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Trends in food consumption according to the degree of food processing among the UK population over 11 years

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Abstract

Although ultra-processed foods represent more than half of the total energy consumed by the UK population, little is known about the trend in food consumption considering the degree of food processing. We evaluated the trends of the dietary share of foods categorised according to the NOVA classification in a historical series (2018–2019) among the UK population. Data were acquired from the NDNS, a survey that collects diet information through a 4-d food record. We used adjusted linear regression to estimate the dietary participation of NOVA groups and evaluated the linear trends over the years. From 2008 to 2019, we observed a significant increase in the energy share of culinary ingredients (from 3·7 to 4·9 % of the total energy consumed; *P*-trend = 0·001), especially for butter and oils; and reduction of processed foods (from 9·6 to 8·6 %; *P*-trend = 0·002), especially for beer and wine. Unprocessed or minimally processed foods (≅30 %, *P*-trend = 0·505) and ultra-processed foods (≅56 %, *P*-trend = 0·580) presented no significant change. However, changes in the consumption of some subgroups are noteworthy, such as the reduction in the energy share of red meat, sausages and other reconstituted meat products as well as the increase of fruits, ready meals, breakfast cereals, cookies, pastries, buns and cakes. Regarding the socio-demographic characteristics, no interaction was observed with the trend of the four NOVA groups. From 2008 to 2019 was observed a significant increase in culinary ingredients and a reduction in processed food. Furthermore, it sheds light on the high share of ultra-processed foods in the contemporary British diet.

Key words: National diet and nutrition survey: Food consumption: Food processing: UK

The global increase in obesity and chronic non-communicable diseases is associated with changes in population dietary habits[1–5]. These changes are characterised by the replacement of traditional meals based on fresh foods and culinary ingredients with ultra-processed foods[6–8].

Among various food classification systems, the NOVA classification developed by Monteiro et al. has become the most widely used in research and policy[9]. NOVA classifies foods into four groups based on the degree and purpose of their industrial processing: Group 1 – Unprocessed or minimally processed foods, such as whole grains and cereals, legumes, fruits, vegetables, eggs and meats; Group 2 – Processed culinary ingredients, such as salt, sugar, oils and fats; Group 3 – Processed foods, such as vegetables and legumes preserved in brine, cheeses and bread; and Group 4 – Ultra-processed foods, such as soft drinks, ready-to-eat or semi-ready-to-eat meals, prepared sauces, cured meats, breakfast cereals, packaged snacks and candy[10].

Ultra-processed foods have an unfavourable nutritional profile that negatively affects the nutritional quality of foods[11–16], with significant consequences for health[17–20] and the environment[21].

The availability and sale of ultra-processed foods have boomed in high-income countries (1970–2000)[22] and, more recently, in middle-income countries (2000–2013)[23]. In a 2019 analysis of global ultra-processed food trends, the UK had the third-highest sales volume of ultra-processed food per capita (140·7 kg/capita/year) compared with eighty high- and middle-income countries[24]. Previous analyses of the National Diet and Nutrition Survey (NDNS) show that ultra-processed foods already account for more than half of the total food energy consumed by the UK population[25]. However, as far as we know, there are no trend studies that have examined the changes in actual food consumption considering industrial processing and the differences between socio-demographic strata in the

Abbreviations: NDNS, National Diet and Nutrition Survey.

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UK. In this sense, this study aims to assess the trend of food consumption in the UK from 2008 to 2019, considering the extent and purpose of industrial food processing and to analyse how these trends vary according to socio-demographic characteristics.

Methods

Data source and sample

Data were acquired from the National Diet and Nutrition Survey (NDNS), a national survey conducted in the UK (England, Wales, Scotland and Northern Ireland). This annual survey has used a standardised methodology since 2008 enabling combined analysis[26]. The 1–11 survey years correspond to the years: 1-2008–2009, 2-2009–2010, 3-2010–2011, 4-2011–2012, 5-2012–2013, 6-2013–2014, 7-2014–2015, 8-2015–2016, 9-2016–2017, 10-2017–2018 and 11-2018–2019. The purpose of the NDNS is to collect detailed information about the food consumption of the UK population. Data collection takes place monthly and considers possible seasonal variations in food consumption[27]. The survey samples were randomly drawn from the UK Postcode Address Archive, which contains a list of all addresses in the four constituent countries. One child (from 1·5 to 18 years) or one child together with an adult (19 years or older) were selected from each of the randomly selected addresses[28]. Data collection included an interview with the researcher to collect socio-demographic and food consumption data as well as a visit with a nurse[27]. Food consumption was assessed using a food diary completed by participants on four consecutive days. Everyone who completed the diary on 3 or 4 d was included in the survey, totalling 15 643 participants.

Data and files used in this study were acquired under license from the UK Data Archive found at http://www.esds.ac.uk The study was approved by the ethics committees of each of the four countries participating in the study.

Food consumption

Food consumption was assessed using 4-d food diaries that included workdays and weekends, thus covering all days of the week. Participants were instructed to record all food and beverages consumed inside and outside the home on that day. Portion sizes were estimated using household measures or weights from packing. After completion, diaries were checked by trained interviewers to improve accuracy. Food consumption data from the complete records were coded and processed using the programme DINO (Diet In, Nutrients Out)[29], and energy and nutrient intakes were estimated using the NDNS food nutrient composition table[30].

