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Conference on 'Architecture of food: Processing, structure and health' Plenary Lecture

How and why ultra-processed foods harm human health

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The analysis of food using a perspective centred on nutrients seems inadequate for understanding the dietary transition and its impact on the growth of obesity and chronic diseases. Industrial food processing is now proposed as the key to explain the relationship between food and health. The NOVA food classification considers the degree and the purpose of food processing, which includes physical, biological and chemical processes used after foods are separated from nature, and before being consumed or prepared as dishes and meals. NOVA has four food groups: (1) unprocessed and minimally processed foods; (2) processed culinary ingredients; (3) processed foods and (4) ultra-processed foods, which are formulations made mostly or entirely from substances derived from group 1 foods and additives, with little if any intact group 1 food. Many investigations linking high ultra-processed food consumption with deterioration of diets and adverse health outcomes are reinforced by prospective studies, systematic reviews and meta-analyses. There are various plausible explanations of why diets high in ultra-processed foods are harmful. Their production and consumption continue to rise worldwide. Efficient and effective public policies and actions that reduce production and consumption of ultra-processed products are needed, to protect human health now and in future.

Key words: Ultra-processed foods: Food processing: NOVA: Human health

NOVA background

Since the 1980s the dietary patterns of the Brazilian population have been monitored, based on family budget surveys carried out by the official Brazilian Institute of Geography and Statistics. In 2009 a new analysis showed that purchases of staple foods such as rice, beans, meat and milk, and also culinary ingredients such as sugar, oils, fats and salt had decreased during the period 1987–2009, while purchases of soft drinks, ready-to-eat meals, sausages, industrialised cakes, pies and cookies had increased[(1)] (see Fig. 1).

The substantial decline in culinary ingredients was striking. Conventionally, recommendations are to avoid them, because salt aside they are very high in dietary energy and are nutritionally unbalanced or depleted. Also impressive was that ready-to-consume foods were displacing long-established food patterns based on meals. The decrease in culinary ingredients showed that families were cutting down on cooking and instead buying and consuming industrialised foods[(1)].

It was apparent that analysis of food in terms of its nutrients was inadequate, and it seemed likely that

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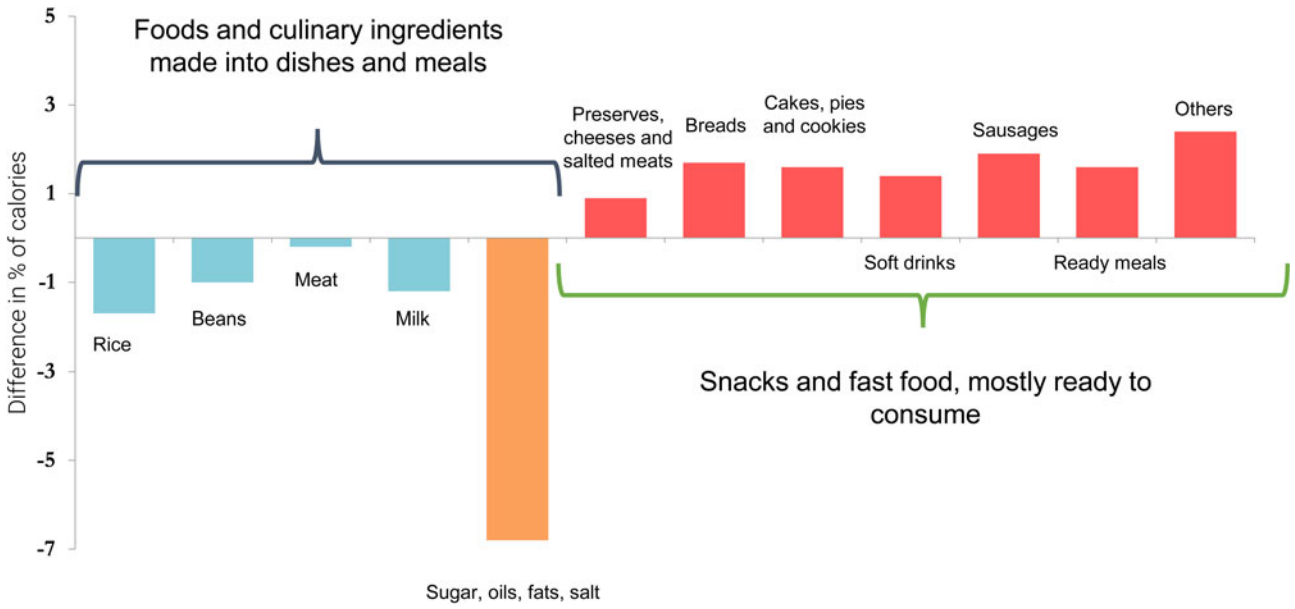

Fig. 1. Changes in food purchases by the Brazilian population (1987–2009). It shows that purchases of staple foods such as rice, beans, meat and milk, and also culinary ingredients such as sugar, oils, fats and salt had decreased during the period 1987–2009, while purchases of soft drinks, ready-to-eat meals, sausages, industrialised cakes, pies and cookies had increased.

industrial food processing would better explain the relationship between food and health[2, 3].

