerships. The optics of these efforts look good to the public; fast-food, soft drink and ultra-processed food companies appear to care deeply about obesity and NCDs. In reality many are simply an extension of cognitive engineering [151,152], a place where a “cholesterol-free” label on a soft drink bottle is transported to a grand scale. Sponsorship of major health organizations and dietetic conferences is part of the systemic approach; however, when faced with new legislation that might curb sales, purveyors of soft drinks are swift in opposition—97% of the time, according to recent U.S. research. Indeed, the financial investments in lobbying efforts are at an astronomical scale—more than \$10 million USD per year on the part of Coca-Cola, PepsiCo and the American Beverage Association [153].

1.9. Disadvantage Compounded

One of the formidable challenges for academics working within health arenas—nutritional and otherwise—is to understand the interconnected ways in which the total lived experience of individuals meets with single “exposures” [154]. The implications of emerging nutritional psychiatry and nutritional dysbiosis research, while relevant for all, are most pronounced for vulnerable populations. The risk of mental disorders in populations, most notably depression, does not occur randomly in

developed nations. Rather, the gradient of risk is steeply slanted toward the disadvantaged [155–159]. From the nutritional perspective, childhood adversities (which already increase risk of later-life NCDs) predict subsequent unhealthy dietary choices in adulthood [160].

Put simply, as much as modern research allows us to deconstruct the individual ingredients of Astrofood and determine their possible effects on dysbiosis, the product is consumed as a whole and it meets with the unique biophysiology of the individual. The latter is determined by collected experiences in the total environment over time, which forces discussions of disadvantage. For young consumers of Astrofood (the ultra-processed food it represents today) and their parents, the total food engineering package described above is likely to be more prominent in day-to-day life.

As we have described in detail elsewhere, research shows that the many forms of socioeconomic disadvantage can translate into a disparate physical and mental environment. The living environment is likely to have a disproportionate number of convenience stores and fast-food outlets. The visible marketing materials on billboards and sidewalk signage are more likely to be dense and cajole unhealthy lifestyle choices. The availability of inexpensive, energy-dense, low nutrient foods is common; in-store, the shelf-space, point-of-purchase options and promotions magnify the position of ultra-processed foods [161,162]. At the same time, the disadvantaged environment is *less* likely to have adequate access to healthy foods; since indoor screen time is connected to snacking and dietary habits, the decreased likelihood of safe, well-managed natural environments for play is also a factor which dictates the interface of ultra-processed foods and biological responses to food.

Disadvantaged families experience higher chronic psychosocial stress and daily hassles; individual and neighborhood-level deprivation have been associated with significantly higher biomarkers of metabolic dysregulation, inflammation and oxidative stress [163–171]. Even if the sugary Astrofood breakfast were given to all students—affluent and low-income—the postprandial responses over time would likely differ. Evidence shows that the healthier background diets of affluent families would help buffer the effects of Astrofood; for example, several studies have shown that tissue levels of phytochemicals and antioxidants—the sort that would buffer the effects of inflammation and metabolic dysregulation—are higher in association with individual and neighborhood SES advantage [172–178]. Research has shown that neighborhood disadvantage is associated with lower diversity of the intestinal microbiome; the gut microbial ecology coincident with deprivation (mostly through ultra-processed dietary patterns) may play important roles in metabolic disturbances [179].

1.10. Remediation, Broken System

Critics of Astrofood were primarily concerned with its sugar content and the message that it sent to children regarding nutrition. If a cake-like substance was good enough for breakfast at school, these early-life experiences might shape relationships with food and nutrition outside of school and over the life course. We agree, and research does show that childhood dietary habits can persist into adulthood [180]. However, in our opinion, it sent (and still sends) an industry-government signal far more devastating than sugar. Astrofood represented the extreme arrogance of food technology, a place where the link between child and nature was interrupted, where disadvantage and social injustice could be remediated with cake (See Figure 1).

The broad lens view of Astrofood forces difficult questions on society; many of these questions pertain to the acceptability and maintenance of socioeconomic and health inequalities. To understand the systems which allow for the current pervasiveness of ultra-processed foods, a brief revisit to Astrofood's point of origin—the 1969 White House Conference on Food, Nutrition and Health—may be helpful. Professor Gordon E. Bivens of the University of Missouri attended as part of the Consumer Task Force and discussed his conference experiences in *The Journal of Consumer Affairs* (1970). Bivens noted “a heavy overlay of business representation...in some instances, the vested interests of industry seemed to affect the way in which the business of the panels—including hearings during the Conference—was conducted” [181]. He also underscored the Social Action Statement which was collectively agreed upon by various

advocacy groups, including those representing women, students, minorities, unions and community organizations. Below are some of the primary points within the Social Action Statement [182].