Covariates

The socio-demographic variables included in this study were: sex (female and male), age group (1–3 years, 4–10 years, 11–18 years, 19–64 years, 65+ years), region (southern England, central England, northern England, Scotland, Wales and Northern Ireland), ethnicity (white, mixed ethnic group, black, Asian and other ethnicities), and occupational social class. Occupational social class was categorised as high (High and lower managerial and professional occupations), intermediate (intermediate occupations, small employers and own account workers, Lower supervisory and technical occupations) and low (routine and manual occupations).

Food classification according to processing

All food items were classified according to NOVA[9], a food classification system based on the nature, extent and purpose of the industrial processing they undergo before consumption. This classification includes four categories (see Box 1).

All foods presented in the NDNS database are coded as food number and grouped into subsidiary food groups (n 155). When possible, the subsidiary food groups were classified directly according to NOVA. When foods within a subsidiary food group belonged to different NOVA groups (n 52), it was the food codes instead of the group, which were classified individually. Hence, it was possible to allocate each underlying ingredient of home-made dishes into the appropriate NOVA group. Food classification details can be found in a previously published article[25].

Data analysis

For each survey day and age group, we defined values for daily energy intake below 1 percentile and above 99 percentiles as outliers. Based on that, tweleve individuals were excluded (n 15 643) and more than 90 % completed the 4-d food diary. The mean of all available days of food diary was used for each person.

Box 1. The NOVA food classification system and its four groups defined according to the extent and purpose of food processing.

Group 1 unprocessed or minimally processed foods	Group 2 processed culinary ingredients	Group 3 processed foods	Group 4 ultra -processed foods
Foods derived directly from plants or animals that have undergone little or no processing after leaving the wild, such as cleaning of inedible parts, grinding, crushing, drying, pasteurizing, and fermenting, and to which no other substances have been added. e.g., beans, grains, fresh or frozen meat, eggs, vegetables, milk	Substances directly obtained from group 1 or from nature by processes such as crushing and pressing, and consumed together with group 1 in culinary preparations. e.g., vegetable oils, butter, salt, and table sugar	Foods produced by industry from the combination of groups 1 and 2. e.g., vegetables in brine, cured meat, cheese and bread made from flour, water and salt	Defined as industrial preparations involving multiple processing steps and techniques and many ingredients, including salt, sugars, oils and fats, substances for industrial use only (soy and milk proteins, hydrogenated fats, and modified starch), and additives added to make the final product more palatable and attractive (flavors, aromas, emulsifiers). e.g., biscuits, confectionary, breakfast cereals, pastries, buns and cakes, packaged salty snacks, sauces, dressing and gravies, soft drinks, milk-based drinks, packaged pre-prepared meals, sausages and other reconstituted meat products

We estimated the distribution of daily energy intake (% of total energy) according to NOVA groups and subgroups: (1) unprocessed or minimally processed = thirteen subgroups; (2) processed culinary ingredients = four subgroups; (3) processed foods = six subgroups; and (4) ultra-processed foods = sixteen subgroups) for each survey year. Linear regression analysis was used to assess how this distribution of NOVA groups and subgroups (% of total energy) varied across the 11 years studied (including year as an ordinal variable). Models were adjusted for the covariates of sex, age group, region, ethnicity and occupational social class. In order to estimate the main changes over the period, the difference in the mean energy share (% of total energy) of the extreme years (year 11 (2019) minus year 1 (2008)) of the NOVA subgroups was calculated.

To examine potential differences in energy share trends (% of total energy) by population subgroups, we evaluated an interaction term between the survey year (as an ordinal variable) and each socio-demographic characteristic using the Wald *F* test.

All analyses were also performed using the contribution of NOVA groups and subgroups to total grams intake (% of total grams).

NDNS study weights were used in all analyses to account for sampling and non-response error. Data analysis was performed using STATA software version 16.1. We considered a *P* value < 0·05 to test statistical significance.

Results

Table 1 presents the evolution of the dietary share of NOVA food groups and subgroups (% of total energy) over the 11 years of the NDNS survey (2008–2019). The dietary share of unprocessed or minimally processed foods (group 1) remained similar from 2008 to 2019 (≅30 % of total energy, *P* for linear trend = 0·505). Processed culinary ingredients (group 2) showed an increase from 3·7 % in 2008 to 4·9 % in 2019 (*P* for linear trend < 0·001) and processed foods (group 3) a decrease from 9·6 % to 8·6 %, respectively (*P* for linear trend = 0·002). No changes were observed in the proportion of ultra-processed foods (group 4), which accounted for more than half of total energy consumed throughout the period (≅56 % of total energy, *P* for linear trend = 0·580).

Regarding unprocessed or minimally processed food subgroups (group 1), there was a significant decrease in the proportion of diet (% of total energy) from 2008 to 2019 for roots and tubers (from 3·9 % to 2·7 %), for red meat (from 4·0 % to 2·2 %), and for 100 % fruit juice (from 1·2 % to 0·8 %). In addition, an increase in the dietary contribution was observed for fruits (from 3·4 % in 2008 to 3·7 % in 2019), for whole grains and cereals (from 2·3 % to 3·2 %), for pasta (from 1·6 % to 1·9 %), for eggs (from 1·5 % to 1·9 %) and for legumes (from 0·5 % to 0·9 %).

