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Change in hyper-palatable food availability in the US food system over 30 years: 1988–2018

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Abstract

Objective: To quantify the change in availability of hyper-palatable foods (HPF) in the US foods system over 30 years (1988–2018).

Design: Three datasets considered representative of the US food system were used in analyses to represent years 1988, 2001 and 2018. A standardised definition from Fazzino *et al.* (2019) that specifies combinations of nutrients was used to identify HPF.

Setting: Analysis of food-item level data was conducted. Differences in the prevalence of HPF were characterised by Cochran's Q and McNemar's tests. Generalised linear mixed models with a fixed effect for time and random intercept for food item estimated change in the likelihood that a food was classified as hyper-palatable over time.

Participants: No participant data were used.

Results: The prevalence of HPF increased 20 % from 1988 to 2018 (from 49 % to 69 %; $P < 0{\cdot}0001$). The most prominent difference was in the availability of HPF high in fat and Na, which evidenced a 17 % higher prevalence in 2018 compared with 1988 ($P < 0{\cdot}0001$). Compared with 1988, the same food items were >2 times more likely to be hyper-palatable in 2001, and the same food items were >4 times more likely to be classified as hyper-palatable in 2018 compared with 1988 (P values $< 0{\cdot}0001$).

Conclusions: The availability of HPF in the US food system increased substantially over 30 years. Existing food products in the food system may have been reformulated over time to enhance their palatability.

Keywords
Nutrition
Food availability
Obesity
Policy

The prevalence of obesity has increased dramatically in the US over the last 30 years; while less than a quarter of the adult population (23 %) had obesity in 1988, almost half of the adult population (42 %) had obesity as of 2018[1,2]. Population-level obesity risk is strongly influenced by the food environment[3,4]. Therefore, characterising changes in the food environment overtime is necessary to identify potential factors in the epidemic.

The US food environment has changed substantially in the past 50 years and has widely been described as obesogenic[4]. Since the 1970s, developments in food science technology and the growing dominance of global food corporations have led to the increased production of foods that are widely available, relatively inexpensive and often highly palatable and/or energy dense[3]. Between the 1970s and early 2000s in particular, US food companies employed changes in their approaches to food product development to enhance their market shares, which consisted of enhancing and expanding product lines while improving food product cost efficiencies. For example, leading food companies such as Kraft General Foods substantially enhanced and expanded their product lines, which included reformulating existing products to enhance their palatability (thereby facilitating consumption and profit) and adding new products to the food system[5,6]. As a result, new food products introduced to the US food system nearly doubled from 1985 to 1998[7]. Most new products were snack items and frozen foods, all of which

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Public Health Nutrition

have maintained strong market shares since their introduction[8]. While the impact of food reformulation on the food system may have also been substantial, this has not previously been investigated.

Despite the historical changes observed in the food environment, few longitudinal studies have examined changes in the US food environment over time and no studies have focussed on product reformulation. Most studies focussed on changes in the availability of individual nutrients that may be implicated in obesity (e.g. sugar, fat)[9–11]. Research has indicated that from the 1970s to early 2000s, the US food supply yielded substantial increases in the per capita availability of most nutrients, including fat[10,11], sugar[9,11] and carbohydrates[10]. Beyond individual ingredients, one study examined longitudinal changes in the availability of ultra-processed foods, foods that are highly processed and manufactured from industrialised ingredients[12]. Findings indicated that between 1980 and 2012 per capita retail sales of ultra-processed foods increased by ~10 %[13]. Overall, preliminary evidence indicates that the availability of fat, sugar and ultra-processed foods may have increased in the US food market in recent decades.