1. Shift nutrition programs out of the USDA and to the U.S. Department of Health, Education and Welfare; “there is a conflict of interest established in the USDA in its dual role—primarily the advocate for the producers of food, and secondarily the distributor of food to the needy”.

2. Free school breakfast and lunch should be offered *regardless* of parental income, and “*nutritious food (should be) selected...while respecting cultural food preferences*”.

3. The overriding remedy for hunger and malnutrition is adequate income and a “*living wage*”; extending the right to all working people to collectively bargain for those wages, as well as working hours and conditions.

4. Mandatory limitation on industry marketing and promotions which inflate consumer costs; mandatory examination and standardization of food processing to “*identify and preserve nutrient content*”.

5. Given the societal benefits, the cost of providing an equitable nutritional landscape throughout the socioeconomic spectrum is minimal; of changes to policy and practice, “*none will require appropriations higher than a fraction of the cost of the space program*”.



Figure 1. Remediation: In response to gross socioeconomic inequalities, disadvantage and social injustice in the total childhood environment, an ultra-processed breakfast food cake (Astrofood) was engineered and marketed for its “nutritional” equivalency. Its legacy remains in plain sight (Image: Susan L. Prescott).

Almost 50 years on, we can look back and put these perspectives into a contemporary context: By highlighting the conflict of interest, leaders who shaped the Social Action Statement were foretelling the words of the USDA Deputy Director Ed Koenig as he “got a brainstorm” with ITT’s Robert Cotton as they spontaneously developed the breakfast Twinkie. From the perspective of health promotion, public health scientists and physicians in the department of health may have been better suited to evaluate what constitutes a nutritious, culturally sensitive breakfast. Although the US Health and Human Services branch now works with the USDA to craft current nutrition guidelines, many experts

see the same industry influence; commenting on the revised 2015 nutrition guidelines, noted pediatric endocrinologist Robert Lustig (who has studied the direct effects of sugar on metabolic syndrome [183]) stated that USDA involvement is akin to “putting the fox in charge of the henhouse” [184].

The Social Action Statement of the Consumer Task Force emphasized school meals regardless of family income because they emphasized the effects of food delivery systems on dignity, highlighting stigma and the emotions felt by children who were receiving “free” food [181]. Today, we know much more concerning the mere perceptions of social exclusion and poverty when they are evoked in laboratory experiments, including how it might influence dietary choices. For example, when researchers invoke feelings of poverty, powerlessness or the perception of belonging to an under-privileged “out-group”, it results in altered dietary choices in the direction of low-nutrient, high-calorie foods [185–187]. Of course, that is briefly-invoked perception in a lab, an “in situ” from which the subject can readily escape; the reality of discrimination can manifest as inflammation and metabolic dysfunction [188–190], and, as mentioned above, compound the inequity of the total environment, nutritional and otherwise.

Today, there is little doubt that a living wage is central to health equity; for example, emerging research shows that in socioeconomic position (SEP) disadvantaged workers, relatively small wage increases are associated with subsequent reductions in depression [191,192]. Lack of a living wage or stagnant minimum wages in concert with lack of welfare buffers can magnify stress and compound an unhealthy lifestyle (e.g., dietary choices) [193–196]. Alarming, global socioeconomic disparities continue to climb, and in the U.S. the life expectancy of the wealthiest can exceed low-income individuals by 10–15 years [197]. Over the last decade, the research supporting the nature-based Mediterranean and ancestral diets has grown increasingly robust, even extending into reducing the risk of mortality [198], but only recently has the affordability of such diets been questioned. Evidence shows they can be relatively expensive [199,200]. Plus, the Mediterranean diet is a broad term, and new research shows that affluent SEP predicts a variant of the diet which is richer in fruit and vegetable diversity, polyphenol and essential fatty acid intake, whole wheat consumption, less pesticide residue and low-AGE preparation of vegetables [201].

Public health has been the vanguard of defending and advancing labor standards as part of its evidence-based effort to reduce health inequalities [202]. As pointed out by professor Frank Houghton, “*Public Health functions, in part at least, to help counter-balance the dominance of bio-medical approaches in the health arena*” [203]. In our opinion that function extends to counter the dominance of engineering of the total food environment. In the increasingly ultra-processed, contemporary world of Twinkies, collective bargaining is a thing of the past; the company’s union labor force now eliminated under new ownership, Twinkies are currently manufactured with new automation—and what was once about 4 ingredients has grown to almost 40 as the products now enjoy a 65-day shelf life [204].