Processed culinary ingredient subgroups (group 2) intake varied from 2008 to 2019. The energy share of table sugar decreased significantly from 1·4 % to 1·2 %, while butter and plant oil intake increased significantly from 1·4 % to 2·2 % and from 0·5 % to 1·1 %, respectively.

Among processed food subgroups (group 3), there was a significant decrease in the energy share of beer and wine from 4·1 % to 3·1 %, vegetables and legumes preserved in brine from 1·1 % to 0·9 %, and an increase in other processed foods from 0·3 % to 0·5 % during the same period.

Among ultra-processed food subgroups (group 4), a significant decrease was observed in the energy share of sausages and other reconstituted meat products (from 4·2 % to 3·7 %), soft drinks (from 2·5 % to 1·1 %) and margarine (from 2·4 % to 1·6 %). On the other hand, significant increase in energy share of packaged pre-prepared meals (from 7·4 % to 8·3 %), breakfast cereals (from 4·2 % to 4·9 %), cookies (from 3·2 % to 4·2 %), pastries, buns and cakes (from 2·9 % to 3·7 %), packaged salty snacks (from 1·9 % to 2·3 %) sauces, dressing and gravies (from 2·0 % to 2·2 %).

The significant differences in the mean energy share of the NOVA subgroups between extreme years, reflecting the entire period studied in the UK population, are shown in Fig. 1. For unprocessed or minimally processed foods, the largest differences were observed for red meat (-1·8 %), roots and tubers (-1·2 %) and whole grains and cereals (0·9 %). Among processed culinary ingredients, the differences between butter (0·8 %) and plant oil (0·6 %) stood out. In processed foods, beer and wine (-1·0 %) presented the largest differences. Regarding ultra-processed foods, soft drinks (-1·4 %), margarine (-0·8 %), sausages and other reconstituted meat products (-0·5 %), breakfast cereals (0·7 %), pastries, buns and cakes (0·8 %), packaged pre-prepared meals (0·9 %), and cookies (1·0 %) differed the most.

No interaction was observed for the trend of energy share of the four NOVA groups when considering the socio-demographic characteristics.

The trend in the share of NOVA food groups and subgroups (% of total grams) over the 11 years is shown in online Supplementary Table 1. The trend in % gram consumption observed in the groups evolved according to the % of energy for processed culinary ingredients (increase from 0·5 % in 2008 to 0·6 % in 2019, *P* for linear trend = 0·043); processed foods (decreased from 7·7 % to 5·5 %, *P* for linear trend < 0·001), with the decrease in consumption of beer and wine being noteworthy (from 6·0 % to 3·9 %, *P* for linear trend < 0·001); and ultra-processed foods (remained ≅29 %; *P* for linear trend = 0·090), with the decreased consumption of milk-based drinks subgroup to be highlighted (from 3·2 % to 2·8 %, *P* for linear trend = 0·005). There was a significant increase in gram share of foods grouped as unprocessed or minimally processed (from 61·9 % in 2008 to 65·2 % in 2019, *P* for linear trend < 0·001), with emphasis on the increase in the water subgroup (from 14·3 % to 21·9 %, *P* for linear trend < 0·001) and decreases in the milk and yogurt subgroups (from 7·4 % to 6·4 %, *P* for linear trend < 0·001) and fresh fruit juice (from 4·8 % to 3·4 %, *P* for linear trend < 0·001).

Discussion

By analysing the representative data of the UK population from 2008 to 2019, we found that the trend of energy share of culinary ingredients, particularly butter and oils, has increased significantly. Moreover, processed foods, particularly beer and wine and vegetables and legumes preserved in brine, have decreased significantly. The energy share of unprocessed or minimally

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Table 1 Trend of dietary share (% of total energy intake) of NOVA food groups and subgroups over 11 years in the United Kingdom (NDNS 2008 to 2019)