All foods are processed in some way, except for some fruits and vegetables. All others have been processed. So, it does not make sense to just divide processed and unprocessed foods. Various processes are innocuous and contribute to a healthy and sustainable diet. For instance, food preservation maintains societies[4]. The NOVA food classification, which was first published in 2010[5], was the result of these research studies and reflections. After being refined through data analysis and discussions, an updated version was included in the 2014 edition of the Dietary Guidelines for the Brazilian Population[6].

The NOVA food classification

Food processing, as identified by NOVA (which is not an acronym), includes the physical, biological and chemical processes used after foods are separated from nature, and before being consumed or prepared as dishes and meals[2]. NOVA has four food groups divided by the nature, extent and purpose of industrial processing. See Table 1[2].

A practical way to identify ultra-processed foods is to look for their markers in lists of ingredients. Markers include the presence of substances never or rarely used in kitchens. These include hydrolysed proteins, soya protein isolate, gluten, casein, whey protein, 'mechanically separated meat', fructose, high-fructose maize syrup, 'fruit juice concentrate', invert sugar, maltodextrin, dextrose, lactose, soluble or insoluble fibre, hydrogenated or interesterified oil; and also, other sources of protein, carbohydrate or fat which are neither foods from NOVA group 1 or group 3, nor culinary ingredients from NOVA group 2. One or more of these food substances usually identifies a product as ultra-processed[7].

Markers also include the presence of classes of additives other than preservatives. These are at the end of lists of ingredients. Many have cosmetic functions. They include flavours, flavour enhancers, colours, emulsifiers, emulsifying salts, sweeteners, thickeners, and antifoaming, bulking, carbonating, foaming, gelling and glazing agents. The presence in the list of ingredients of one or more of these types of additives also usually identifies a product as ultra-processed[7].

Ultra-processed foods, diets and diseases

Impact on diet quality

The main metric used to identify ultra-processed food consumption patterns is the percentage of ultra-processed food in diets, in calories or in grams. This information has been published using data from national surveys in several countries[8–17]. There is a large variation of ultra-processed food consumption between countries, from less than 16 % of the total energy in Colombia[14] up to 57 and 58 % in the UK and USA, respectively[15,18].

There are some publications regarding ultra-processed trends. Brazil[16] and Mexico[12], for instance, have a long series of budget surveys. These countries had a low-ultra-processed food consumption in the 1980s and 1990s and now they are both close to 20 % of the total energy. In Mexico, the ultra-processed food consumption increased from 10 % in 1984 up to 23 % in 2016[12]. In Brazil, the consumption of ultra-processed foods was 10 % of the total energy of diets in 1987–1988 and it

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Table 1. NOVA food groups: definition and examples