In addition to limited research documenting changes in the food environment over time, the existing literature also has limitations in its primary focus on individual nutrients. No prior work has focused on the availability of certain foods that may be difficult to stop eating. For example, hyper-palatable foods (HPF) are designed with combinations of palatability-inducing ingredients (fat, sugar, Na and/or carbohydrates) that together enhance a food's palatability and produce an artificially rewarding eating experience[14]. Importantly, the palatability induced by the combination of ingredients in HPF is beyond what any single ingredient would produce alone[15,16]. Several prior studies have examined changes in other constructs in the literature, such as energy-dense foods and ultra-processed foods, both of which have increased over time[13,17]. However, neither energy density nor ultra-processing directly addresses hyper-palatability, which may be most directly related to overeating. In this regard, foods may have high energy density (e.g. unsalted nuts) or be extensively processed (e.g. canned beans), but not have elevated palatability. Therefore, such foods may not be difficult to stop eating and would not represent major concerns regarding energy intake. In this regard, our preliminary work indicated that HPF high in carbohydrates and Na may lead to excess energy intake within a meal and predict weight gain longitudinally; however, energy-sdense foods and ultra-processed foods did not have the same predictive utility[18]. Thus, examining changes in the availability of HPF in the US food system may be important and may reveal the degree to which the US population may have been exposed to foods that are difficult to stop eating over the past decades. Recently, we characterised the prevalence of HPF in the US food system using a standardised definition that identifies combinations of nutrients at thresholds that may yield hyper-palatability[14]. In 2016, HPF availability was extensive and comprised > 60 % of foods in the US food system[14]. However, the study was cross-sectional and did not examine HPF availability over time. Thus, the purpose of this study was to investigate the change in HPF prevalence over 30 years, from 1988 to 2018, using data considered representative of the US food system. The timeframe of 1988–2018 was chosen to reflect a period in which the US food system changed substantially and for which data representing the US food system were available from the US Department of Agriculture (USDA). We hypothesised that HPF prevalence significantly increased in the US food system over the past three decades, and that change in HPF availability may have resulted from the reformulation of existing products in the food system to be hyper-palatable.

Methods

Data sources

The study analyzed three databases from the USDA and the Center for Disease Control and Prevention that represented the US food system in 1988, 2001 and 2018[19–21]. Data representing years 2001 and 2018 were obtained from the USDA's Food and Nutrient Database for Dietary Studies (FNDDS)[20,21]. FNDDS data contain detailed nutrient data on foods and beverages available in the US food system. Food and beverage items for the FNDDS are sourced from the National Health and Nutrition Examination Survey (NHANES) 24-h dietary recall assessment, in which participants provide information regarding all foods and beverages consumed in a 24-h period[19], and then aggregated into the FNDDS databases. Foods in the FNDDS databases are subsequently matched with the National Nutrient Database for Standard Reference database, which provides detailed food composition information (nutrient values, serving size, etc.) for all items in the dataset[22].

In parallel with FNDDS, data from the NHANES-III 24-h dietary recall assessment were obtained to characterise foods available in the US food system for 1988–1994. Because NHANES-III pre-dated the development of the FNDDS by the USDA, these data were processed to be consistent with the formatting of FNDDS for comparative analysis (as detailed in the supplemental information section).

Following completion of data processing, each database contained approximately 6000 items for analysis (Table 1). Over half of the food items (*n* 3893) were present in each database, reflecting their consistency in the food system from 1988 to 2018. On average, there were 1377 items (SD = 936) unique to one dataset, reflecting the presence of new food products introduced to the food system at each time point.

Public Health Nutrition

Table 1 Descriptive information for the databases used in analyses

	n total items (foods and beverages)	*n* items excluded* (e.g. liquids)	*n* total items available for analysis
NHANES-III 1988	6846	606	6216
FNDDS 2001	6974	849	6125
FNDDS 2018	7083	1002	6081

Note. NHANES-III = national health and nutrition examination survey-III; FNDDS = food and nutrient database for dietary studies.
*Excluded liquid products (for which the hyper-palatable food definition does not apply), items with zero kcal and infant formula/foods.