	Year 1 2008/10		Year 2 2009/11		Year 3 2010/12		Year 4 2011/13		Year 5 2012/14		Year 6 2013/15		Year 7 2014/16		Year 8 2015/17		Year 9 2016/18		Year 10 2017/19		Year 11 2018/20		Adjusted Linear Trend Coef†	p for trend*
NOVA groups nad subgroups	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Unprocessed or minimally processed foods	30·4	(0·5)	29·7	(0·5)	30·3	(0·5)	30·4	(0·5)	30·3	(0·5)	28·9	(0·5)	30·1	(0·5)	30·2	(0·5)	30·4	(0·6)	30·8	(0·5)	29·8	(0·5)	-0·033	0·505
Milk and plain yoghurt	5·1	(0·2)	5·2	(0·2)	4·7	(0·1)	4·8	(0·1)	5·1	(0·1)	5·0	(0·2)	5·0	(0·2)	5·0	(0·2)	4·9	(0·2)	5·1	(0·1)	4·8	(0·2)	-0·007	0·614
Roots and tubers	3·9	(0·2)	3·5	(0·2)	3·4	(0·1)	3·6	(0·1)	3·4	(0·1)	3·2	(0·1)	2·9	(0·1)	2·8	(0·1)	3·1	(0·1)	3·3	(0·1)	2·7	(0·1)	-0·087	0·000*
Fruit	3·4	(0·2)	3·2	(0·2)	3·2	(0·2)	3·4	(0·2)	3·5	(0·1)	3·2	(0·1)	3·4	(0·1)	3·5	(0·1)	3·6	(0·2)	3·7	(0·1)	3·7	(0·2)	0·042	0·004*
Red meat	4·0	(0·2)	3·1	(0·2)	3·4	(0·2)	3·1	(0·2)	3·2	(0·2)	2·9	(0·2)	3·0	(0·2)	2·7	(0·1)	2·8	(0·2)	2·6	(0·1)	2·2	(0·1)	-0·123	0·000*
Poutry	2·8	(0·2)	2·5	(0·1)	3·0	(0·2)	2·6	(0·1)	2·7	(0·1)	2·7	(0·2)	3·1	(0·2)	3·1	(0·2)	3·0	(0·2)	2·9	(0·2)	2·8	(0·2)	0·030	0·054
Cereal [a]	2·3	(0·1)	2·5	(0·1)	3·0	(0·2)	2·7	(0·2)	2·4	(0·2)	2·5	(0·2)	2·9	(0·2)	2·8	(0·2)	2·7	(0·2)	2·8	(0·2)	3·2	(0·2)	0·052	0·002*
Pastas	1·6	(0·1)	1·7	(0·1)	1·7	(0·1)	1·8	(0·1)	1·9	(0·1)	1·7	(0·1)	1·6	(0·1)	1·8	(0·1)	1·6	(0·1)	2·0	(0·2)	1·9	(0·1)	0·026	0·030*
Eggs	1·5	(0·1)	1·4	(0·1)	1·4	(0·1)	1·5	(0·1)	1·5	(0·1)	1·5	(0·1)	1·6	(0·1)	1·7	(0·1)	1·9	(0·1)	1·9	(0·1)	1·9	(0·1)	0·054	0·000*
Vegetables	1·7	(0·1)	1·5	(0·1)	1·6	(0·1)	1·5	(0·1)	1·4	(0·1)	1·5	(0·1)	1·5	(0·1)	1·6	(0·1)	1·7	(0·1)	1·7	(0·1)	1·6	(0·2)	0·003	0·568
Fresh fruit juice (100% fruit) [b]	1·2	(0·1)	1·3	(0·1)	1·2	(0·1)	1·3	(0·1)	1·3	(0·1)	1·0	(0·1)	0·9	(0·1)	1·0	(0·1)	1·0	(0·1)	0·7	(0·1)	0·8	(0·1)	-0·050	0·000*
Fish	1·3	(0·1)	1·2	(0·1)	1·3	(0·1)	1·2	(0·1)	1·1	(0·1)	1·3	(0·1)	1·2	(0·1)	1·3	(0·1)	1·2	(0·1)	1·4	(0·1)	1·1	(0·8)	-0·005	0·590
Legumes	0·5	(0·0)	0·5	(0·0)	0·7	(0·0)	0·8	(0·1)	0·7	(0·1)	0·6	(0·1)	0·7	(0·1)	0·7	(0·0)	0·9	(0·1)	0·8	(0·1)	0·9	(0·1)	0·028	0·000*
Other unprocessed or minimally processed foods [c]	2·1	(0·1)	2·1	(0·1)	1·9	(0·1)	2·2	(0·2)	2·1	(0·2)	1·9	(0·2)	2·3	(0·2)	2·3	(0·1)	2·1	(0·2)	1·9	(0·2)	2·2	(0·1)	0·003	0·802
Processed culinary ingredients	3·7	(0·2)	4·6	(0·2)	4·3	(0·2)	4·1	(0·2)	4·3	(0·2)	4·4	(0·2)	4·8	(0·2)	4·8	(0·2)	5·2	(0·2)	4·7	(0·2)	4·9	(0·2)	0·101	0·000*
Table sugar	1·4	(0·1)	1·8	(0·1)	1·6	(0·1)	1·7	(0·1)	1·5	(0·1)	1·8	(0·2)	1·7	(0·1)	1·5	(0·1)	1·3	(0·1)	1·3	(0·1)	1·2	(0·1)	-0·040	0·000*
Butter [d]	1·4	(0·1)	1·8	(0·2)	1·5	(0·1)	1·4	(0·1)	1·7	(0·1)	1·5	(0·1)	1·9	(0·1)	1·8	(0·1)	2·4	(0·2)	1·9	(0·1)	2·2	(0·1)	0·071	0·000*
Plant oil	0·5	(0·0)	0·7	(0·1)	0·9	(0·1)	0·7	(0·1)	0·7	(0·0)	0·8	(0·1)	0·9	(0·1)	1·2	(0·1)	1·1	(0·1)	1·1	(0·1)	1·1	(0·1)	0·061	0·000*
Other processed culinary ingredients [e]	0·3	(0·0)	0·4	(0·1)	0·3	(0·1)	0·4	(0·1)	0·4	(0·1)	0·3	(0·0)	0·4	(0·1)	0·4	(0·1)	0·4	(0·1)	0·4	(0·1)	0·4	(0·1)	0·008	0·095
Processed foods	9·6	(0·3)	9·2	(0·4)	8·5	(0·3)	8·9	(0·3)	9·0	(0·4)	8·4	(0·4)	8·4	(0·3)	8·6	(0·3)	7·9	(0·3)	8·5	(0·4)	8·6	(0·4)	-0·101	0·002*
Beer and wine	4·1	(0·3)	3·3	(0·3)	3·4	(0·2)	3·6	(0·2)	3·8	(0·4)	3·3	(0·3)	3·1	(0·3)	3·4	(0·2)	2·8	(0·2)	3·3	(0·3)	3·1	(0·3)	-0·073	0·003*