NOVA group	Definition	Examples
(1) Unprocessed and minimally processed foods	Unprocessed (or natural) foods are edible parts of plants (seeds, fruits, leaves, stems, roots) or of animals (muscle, offal, eggs, milk) and fungi, algae and water, after separation from nature. Minimally processed foods are unprocessed foods altered by processes that include removal of inedible or unwanted parts, drying, crushing, grinding, fractioning, filtering, roasting, boiling, non-alcoholic fermentation, pasteurisation, refrigeration, chilling, freezing, placing in containers and vacuum-packaging. These processes are designed to preserve natural foods, to make them suitable for storage or to make them safe or edible or more pleasant to consume. Many unprocessed or minimally processed foods are prepared and cooked at home or in restaurant kitchens in combination with processed culinary ingredients as dishes or meals.	Fresh, squeezed, chilled, frozen or dried fruits and leafy and root vegetables; grains such as brown, parboiled or white rice, maize cob or kernel, wheat berry or grain; legumes such as beans, lentils and chickpeas; starchy roots and tubers such as potatoes, sweet potatoes and cassava; fungi such as fresh or dried mushrooms; meat, poultry, fish and seafood, whole or in the form of steaks, fillets and other cuts, fresh, chilled or frozen; eggs; fresh or pasteurised milk; fresh or pasteurised fruit or vegetable juices (with no added sugar, sweeteners or flavours); grits, flakes or flour made from maize, wheat, oats or cassava; tree and groundnuts and other oily seeds (with no added salt or sugar); herbs and spices used in culinary preparations, such as thyme, oregano, mint, pepper, cloves and cinnamon, whole or powdered, fresh or dried; fresh or pasteurised plain yogurt; tea, coffee and drinking-water. Also, foods made up of two or more items in this group, such as dried mixed fruits, granola made from cereals, nuts and dried fruits with no added sugar, honey or oil; pasta, couscous and polenta made with flours, flakes or grits and water and foods with vitamins and minerals added generally to replace nutrients lost during processing, such as wheat or maize starch fortified with iron and folic acid.
(2) Processed culinary ingredients	Processed culinary ingredients, such as oils, butter, sugar and salt, are substances extracted from group 1 foods or from nature by processes that include pressing, refining, centrifuging, milling, extracting and drying, so as to make durable products suitable for use in home and restaurant kitchens to prepare, season and cook group 1 foods and to hand-make with them varied and enjoyable dishes and meals, such as stews, soups and broths, salads, breads, preserves and desserts. They are rarely or never consumed by themselves.	Vegetable oils crushed from seeds, nuts or fruits; butter and lard obtained from milk and pork; sugar and molasses obtained from cane or beet; honey extracted from combs and syrup from maple trees; starches extracted from maize and other plants, and salt mined or from seawater, vegetable oils with added antioxidants, and table salt with added drying agents. Also, products consisting of two group 2 items, such as salted butter, and group 2 items with added vitamins or minerals, such as iodised salt.
(3) Processed foods	Products made by adding salt, oil, sugar or any other group 2 ingredients to group 1 foods and using preservation methods, such as canning and bottling, and, in the case of bread and cheese, non-alcoholic fermentation. Processes and ingredients here aim to increase the durability of group 1 foods and make them more enjoyable by modifying or enhancing their sensory qualities. These products may contain additives that prolong product duration, protect original properties or prevent the proliferation of harmful microorganisms.	Canned or bottled vegetables and legumes in brine; salted or sugared nuts and seeds; salted, dried, cured or smoked meats and fish; canned fish (with or without added preservatives); fruits in syrup (which may add antioxidants); freshly made unpackaged bread and cheeses.
(4) Ultra-processed foods	Ultra-processed foods are not modified food. They are formulations made mostly or entirely from substances derived from foods, and additives, with little if any intact group 1 food. Ingredients usually include those also used in processed foods, such as sugars, oils, fats and/or salt. Ultra-processed products also include other sources of energy and nutrients solely of industrial use. Some of these are directly extracted from foods, such as casein, lactose, whey protein and gluten. Many are derived from further processing of food constituents, such as hydrogenated or interesterified oils, hydrolysed proteins, soya protein isolate, maltodextrin, invert sugar and high-fructose maize syrup.	Carbonated soft drinks; sweet or savoury-packaged snacks; chocolate, candies (confectionery); ice cream; mass-produced packaged bread and buns; margarine and other spreads; cookies (biscuits), pastries, cakes and cake mixes; breakfast 'cereals', 'cereal' and 'energy' bars; 'energy' drinks; milk drinks, 'fruit' yogurts and 'fruit' drinks; 'cocoa' drinks; 'instant' sauces; infant formulas, follow-on milk, other baby products; 'health' and 'slimming' products such as meal replacement shakes and powders. Many ready-to-eat products, including pre-prepared pies, pasta and pizza dishes; poultry and fish 'nuggets' and 'sticks', sausages, burgers, hot dogs and other reconstituted meat products, powdered and packaged 'instant' soups, noodles and desserts.

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reached 21 % in 2018. In high-income countries such as Canada[19] and Spain[20], these publications show a solid increase over time in Canada[19], from 24 % in 1939 to 55 % in 2001. And a very large increase, from 10 to almost 30 % in 20 years, in Spain[20].

In the USA, consumption is very high, and reached 67 % of the total energy in children in 2017–2018[8,21]. In the UK, data from the period 2008–2019 show a decrease in consumption of soft drinks, sausages and margarine, but an increase in biscuits, salty snacks and ready-to-eat meals[22]. Overall, ultra-processed foods intake is about 56 % of total energy[22].