Measures

HPF were identified in all databases using the quantitative definition of HPF developed by Fazzino *et al.*[14] Consistent with theoretical and empirical evidence indicating a combination of palatability-inducing ingredients (fat, sugar, carbohydrates and/or Na) may induce hyper-palatability, the definition specifies the following combinations of nutrients at thresholds that may yield hyper-palatability: (1) fat and Na; (2) fat and sugar and (3) carbohydrates and Na (criteria are described below in data processing section). Initial evidence indicated that the HPF definition has strong convergent validity for identifying foods hypothesised to be hyper-palatable (e.g. fast foods, etc.), discriminant validity for foods hypothesised to not be hyper-palatable (e.g. fresh vegetables)[14] and predictive utility for obesity-related outcomes[18].

Food categories were identified by the USDA, which categorises all foods items in their datasets in accordance with the following What We Eat in America (WWEA) categories: (1) milk/milk products; (2) meats; (3) eggs; (4) beans/nuts; (5) grains; (6) fruits; (7) vegetables; (8) fats/oils/dressings and (9) sugars/sweets[19]. For food items that represent mixed/combination dishes, the USDA assigns the best fitting WWEA category based on the representation of items in the dish. Food item categories are provided in NHANES and FNDDS datasets for analysis.

Data processing

Data were processed in preparation for applying the HPF definition consistent with the procedures from Fazzino *et al.*[14] (detailed in the supplemental information section). Liquids were removed before analyses because the HPF definition does not apply to liquids[14]. Total values for each nutrient (e.g. total fat) were used in percent kcal calculations, consistent with Fazzino *et al.*[14] The HPF definition was applied to all foods in the databases using the following criteria: (1) fat and Na, FSOD (> 25 % kcal from fat, ≥ 0·30 % Na); (2) fat and simple sugars, FS (> 20 % kcal from fat, > 20 % kcal from sugar) and (3) carbohydrate and Na, CSOD (> 40 % kcal from carbohydrates, ≥ 0·20 % Na)[14]. Items that met the above threshold for at least one of the three categories were classified as hyper-palatable in each database.

Data analysis

Data analysis was conducted with R Statistical Software Version 4.1.2 using the rstatix and irr packages and IBM Statistics for Windows programs[23–25]. To test whether there were differences in the availability of HPF from 1988 to 2018, a Cochran's Q test[26] was conducted to determine if the overall proportion of HPF foods present in all databases (*n* 3893) differed over time, while pairwise McNemar's tests with Bonferroni correction tested whether HPF proportion differed between each database. Parallel analyses were also conducted to characterise the difference in availability of each HPF group: FSOD, FS and CSOD foods over time.

Second, to determine whether the likelihood that foods in the food system were hyper-palatable changed over time, the association between database year and HPF status (yes *v.* no) was modeled using a generalised linear mixed model with a binomial distribution, logit link and autoregressive heterogenous covariance structure. A random intercept was specified for food items to account for correlated HPF status across repeated food items, and database year was included as a fixed effect with three levels (1988, 2001 and 2018). The Kenward–Roger approximation was used to estimate the df[27]. Three parallel models were also conducted for each HPF group (FSOD, FS or CSOD) as a binary outcome. Additionally, to determine whether there were differences in the types of foods that were hyper-palatable over time, a generalised linear model with a binomial distribution was run specifying fixed effects for time, nine USDA-defined WWEA food categories (milk/milk products, meats, eggs, beans/nuts, grains, fruits, vegetables, fats/oils/dressings and sugars/sweets) and the interaction between food type and time. Vegetables were the reference group as they are hypothesised to not be hyper-palatable when fresh/raw[14]. OR representing the multiplicative interaction effect between year and food category on the odds of HPF status were calculated by exponentiating the sum of the corresponding main effects and interaction effect coefficients. Food items that were present in 2+ databases were included in the analytic models, which facilitated an examination of the change in likelihood that the same food was hyper-palatable over time.