Cheese	2·8	(0·1)	2·9	(0·2)	2·9	(0·1)	2·8	(0·1)	2·9	(0·1)	2·7	(0·2)	2·9	(0·2)	2·7	(0·1)	2·8	(0·2)	2·9	(0·2)	2·7	(0·2)	-0·003	0·813
Vegetables and other plant foods preserved in brine	1·1	(0·1)	1·0	(0·1)	1·0	(0·1)	0·8	(0·0)	0·9	(0·1)	0·9	(0·1)	0·9	(0·1)	0·9	(0·1)	0·7	(0·0)	0·7	(0·0)	0·9	(0·1)	-0·027	0·000*
Processed breads	0·8	(0·1)	0·9	(0·1)	0·6	(0·1)	0·7	(0·1)	0·6	(0·1)	0·7	(0·1)	0·5	(0·1)	0·6	(0·1)	0·6	(0·1)	0·6	(0·1)	0·7	(0·1)	-0·014	0·171
Salted, dried, or smoked meat or fish	0·5	(0·1)	0·6	(0·1)	0·6	(0·1)	0·6	(0·0)	0·5	(0·1)	0·4	(0·0)	0·6	(0·1)	0·5	(0·0)	0·6	(0·0)	0·5	(0·1)	0·5	(0·0)	-0·003	0·564
Other processed foods [f]	0·3	(0·1)	0·3	(0·1)	0·2	(0·0)	0·4	(0·1)	0·3	(0·1)	0·3	(0·1)	0·3	(0·1)	0·5	(0·1)	0·4	(0·1)	0·4	(0·1)	0·5	(0·1)	0·020	0·003*
Ultra-processed foods	55·3	(0·6)	56·5	(0·6)	56·9	(0·6)	56·5	(0·6)	56·4	(0·7)	58·3	(0·7)	56·7	(0·6)	56·4	(0·6)	56·5	(0·7)	56·0	(0·7)	56·6	(0·7)	0·034	0·580
Ultra-processed breads	10·5	(0·2)	11·1	(0·2)	11·3	(0·3)	11·5	(0·3)	11·4	(0·2)	10·8	(0·3)	10·9	(0·3)	11·1	(0·3)	10·9	(0·3)	10·6	(0·2)	10·3	(0·3)	-0·045	0·074
Packaged pre-prepared meals [g]	7·4	(0·3)	7·5	(0·3)	7·2	(0·3)	7·7	(0·3)	7·6	(0·3)	8·3	(0·4)	7·9	(0·3)	8·6	(0·3)	8·5	(0·3)	8·1	(0·3)	8·3	(0·3)	0·119	0·000*
Breakfast cereals	4·2	(0·2)	4·2	(0·2)	4·3	(0·2)	4·4	(0·2)	4·4	(0·2)	4·9	(0·2)	4·5	(0·2)	4·4	(0·2)	4·7	(0·2)	4·7	(0·2)	4·9	(0·2)	0·064	0·001*
Sausage and other reconstituted meat products	4·2	(0·2)	3·7	(0·2)	4·0	(0·2)	3·8	(0·1)	3·7	(0·2)	3·6	(0·2)	3·7	(0·2)	3·2	(0·1)	3·1	(0·0)	3·2	(0·1)	3·7	(0·2)	-0·076	0·000*
Confectionary	3·5	(0·2)	3·5	(0·2)	3·3	(0·1)	3·4	(0·1)	3·7	(0·2)	3·9	(0·2)	3·5	(0·2)	3·5	(0·2)	3·6	(0·1)	3·5	(0·2)	3·4	(0·2)	0·004	0·796
Biscuits	3·2	(0·1)	3·6	(0·1)	3·3	(0·2)	3·8	(0·2)	3·5	(0·2)	3·5	(0·2)	3·8	(0·2)	3·9	(0·2)	3·9	(0·2)	3·9	(0·2)	4·2	(0·3)	0·076	0·000*
Pastries, buns, and cakes	2·9	(0·1)	3·0	(0·2)	3·2	(0·2)	3·4	(0·2)	3·6	(0·2)	3·5	(0·2)	2·9	(0·2)	3·4	(0·2)	3·3	(0·2)	3·4	(0·2)	3·7	(0·2)	0·049	0·004*
Industrial chips (French fries)	2·9	(0·2)	2·8	(0·2)	2·9	(0·2)	2·4	(0·1)	2·6	(0·2)	2·7	(0·1)	3·0	(0·2)	2·6	(0·2)	2·6	(0·2)	2·5	(0·1)	2·5	(0·2)	-0·027	0·077
Soft drinks, fruit drinks and fruit juices	2·5	(0·1)	2·5	(0·2)	2·7	(0·2)	2·5	(0·1)	2·3	(0·1)	2·5	(0·2)	2·3	(0·2)	2·0	(0·2)	2·0	(0·2)	1·5	(0·1)	1·1	(0·1)	-0·122	0·000*
Milk-based drinks	2·0	(0·1)	2·2	(0·1)	2·2	(0·1)	2·2	(0·1)	2·2	(0·1)	2·4	(0·1)	1·8	(0·1)	2·0	(0·1)	2·0	(0·1)	2·2	(0·1)	2·0	(0·1)	-0·017	0·119
Packaged salty snacks	1·9	(0·1)	2·0	(0·1)	1·9	(0·1)	2·1	(0·1)	2·0	(0·1)	2·1	(0·1)	2·1	(0·1)	2·0	(0·1)	2·3	(0·1)	2·1	(0·1)	2·3	(0·1)	0·030	0·005*
Industrial pizza	1·8	(0·2)	2·0	(0·2)	1·7	(0·2)	1·7	(0·2)	1·6	(0·2)	2·1	(0·2)	2·2	(0·2)	2·0	(0·2)	2·3	(0·2)	2·0	(0·2)	2·0	(0·2)	0·035	0·053
Margarine and other spreads	2·4	(0·1)	2·3	(0·1)	2·3	(0·1)	2·3	(0·1)	2·0	(0·1)	1·9	(0·1)	1·6	(0·1)	1·4	(0·1)	1·4	(0·1)	1·7	(0·1)	1·6	(0·1)	-0·099	0·000*
Sauces, dressing and gravies	2·0	(0·1)	2·1	(0·1)	2·4	(0·1)	2·1	(0·1)	1·9	(0·1)	2·2	(0·1)	2·2	(0·1)	2·3	(0·1)	2·2	(0·1)	2·5	(0·1)	2·2	(0·1)	0·025	0·009*
Industrial desserts	0·7	(0·1)	0·9	(0·1)	0·9	(0·1)	0·8	(0·1)	0·9	(0·1)	1·0	(0·1)	0·9	(0·1)	1·1	(0·1)	0·8	(0·1)	0·9	(0·1)	1·0	(0·1)	0·011	0·168
Other ultra-processed foods [h]	3·3	(0·2)	3·2	(0·2)	3·3	(0·2)	2·6	(0·1)	2·9	(0·2)	3·2	(0·2)	3·3	(0·2)	2·9	(0·2)	3·1	(0·2)	3·2	(0·2)	3·4	(0·2)	0·006	0·746