Data from Euromonitor, the world's leading provider of strategic market research reporting, show that ultra-processed foods and drinks sales are growing almost everywhere. During the period 2006–2019, in Australasia and North America, and Western Europe sales of ultra-processed foods increased from 128 kg/per capita to 134 kg/per capita and from 106 kg/per capita to 115 kg/per capita, respectively. There are regions where ultra-processed sales are still comparatively low, such as Africa and Asia. Regions with lower consumption show a higher increase rate[23].

A systematic review of the impact of ultra-processed food on diet quality, including a meta-analysis, with data from 13 countries, shows that an increase in consumption of ultra-processed foods is associated with a decline of the overall dietary nutrient profile[24]. The higher the ultra-processed food intake, the higher the energy intake, and that of saturated fats and free sugars, and the lower the intake of fibre, protein and potassium[24]. Also, the higher the ultra-processed foods consumption, the lower the consumption of vegetables and fruits[24].

Impact on diseases

Investigations from many countries link high ultra-processed food consumption with greater risk of disorders, diseases and premature death. Cohort studies have found links with obesity and adiposity outcomes, type 2 diabetes, hypertension, dyslipidaemia, hyperuricaemia, CVD, breast, ovarian, brain and overall cancer, non-alcoholic cirrhosis, Crohn's disease, chronic renal failure, depression, cognitive decline, dementia and all-cause mortality[25–39].

These are reinforced by at least forty-one prospective studies, and eleven systematic reviews and meta-analyses. For adiposity, a recent meta-analysis comparing the highest and lowest consumption quartile of ultra-processed food was 1·55 for obesity, 1·36 for overweight and 1·41 for abdominal obesity[25]. For this outcome, as well as prospective studies and systematic reviews with meta-analyses[25], there is a randomised clinical trial[40].

Twenty adults were confined at a clinical centre, randomised into two groups, to consume, ad libitum, either an ultra-processed food diet or a non-ultra-processed food diet for 2 weeks. They exchanged their diets after this period. Both groups had meals which contained the same amount of energy, macronutrients, sugar, sodium and fibre. When participants were on the ultra-processed food diet, they ate about 500 calories more every day, in relation to the day they were on the non-ultra-processed diet. They gained an average of almost 1 kg after the week they were on the ultra-processed food diet and lost the same amount after the week they were on the unprocessed food diet. This showed that high ultra-processed food diets cause higher energy intake and weight gain[40].

Type 2 diabetes has been investigated by prospective cohort studies in France[41], UK[42], Spain[43] and the Netherlands[44]. Meta-analysis found that each 10 % increase in ultra-processed food intake (kJ/day) was associated with a 15 % higher risk of type 2 diabetes[37].

A meta-analysis published in 2022 using nine observational studies showed that a higher ultra-processed food consumption increased by 23 % the risk of hypertension, comparing highest and lowest categories of ultra-processed foods consumption[38].

For CVD, a meta-analysis evaluated the association between ultra-processed food and CVD incidence and mortality. A higher intake of ultra-processed food was associated with a 29 % increased risk of CVD incidence and mortality and a 34 % increased risk of cerebrovascular disease incidence and mortality[27].

Ultra-processed food has been associated with all-cause mortality in prospective cohorts conducted in the USA, Spain, France and Italy. Meta-analysis showed that ultra-processed foods consumption increased all-cause mortality by 21 % comparing highest and lowest categories of ultra-processed foods consumption[36].

Reasons for harm

There are many reasons why ultra-processed foods are problematic. Usually, they are convenient, practical and portable, generally designed to be consumed anywhere – in front of television or a computer, in the workplace or walking or driving –, and dispense with the use of plates and cutlery[7]. Most of the time, they are sold as snacks, drinks or ready-to-eat or ready-to-heat meals. So, they displace freshly prepared meals based on natural or minimally processed foods. Some studies showed that portion sizes as served in fast-food outlets have increased significantly in recent decades[45] and a direct association of bigger portions with total energy intake and weight gain was found[46,47].

The set of these unfavourable extrinsic characteristics of ultra-processed foods is further amplified by aggressive and sophisticated marketing. It changes social norms, especially among the most vulnerable consumers, such as children[48]. Many marketing strategies for these products rely on unsubstantiated health claims. In low- and middle-income countries, advertising quickly penetrates emerging markets[49].

Also, there are various plausible biological reasons why ultra-processed foods increase the risk of disease. One is the negative impact of the consumption of ultra-processed foods on diet quality[24]. Although, studies adjusted for intake of total fat, sugar and sodium[25] still show associations with disorders and diseases, so other characteristics of ultra-processed foods besides dietary profile are evidently harmful to health.