In an interesting metaphorical twist to the origins of the ultra-processed Astrofood vis-a-vis its Twinkie backbone—the co-owner of Twinkies recently purchased the Playboy Mansion in Los Angeles [205]. The fantastical mansion is far afield from South Los Angeles where income is low, but ultra-processed and fast-foods are widely available [206,207]. Indeed, the nutritional landscape of South Los Angeles is a 32-square mile area which houses about 45% of fast-food outlets found within the entire 500 square mile City of Los Angeles [208]. However, some young people are beginning to view the engineered ultra-processed and fast-food environment for what it is—a matter of power, inequality and food justice. With education, youth can see the connections between a package of modern Astrofood-cake in an urban corner store, and how a purchase not only enhances dysbiosis, but funds the deed to the mansion on the other side of the city. Researchers are demonstrating that when young people see such connections, they are far more likely to understand the importance of healthy dietary patterns vs. another informational session on a dietetics pyramid or academic guideline [209–211].

The Consumer Task Force recognized the value of food processing and packaging, but their emphasis on preserving the nutrient content of foods during production and transport underscored that

nutrient preservation should be the guiding principle. It is clear from their statement that the notion of Astrofood would have been objectionable. Moreover, the request in the Social Action Statement for government to develop innovative ways to address marketing and promotion is important. Beyond the ways in which food cues, celebrity endorsements and “free” toys influence childhood dietary choices (toward ultra-processed and fast-foods), the targeted marketing of disadvantaged communities adds to the cost of the food dollar, contributes to the dominance of unhealthy foods, and diminishes the opportunity to fulfill human potential [161,162,212]. Full page ads in leading magazines and nationwide newspaper campaigns for ITT Astrofood weren’t free; they cost consumers somewhere along the line before the product was, as Koenig said, dumped by the hundreds in school hallways, before the costs at the intersection of sugar and disadvantage could be measured.

Finally, in making reference to the costs of the space program (the White House conference was mere months removed from the 20 July 1969 lunar landing), the Social Action Statement was underscoring societal priorities and commitment to equity. As we have discussed in detail elsewhere [213], the benefits to society—financial and otherwise—of an intense, collaborative “moon shot”-like effort to promote mental health and eliminate health inequalities are virtually immeasurable. Half-a-century later we are, in a sense, back to the future. In the U.S., billions in public funds are being invested in crewed missions to Mars while socioeconomic and health inequalities continue to grow, and the NCDs crisis is described as epidemic. Intellectual escapism allowed for the Social Action Statement to be ignored; just as surely as the research subject could abandon the temporary subjective feeling of poverty, so too policy makers dodged the difficult questions forced upon them. Astrofood was an easy out. But here we are, 50 years on and the very same issues raised by the Consumer Task Force are no less relevant.

The 1969 White House Conference on Food, Nutrition and Health concluded with a promissory note to hold a follow-up conference one year later. It never happened, and still hasn’t. In its stead are many industry-supported conferences under the banner of dietetics, and expert papers conflating ancestral fermentation and the use of fire with polysorbate and sucralose, both positioned as forms of food processing. Moreover, the 21st century resonance of Astrofood—and its entanglement with industry-government relations—is evident at many turns. In May, 2017, the Trump administration responded to food industry lobbying and rolled back even modest attempts to restrict sodium and include minimum whole grain standards in federal school meal programs. In the announcement, the new USDA secretary claimed that removing caps on sodium and the requirement for whole grain minimums was an effort to “make school meals great again” by improving palatability [214].

2. Conclusions

Emerging studies in pediatric health demonstrate the overall importance of a healthy lifestyle—fruits, vegetables, whole foods, physical activity, quality sleep, avoiding ultra-processed foods and excess screen time—in academic achievement and early life mental health [215,216]. In scientific jargon these lifestyle variables are “exposures”; they are parts of the total lived experience with enormous implications to the individual and society as a whole, especially when viewed over time. Nutrition is one of many factors associated with childhood health adversities which predict academic achievement [217], and as such, society has an obligation to protect all of its most vulnerable.

Reexamining Astrofood through a contemporary lens allows us to place advances in nutritional psychiatry and the microbiome onto an ultra-processed product that was developed, marketed and distributed to disadvantaged children. Viewed from this biological perspective, contemporary research would suggest the product was not in favor of childhood cognitive and emotional development; rather, its ingredients are those associated with dysbiosis and inflammation according to many recent studies. However, the Astrofood rewind isn’t simply an act of academic curiosity. In the contemporary environment where Astrofood-like products dominate, the same systems that allowed for its market penetration are operating today. Looking back on the origins of Astrofood and the acceleration of ultra-processed foods is an important exercise; it helps to underscore the disconnect between a

hunger for technological applications in the interest of profits, and the mission of public health to eliminate actual hunger and literally and figuratively nourish populations such that they can meet the WHO definition of health—i.e., fulfillment of potential. In a world where some 10 billion people will need nourishing food by 2015, solutions to the grand challenges of the Decade of Nutrition will certainly require the expertise of food technology; however, the intellectual escapism and dishonesty which defends the ultra-processed foods ignores the NCDs crisis and Planetary Health. The archives of Astrofood provides clues to undoing the tangled knots which otherwise maintain an untenable status quo.

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