[a]Including grains and flours; [b]Including ultra-high temperature processing (UHT) or pasteurized, and smoothies; [c]Including coffee, tea, sea foods, fungi, nuts, and freshly prepared dishes based on one or more unprocessed or minimally processed food; [d] Including lard and suet shredded; [e] Including starches, coconut and milk cream, gelatin powder, and vinegar; [f] Including salted, sweetened, or oil-roasted nuts or seeds, condensed milk, and commercial baby foods; [g] Including frozen and shelf-stable dishes and canned soups; [h] Including baked beans, meat alternatives, soy and other drinks as milk substitutes, infant formula, and distilled alcoholic drink· SE = standard error.

†Adjusted for age (years), sex, occupational social class and ethnicity (white, mixed ethnic group, black, Asian and other race). *p value<0·05 for linear trend across years.

processed foods and ultra-processed foods did not change significantly during this period. While the energy share of roots and tubers, red meat and fresh fruit juice in the diet tended to decline, the energy share of fruits, whole grains and cereals, pasta, eggs and legumes augmented. Among ultra-processed foods, the energy share of packaged pre-prepared meals, breakfast cereals, cookies, pastries, buns and cakes, packaged salty snacks and sauces, dressing and gravies sauces increased, while the share of sausage and other reconstituted meat products, sweetened beverages and margarine decreased over the entire period.

The previously described trends in the energy share of Nova groups in the UK population did not vary according to sociodemographic characteristics. A study carried out in a nationally representative sample of USA adults, also observed an increase in the energy contribution of processed culinary ingredients from 2001 to 2018 that did not differ by age group, education