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Thus, evidence showed that consumption of large amounts of ultra-processed foods lead to lower water intake[50] and higher intake of food additives[51]. Some additives such as artificial sweeteners, emulsifiers and colourings, evidently harm gut microbiota[52]. Furthermore, additives combined with fat, salt and sugar create hyperpalatable foods which may be addictive and so consumed excessively[7].

In addition, ultra-processing damages or destroys the whole food structure (its matrix). This evidently adversely affects food absorption and bioaccessibility and inflames gut microbiota[52]. It also destroys the phytochemicals in food[53].

The packages of ultra-processed food contain plastic molecules, such as phytates and bisphenols[54]. A study identified that bisphenol A promotes insulin resistance and oxidative stress[55]. Also, processing using intense heat and extrusion can create acrolein and acrylamide that have been linked to oxidative stress and insulin resistance[55].

Other factors, such as increased glycaemic response, reduced satiety and thermic effect[56], also plausibly explain why ultra-processed foods increase the risk of various disorders and diseases and premature death.

Public policies and actions

Public health policies and actions designed to reduce consumption of ultra-processed food, or else of fatty, sugary and/or salty foods that are usually ultra-processed, are in place in a number of countries[57].

The 'golden rule' of the official Brazilian dietary guidelines is 'Always prefer natural or minimally processed foods and freshly made dishes and meals to ultra-processed foods'[6]. These guidelines also consider the cultural, social and environmental aspects involved in food choices.

In Brazil, the National School Feeding Program offers free school meals to all students in public schools (primary, middle and high school). It regulates processed and ultra-processed food to a maximum of 20 % of the total budgets, prohibits ultra-processed foods in any form to children up to 3 years of age and also prohibits soft drinks, chocolate, candies, cookies, cakes with toppings or fillings and powdered food to all children[58].

Other countries have recommended less ultra-processed food or less food that is in effect ultra-processed in their official guidelines. These include France, Israel, Chile, Uruguay and Ecuador[59–63].

The Pan-American Health Organization Nutritional Profile Model recommends front-of-package warning labels on processed and ultra-processed foods with high amounts of sugar, sweeteners, fat and/or sodium. It also recommends fiscal policies and restriction of sales and advertising[64]. Chile, Mexico, Uruguay, Peru, Brazil and Ecuador have implemented front-of-package labels warning of high content of sugar, saturated fat and sodium[58,65–69]. In Mexico, the labels also warn about non-nutrient components, such as sweeteners[65]. Chile has also regulated marketing on food packaging. Products with warning labels cannot carry promotional strategies such as cartoon characters[69].

In Brazil, food corporations have impeded regulation[70–73]. The current Brazilian front-of-package labels include only added sugar, saturated fat and sodium with more flexible cut-off points, and use a warning in the form of a magnifying glass, in reduced size compared to other Latin American countries[70].

Various countries restrict advertising of poor nutritional quality products during children's programmes and/or during programmes with a high audience of children and adolescents[74–76]. More general policies have so far only been established in Portugal, where the advertising of products with poor nutritional quality on websites, social networks and mobile applications for children under sixteen is forbidden[77].

Fiscal policies are implemented in some countries. Currently more than forty countries have taxed sugary drinks[78], which has reduced their consumption. In Chile and Mexico, fiscal policies implemented with other measures (such as marketing regulation and front-of-package warning labels) decreased the sales of sugary drinks by 24 and 7·6 % in 2 years, respectively[79,80].

So far, few public policies have been directed specifically at ultra-processed food, and worldwide their production, sales and consumption continue to increase[23,81]. The biggest obstacle to public policies and actions to reduce the consumption of ultra-processed foods is corporate influence on policy decision-taking and implementation[70–72]. This strategy includes lobbying policy makers; stressing the economic importance of corporations; promoting deregulation; shaping the evidence on diet and health; financial incentives and establishing relationships with the media. Corporate interests' conflict with those of public health, and corporate representatives should be excluded from policy discussions and decisions[70].

Conclusion

We believe that there is already enough high-quality evidence to state that ultra-processed foods are harmful. Efficient and effective local, national and international public policies and actions that will reduce production and consumption of these products are needed, to protect human health now and in future, and that of the living and physical world. Above all, what is needed is concerted political will that engages citizens, social movements, health professionals, the media, policy-makers in government at all levels and the food industry as a whole.

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Conflict of Interest

None.

Authorship

R. B. L. contributed to the conception and design of the article, writing of the manuscript and approved its publication. M. F. B., M. A. L. and G. C. A. contributed to the design of the article, writing and critical review of the manuscript and approved its publication.

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