To evaluate whether specific foods were consistently identified as HPF across all three databases, sensitivity analyses were performed on a subset of items present in all three databases (*n* 613) using Fleiss' κ test[28]. Items included in the sensitivity analysis were selected to be representative of the composition of the databases, with 10 % of food items selected from each of nine WWEA food categories (milk/milk products, meats, eggs, beans/nuts, grains, fruits, vegetables, fats/oils/dressings and sugars/sweets).

Public Health Nutrition

Finally, supplemental analyses were conducted to characterise the change in availability of individual nutrients (total fat, sugar, carbohydrates, Na and fibre) in foods over time using linear mixed models that specified a random intercept for food item and fixed effect for database year.

Results

HPF prevalence by year

HPF prevalence by year is presented in Table 2. There was a 20 % difference in the prevalence of HPF in 1988 (49 %) compared to 2018 (69 %; McNemar's $P < 0{\cdot}0001$). The proportion of foods that met HPF criteria significantly differed across years (Cochran's Q $\chi^2(2) = 468{\cdot}12$, $P < 0{\cdot}0001$) and between each pair of years (McNemar's test: all P values $< 0{\cdot}0001$), indicating that the proportion of foods that met HPF criteria was significantly greater in 2001 and 2018 compared to 1988 (Table 2), and in 2018 compared to 2001 (Table 2). A similar pattern was revealed for the proportion of FSOD HPF, FS HPF and CSOD HPF in 2001 and 2018 compared to 1988 (Table 2; P values $< 0{\cdot}001$). The most prominent differences were in the availability of FSOD HPF, which evidenced a 17 % higher prevalence in 2018 compared to 1988 (Table 2).

Change in food item hyper-palatability over time

Findings from the generalised linear mixed model indicated that the likelihood that food items in the US food system were hyper-palatable increased over time. Specifically, food items in 2001 were 2·4 times more likely to be hyper-palatable compared to the same food items in 1988 (Table 3). Furthermore, food items in 2018 were >4 times more likely to be hyper-palatable compared to the same food items in 1988 (Table 3).

Regarding HPF groups, food items from each HPF group were significantly more likely to be classified as hyper-palatable in 2001 and 2018 compared to 1988 (Table 2). Most notably, foods items were >2 times more likely to be classified as FSOD HPF in 2001, and >4 times more likely to be classified as FSOD HPF in 2018 than the same food items in 1988 (Table 3).

Results from the generalised linear mixed model testing change in hyper-palatability by USDA-defined food categories revealed that there were significant differences in the degree to which foods in the nine different food categories were likely to be hyper-palatable across years (Table 4). The main effect estimates revealed that foods in most food categories were 3–16 times more likely to be hyper-palatable compared to vegetables (the reference group) (OR = 3·25 to 16·20; Table 4). However, the interaction term between database year and food category was statistically significant for most food types, revealing a multiplicative effect, suggesting that the degree to which foods changed in their hyper-palatability differed across the food categories (Table 4). More specifically, results of the interactions indicated that foods in the beans/nuts, fats, grains and sweets categories had a significantly higher likelihood of being hyper-palatable in 2001 compared to the same foods in 1988 (OR = 1·27 to 30·60; Table 4). Furthermore, with the exception of fruits and eggs, foods in each food category had a significantly higher likelihood of being hyper-palatable 2018, compared to the same foods in 1988 (OR = 2·49 to 53·37; Table 4). Additionally, when considering the joint effect of food category and year, food items in almost all categories showed stronger associations with HPF status in 2018, although associations with HPF status were still significant for food items in most categories in 2001. Notably, the same grain foods were thirty times more likely to be hyper-palatable in 2001 compared to 1998 (OR = 30·60), and were fifty-three times more likely to be hyper-palatable in 2018 compared to the same food in 1988 (OR = 53·37), relative to vegetables (Table 4).