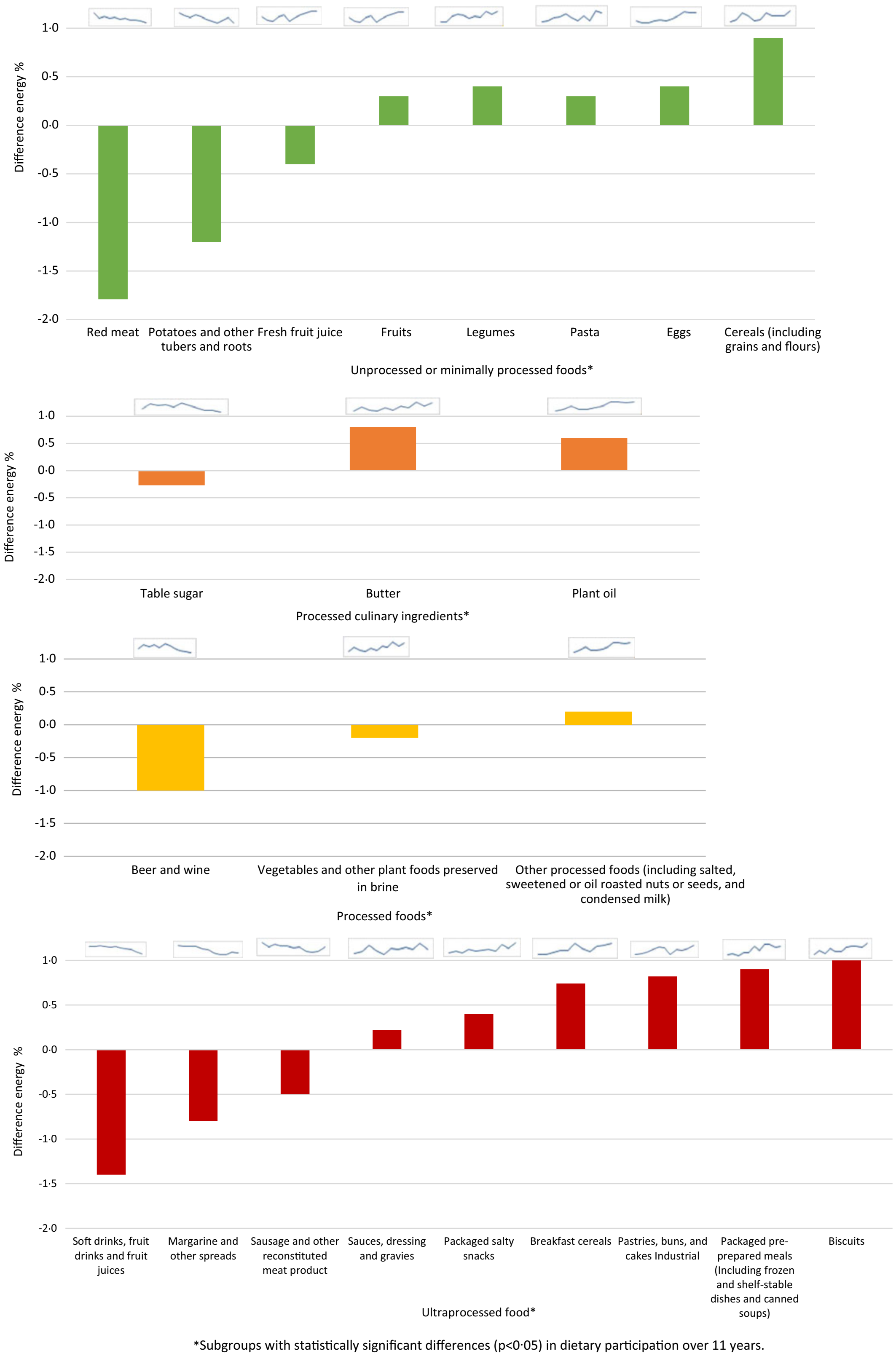

Fig. 1. Changes in food consumption of the UK population according to NOVA classification subgroups between 2008 and 2019.

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or income level but increased the most among non-Hispanic blacks, followed by Hispanics and non-Hispanic whites. Among US adults, however, a borderline significant trend toward increased contribution of processed foods that did not differ by age group was observed. A trend toward increased consumption of processed foods was observed only among females, among non-Hispanic whites and among individuals with a lower household income level. This study observed a decrease in the contribution of unprocessed/minimally processed foods, that was similar among both sexes, among all races/ethnicities, across all education and income levels, decreasing the most among adults aged 60 years and older followed by middle-aged adults and younger adults. Over this period, an increase in the contribution of ultra-processed foods was observed that was similar across all age groups, education and income levels and that increased to a greater extent among males than among females. This increase was only confirmed among non-Hispanic whites and non-Hispanic blacks[34].

As among US adults, a study carried out in a nationally representative sample of US youths between 1999 and 2018, also observed an increase in the energy contribution of processed culinary ingredients, a non-significant change in the contribution of processed foods, a decrease in the contribution of unprocessed/minimally processed foods and an increase in the contribution of ultra-processed foods. A similar increase in the contribution of ultra-processed foods was observed across all sex, age, education and income-level youth population subgroups; however, the increase observed among non-Hispanic Black youths and Mexican American youths was significantly higher than the increase among non-Hispanic White youths[35].

The replacement of unprocessed or minimally processed foods and culinary preparations by ultra-processed foods is occurring worldwide. In the UK, this substitution can be said to have already taken place and reached a plateau where the overall increase in the ultra-processed food group is no longer observed. Ultra-processed foods have become a significant source, and in some cases the main source, of dietary energy, in high-income countries, including the UK[31,32]. While sales of these products appear to be stagnant in high-income countries (due to market saturation), the sales of ultra-processed foods have grown more rapidly in middle-income countries[22,33].

From 2000 to 2016, an analysis of food sales in eighty countries highlighted the global trend of increasing ultra-processed food sales worldwide, except Western Europe, North America and Australasia. The UK had the third-highest volume of ultra-processed food sales (140·7 kg/person), trailing only the Netherlands (143·8 kg/person) and Germany (141·8 kg/person)[24]. Our findings are consistent with these studies on global sales trends, highlighting that ultra-processed food consumption in the UK has remained high in recent years (57 %).