Sensitivity analysis

There was significant and moderate agreement between databases in classifying the same food items over time as hyper-palatable (Fleiss' $\kappa = 0{\cdot}482$, $P < 0{\cdot}001$), indicating agreement between the databases in classifying food HPF status was greater than expected by chance. However, there were substantial differences in whether the same foods were classified as hyper-palatable over time, likely reflecting changes in the formulations of foods across years.

Nutrient analyses

Nutrients available in foods across time are reported in Table 5. Mean grams of total fat, sugar and carbohydrates per serving in foods were significantly higher in 2018 compared to 1988 (all P values $< 0{\cdot}001$), whereas mean grams of fibre per serving were significantly lower than 1988 ($P < 0{\cdot}0001$). Na did not significantly differ by year ($P = 0{\cdot}218$; Table 5).

Discussion

Despite widespread discussion in the literature regarding changes in the food environment and population-level obesity rates, few longitudinal studies have documented changes in the US food environment over time. The current study examined the change in availability of HPF in the US foods system over the past 30 years using data considered to be representative of the US food system. A standardised, quantitative definition was used to identify HPF[14]. The results revealed that the prevalence of HPF changed substantially over the past 30 years, rising 20 % from 1988 to 2018. The most prominent change was in the availability of HPF that was elevated in fat and Na (FSOD). Furthermore, findings indicated that the same food items

Public Health Nutrition

Table 2 Hyper-palatable food (HPF) availability across years

	1988	2001	2018	*P* value 1988 *v.* 2001	*P* value 1988 *v.* 2018	*P* value 2001 *v.* 2018
Overall prevalence (% HPF)	49	62	69	<0·0001	<0·0001	<0·0001
Prevalence by HPF group (% HPF group)						
Fat and Na HPF	32	42	49	<0·0001	<0·0001	<0·0001
Fat and sugar HPF	12	13	13	0·001	0·0003	0·183
Carbohydrate and Na HPF	10	13	12	0·0003	0·0003	0·641
Overlap*	7	12	11	–	–	–

*Overlap = food items that met HPF criteria in more than one cluster.

Table 3 Change in likelihood of food item hyper-palatability in the US food system over time

Year	OR	95 % CI	*P*-value
HPF overall			
1988	–	–	
2001	2·41	2·23, 2·61	<0·0001
2018	4·09	3·75, 4·46	<0·0001
FSOD HPF			
1988	–	–	
2001	2·55	2·28, 2·85	<0·0001
2018	4·28	3·77, 4·86	<0·0001
FS HPF			
1988	–	–	
2001	2·02	1·58, 2·57	<0·0001
2018	2·26	1·73, 2·95	<0·0001
CSOD HPF			
1988	–	–	
2001	1·89	1·59, 2·25	<0·0001
2018	1·62	1·33, 1·97	<0·0001

HPF: hyper-palatable foods; FSOD: fat and Na HPF; FS: fat and sugar HPF; CSOD: carbohydrate and sugar HPF.
Note. Model specified random intercept for food item and fixed effect for database year.

were >4 times more likely to be classified as hyper-palatable in 2018 compared to 1988, reflecting changes in the nutrient contents of foods from 1988 to 2018. Analyses of USDA-defined food categories further revealed the extensive degree to which foods across various food categories are hyper-palatable in the US food system. Findings highlighted particular increases in the likelihood that foods from grains, fats and meats categories were classified as hyper-palatable in 2001 and 2018, compared to the same foods in 1988. Thus overall, findings indicate that the availability of HPF in the US food system has increased substantially in the past 30 years, and likely reflects a reformulation of food products over time to enhance their palatability.