Studies using household budget surveys conducted in Mexico (from 1984 to 2016) and Canada (from 1938 to 2011) have also shown that there has been a gradual decline in unprocessed or minimally processed foods and culinary ingredients – characterising culinary preparations – and an increase in ultra-processed food in recent decades[6,8]. In the USA, trend analyses over the past two decades (2000 to 2018) have shown an increase in the consumption of ultra-processed foods and culinary ingredients accompanied by a decrease in the consumption of minimally processed foods among adults and children[34,35]. In our study, targeting the recent period 2008–2019, we observed an increase in the energy share of processed culinary ingredients among the UK population due to increased consumption of butter and plant oils substituting margarine, which presented a decline over time. This replacement may result from the fact that margarines which are produced through intensive processing and chemical transformation of vegetable oils, contain trans-fats, which are more harmful than saturated fats[36]. We also observed the maintenance of the energy share of unprocessed or minimally processed foods in the British diet, with increases in some subgroups (whole grains and cereals, pasta, eggs and legumes) and decreases in others (roots and tubers, red meat and fresh fruit juice), which may indicate a change in the pattern of British culinary preparations during this period.

The decrease in consumption of fresh red and ultra-processed meats, such as sausages and other reconstituted meat products, observed in this study is consistent with current recommendations to reduce consumption of these foods. In the UK, a review of dietary recommendations by the Scientific Advisory Committee on Nutrition in 2011 recommended the reduction of red and processed meat consumption by adults from ≅90 g/d or more to ≅70 g/d[26]. The report 'The Global Syndemic of Obesity, Malnutrition and Climate Change', published in The Lancet Commission, demonstrates that red meat and ultra-processed foods are among the major contributors to the global syndemic[21].

Our results also showed that despite the reducing energy share of table sugar as a culinary ingredient, there was an increase in the consumption of ultra-processed foods rich in sugars, such as breakfast cereals, biscuits, pastries, buns and cakes. There is already a consensus that high consumption of free sugars contributes to obesity, type 2 diabetes, dyslipidaemia, hypertension, and CHD[37–39] and, consequently, most dietary recommendations limit their intake. However, more focused efforts are needed to put this recommendation into practice as most free sugar is added to foods before they are marketed and sold. A study conducted with data from the national survey showed that ultra-processed foods were the ones that contributed the most to sugar consumption in the UK and the elimination of these products could reduce the prevalence of excessive free sugar intake by 47 %[15]. Initial stages of the UK government's sugar reduction programme, which challenged the food industry to voluntarily reduce the sugar from some products, produced only slow progress towards proposed targets[40].

Energy share reduction of sweetened beverages observed in the period occurred despite no change in the volume (in grams) of these beverages. That may be due to reductions in the sugar concentration of sweetened beverages associated with the UK sugar reduction program and the taxation initiative of the Soft Drink Industry Levy (SDIL) launched in 2015[41,42]. The SDIL was successful in reducing sugar from soft drinks, when compared to that seen for the food categories included in the sugar reduction programme[40]. However, when targeting sugar, the SDIL has hastily contributed to increases in the consumption of drinks with artificial sweeteners[43], which have also been associated with adverse health effects[44,45]. Regarding the contribution of NOVA groups and subgroups to the total grams, an increase of unprocessed or minimally processed foods was observed, unlike the energy share, which is due, at least in part, to the increase in water consumption. The increase in water consumption was accompanied by a decrease in the gram contribution of each one of the remaining beverages, regardless of the degree of processing (milk and plain yogurt, fresh fruit juice, beer and wine and milk-based drinks). This trend of replacing drinks with water in a country like the UK, with high consumption of ultra-processed foods, is positive taking into account studies assessing an inverse association between the energy share of ultra-processed foods and water intake[46].

Our study pioneers analysing trends of food consumption considering the degree of industrial processing among the UK population. In addition, we use data sourced from the NDNS, which uses a high-quality dietary assessment method that provides a detailed analysis of different foods consumed, several assessment days and considers the daily variability of each individual. However, some potential limitations are also noteworthy. The data used were self-reported and may be subject to recording errors. Although food records are recognised as one of the most comprehensive methods for assessing dietary intake, a limitation of this method is the underreporting of some foods, particularly unhealthy foods. Although previous study had shown the mean daily energy intake significant decrease of 164 kJ (39 kcal) between days 1 and 4, the size of the effect was relatively minor[47]. The underreporting of ultra-processed foods may have increased over time, considering the growing awareness of the harmful effects of these products on health. However, NDNS data are accurate and validated through painstaking collection methods, with review by trained personnel which helps to minimise misreporting. Although NDNS collects limited information indicative of food processing (i.e., meal location and product brands), the data are not consistently determined for all food items, which can lead to a food classification error. However, standardised NDNS methods minimise potential error and bias.

Food consumption trends according to the degree of food processing highlight a significant increase in processed culinary ingredients and a reduction in the consumption of processed food in the British diet from 2008 to 2019. Furthermore, it sheds light on the high share of ultra-processed foods in the contemporary British diet.

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Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114522003361

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