Our findings provide evidence that the increasing availability of HPF over time may be one key factor contributing to the obesogenic food environment in the US. The results revealed a 13 % increase in HPF availability from the late 1980s to early 2000s, a period during which food companies employed major changes in their approaches to food product development, which included enhancing the palatability of existing food products by adding and adjusting nutrient and flavor profiles[29–31]. The change to food product formulation likely served to enhance population-level food product consumption and therefore food company profits[29–31]. HPF availability increased by an additional 7 % from 2001 to 2018, which is also noteworthy when considered in context of the food market and public health environment. First, in 2001, the US Surgeon General released the first call to action to address obesity and directly identified food companies as a contributor to the epidemic[32]. In response, food companies pledged to improve product formulations to promote healthy eating[30,33,34]. However, during the same period, food company priorities were focused on expanding their market shares, enhancing food production cost efficiency and meeting demand for consumer concerns regarding health and taste[6,35,36]. Evidence from the present study of a continued rise in the prevalence of HPF from 2001 to 2018 indicates that food company goals were likely prioritised over pledges to improve products for consumer health. In this regard, our findings that foods were >4 times more likely to be hyper-palatable in 2018 than 1988 indicates that food products were likely reformulated by the food companies; however, reformulations may have focused on artificially enhancing food product palatability. In summary, our findings indicate that the practices introduced to the food companies in the 1980s focused on product reformulation and enhancement may have had ongoing deleterious effects on our food system, contributing to the current obesogenic food environment in the US.

An interesting finding from the study is that while the prevalence of HPF from all three groups (FSOD, FS and CSOD) significantly increased from 1988 to 2018, the change in the availability of FSOD foods was most prominent (17 %). Our findings overall highlight both the wide availability of FSOD foods in the food system (>50 % of HPF across all years), and the disproportionate increase in the availability of FSOD foods since the late 1980s. FSOD commonly consists of meal-based items and savory foods[14,18] and the findings may reflect the increase of frozen foods and quick preparation items that were introduced to the food system in the 1980s[6,31]. Relatedly, our analyses indicated that foods from the USDA-defined categories of fats, meats and dairy, foods that are commonly frozen or quick-preparation foods, yielded escalating increases in their likelihood of being hyper-palatable over the 30-year period. In contrast, FS and CSOD foods each comprised less than one-fifth of HPF available and their presence in the food system has remained relatively consistent. Overall, the change in HPF prevalence may largely be

Table 4 Change in likelihood of food item hyper-palatability over time by USDA-defined food category

Variable	β	SE	P-value	OR	95 % CI
Main effects					
Year					
1988	Ref		–	–	
2001	1·01	0·11	<0·00001	2·75	2·22, 3·40
2018	0·39	0·13	0·0002	1·47	1·14, 1·90
Food type					
Vegetables	Ref		–	–	
Beans/nuts	1·18	0·23	<0·00001	3·25	2·06, 5·12
Dairy	1·58	0·25	<0·00001	4·85	2·96, 7·94
Eggs	2·15	0·49	<0·00001	8·55	3·27, 22·3
Fats	–0·20	0·38	0·59	0·82	0·39, 1·71
Fruits	–3·08	0·47	<0·00001	0·05	0·02, 0·12
Grains	2·79	0·15	<0·00001	16·2	12·1, 21·7
Meats	1·49	0·13	<0·00001	4·40	3·45, 5·62
Sweets	1·59	0·28	<0·00001	4·91	2·84, 8·49
Interaction effects					
Vegetables					
2001	Ref		–	–	
2018	Ref		–	–	
Beans/nuts					
2001	–1·65	0·25	<0·00001	1·72	0·74, 4·00
2018	–0·65	0·28	0·002	2·49	0·99, 6·26
Dairy					
2001	–0·35	0·27	0·20	9·43	3·85, 23·11
2018	1·16	0·34	0·001	22·93	7·58, 69·37
Eggs					
2001	0·15	0·55	0·78	27·55	5·12, 148·09
2018	0·52	0·63	0·41	21·26	3·00, 150·45
Fats					
2001	2·11	0·44	<0·00001	18·48	4·82, 70·90
2018	3·02	0·53	<0·00001	24·51	4·67, 128·60
Fruits					
2001	–0·99	0·55	0·07	0·05	0·01, 0·23
2018	0·58	0·59	0·33	0·12	0·02, 0·63
Grains					
2001	–0·38	0·16	0·02	30·60	17·54, 53·38
2018	0·80	0·19	0·00002	53·37	28·55, 99·74
Meats					
2001	0·21	0·13	0·11	15·07	9·40, 24·16
2018	1·69	0·16	<0·00001	35·25	21·22, 58·56
Sweets					
2001	–1·19	0·31	0·0001	4·11	1·53, 11·01
2018	–0·61	0·33	0·007	3·95	1·41, 11·09

Model specified random intercept for food item and fixed effects for database year, food category and the interaction of year and food category. OR for main effects represent exponentiated main effects coefficients. OR for interaction effects represent the multiplicative effect of the specified year and food type on the odds of food item HPF.
Ref: reference category.

Table 5 Availability of individual nutrients in foods across years

	1988 Mean	SD	2001 Mean	SD	2018 Mean	SD	*P* value 1988 *v.* 2001	*P* value 1988 *v.* 2018
Fat (g)	8·72	10·78	9·40	11·21	9·72	11·21	<0·001	<0·001
Sugar (g)	4·97	9·61	6·67	13·47	6·50	13·21	<0·001	<0·001
Carbohydrates (g)	15·73	18·84	9·66	13·98	17·48	21·98	<0·001	<0·001
Na (g)	0·39	0·52	0·38	0·40	0·39	0·39	0·391	0·218
Fibre (g)	1·57	2·43	1·68	2·56	1·53	2·40	<0·001	<0·001

P values reported from linear mixed models that specified a random intercept for food item and fixed effect for database year.
All nutrients represent total values (e.g. total fat).

explained as the substantial increases in the availability of FSOD foods, accompanied by smaller increases in FS and CSOD. Our findings are also consistent with our analyses of individual nutrient availability, which indicated significant increases in the availability of total fat, sugar and carbohydrates per serving, all of which are used to create HPF.

The current study had several limitations. First, the study used data from two sources, the FNDDS (representing 2001 and 2018), and the NHANES-III database (representing 1988), and differences in the databases from 1988 to 2000 could reflect structural differences across databases. However, the procedure for creating the 1988 database directly paralleled procedures the USDA uses to create the FNDDS databases for 2001 and 2018 and resulted in key similarities to the FNDDS databases (e.g. all databases had ~6000 items for analysis) that support database consistency with the FNDDS databases. Additionally, our supplemental analyses are consistent with the prior literature in documenting significant increases in fat, sugar, and carbohydrate availability in the US food system since the 1980s[9–11], thus further supporting the validity of the combined data sources for characterising change in the US food system. In addition, the current study did not examine changes in the availability of beverages, as the HPF definition does not apply to liquids. Future work characterising temporal changes in beverage nutrition may reveal additional obesogenic drivers in a changing US food system over time.

Conclusions and implications

The availability of HPF in the US food system has expanded substantially over the past 30 years. The current US food supply is highly saturated with HPF, which our findings indicate comprised almost 70 % of available foods as of 2018. The growing availability of HPF over time, particularly HPF high in fat and Na, may have resulted from the reformulation of existing food products in the food system to be hyper-palatable. Thus, expanding HPF availability may be one key contributor to the obesogenic food environment in the US. Given potential consequences for population health, policy-level action is needed to address the presence of HPF in the food system. Policy may focus on limiting the nutrient thresholds allowed in foods to be below HPF thresholds (e.g. foods should contain <25 % kcal from fat and <0·30 % g from Na). The approach would be beneficial and highly feasible as it could largely decrease the availability of HFP in the food system and would not require the removal of HPF items from the food system altogether (which would be infeasible). Given that reformulation of food products to enhance their palatability may be a key strategy employed by US food companies, policy action targeting nutrient combinations in individual foods may be the most necessary and direct approach to regulating the presence of foods in the food environment that may be difficult to stop eating.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980022001227

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Public Health Nutrition