Factsheet
Food Processing

Cosun
Nutrition Center

Food Processing Factsheet

Nutritional recommendations have evolved from advice on nutrients to advice on foods. Dietary patterns are now also a more integral part of dietary guidelines. The consumption of ultra-processed foods (UPF) is one of the patterns in relation to health risks that has attracted interest in recent years among nutrition scientists and the media. A number of countries have included limiting the consumption of UPF in their official dietary guidelines, but various nutrition experts question the scientific basis for this. Scientific evidence of an unfavourable effect of UPF on the development of chronic diseases is discussed in this factsheet.

According to Richard Wrangham[1], Professor of Biological Anthropology, the ancestors of *Homo sapiens* learned around a million years ago to control fire, letting them prepare better tasting and more easily digestible foods. The majority of food processing methods developed after the introduction of farming around 11,000 years ago. Beer (7,000 BC), cheese (5,000 BC), chocolate (1900 BC), mustard (400 AD), tofu (965 AD), high-fructose corn syrup (1957) and cultured meat (2013) are a few of the countless innovations that new foods have added to the human diet. Drying, fermenting, salting and smoking are among the methods used. Food processing is useful and often necessary because it benefits edibility, digestibility, perishability, microbiological and other safety characteristics, composition (nutritional value), palatability, sustainability and convenience[2,3].

Prior to World War I, food processing consisted of such simple actions as cleaning, sorting, cutting, chopping, pureeing, grinding and heating, followed by canning, preserving, freezing and packaging. In the 1930s, the food industry began to extract components from food. This approach developed rapidly during World War II and boomed from the 1950s onwards. Additives and micronutrients were added to various types of foods. Using a combination of heating and physical-chemical processing, components of food were isolated and combined in a new product, such as ready-to-eat meals, savoury snacks and all kinds of sweets.

In recent years, the extensive processing of foods has been subject to criticism and introduced the concept of 'ultra-processed foods' (UPF). UPF are considered problematic in terms of nutrition due to their low levels of fresh ingredients, dietary fibre and micronutrients and may contain harmful ingredients such as additives. There is a great deal of debate among nutrition experts concerning the effect of UPF on our health, such as by Mike Gibney in 2019 and judging by the debate between Carlos Monteiro (advocate of a recommendation) and Arne Astrup (opposed to this) at an important American nutrition conference[4,5].

The summary of this factsheet can be downloaded on this page

Definition

There are a number of different definitions (and therefore classifications) of UPF, which has resulted in different associations with health risks[6], including in one and the same data file[7]. A consistent definition appears to be difficult to achieve. The English Health Council (Scientific Advisory Committee on Nutrition, SACN) analysed seven classification systems[3]. Only the so-called NOVA classification met all five pre-established criteria, including a workable definition and use in research into health effects. NOVA, developed by Brazilian Carlos Augusto Monteiro, is the most commonly used classification system based on the degree of processing. It differentiates between four categories of foods (see **Table 1**).

Monteiro (in[4]) uses the following definition of ultra-processed foods: ''Industrial formulations made mostly or entirely with substances extracted from foods, often chemically modified, and from additives, with little if any whole food added. Sequences of processes are and must be used to obtain, alter, and combine the ingredients and to formulate the final products (hence "ultra-processed")." According to Gibney *et al.*[8], this definition makes several interpretations possible. Gibney[9] has shown that the NOVA classification has changed seven times in ten years. The emphasis was initially on the number of ingredients and processing method, but the goal of the processing, such as to improve taste, is now also a central element of the classification.

The definitions have also been expanded with more elements. In a recent study, over 300 experts classified more than 200 foods and the results showed considerable inconsistency between the individuals involved in the classification of the foods in one of the four categories in the NOVA classification system[10]. With four of the over 200 foods, there was complete agreement on the allocation in one of the four NOVA categories. Apparently, it is difficult for scientists to uniformly interpret the classification system for UPF and according to Gibney[7] and Forde[6], every grouping is somewhat subjective. Moreover, Hässig *et al.*[11] found a strong correlation between estimates of the processing level and the NOVA classification system by laypersons in Switzerland.

Table 1. NOVA classification[4]

Group 1	Unprocessed or minimally processed foods, such as vegetables, fruits, meat and fish. Additives are absent in this group. Minimal processing methods include the boiling, freezing, peeling and crushing of fruit.
Group 2	Culinary cooking ingredients from group 1 or from nature, such as salt, olive oil and sugar. Used to prepare and season group 1 foods.
Group 3	Processed foods designed for a longer shelf life and improved taste, such as canned vegetables, bread prepared by a local bakery, beer and wine.
Group 4	Ultra-processed foods: industrial formulations that usually contain more than five ingredients, such as ready-to-eat meals, supermarket bread, follow-on milk, chocolate, chips, cookies, regular and diet soft drinks, meat substitutes and pizza. An additive is an ingredient.

Health effects

A Dutch cohort study showed that the risk of developing type 2 diabetes is not the same for different groups of UPF[12]. A dietary pattern with a relatively large number of hot savoury snacks and a pattern with a relatively large number of cold savoury snacks was associated with an increased risk of developing type 2 diabetes. A traditional Dutch diet was not associated and a pattern with a relatively large number of sweet snacks and baked goods was inversely associated with the development of type 2 diabetes[12].

The consumption of UPF was allegedly linked to negative effects on public health, particularly obesity and chronic diseases[13,14]. The number of studies into the relationship between UPF and health has increased considerably in recent years. Observational (epidemiological) research shows a positive link between the degree of UPF consumption and an increased risk of chronic lifestyle diseases[15]. In one experimental study, higher consumption of UPF resulted in weight gain and a higher energy intake. In the various overview articles of cohort studies published, associations were identified between the consumption of UPF and higher blood pressure[16], more dental caries in children and adolescents[17], a higher risk of irritable bowel syndrome[15,18], cardiovascular diseases[15,18], overweight and obesity[5,18,19], type 2 diabetes[20,21], gestational diabetes and preeclampsia[22], cancer[15,18,23], depression[18,24] and total mortality[13,15,26]. Various pathological processes underly the aforementioned diseases and conditions, making it challenging to find a (common) mechanism of action for all of these processes[27].

The extent to which these links can be attributed entirely to food processing or are caused in full or in part by the underlying suboptimal nutrient composition and the high energy density of many UPF is still unclear. Other characteristics, such as education, smoking behaviour and alcohol use, may also differ between people who consume much or little UPF. From an epidemiological perspective, in spite of a variety of statistical techniques, these factors are difficult to isolate, resulting in residual confounding. For example, UPF contains more energy, saturated fat, sugars and salt than less processed food[28]. Salt, sugar and fat are common ingredients in UPF and are usually included in larger quantities than in less processed food[4]. Research conducted in 13 countries (with middle and high incomes) shows that high consumption of UPF is associated with

a higher intake of energy, free sugars and saturated fat and a lower intake of dietary fibre, protein and various micronutrients, including potassium. The consumption of minimally processed food, such as fruit, vegetables and legumes, was lower with a high consumption of UPF[29]. A study by Cordova *et al.*[30] shows that it is imprudent to treat UPF as a single group because the effects of various groups of foods differ. High consumption of UPF was found to be associated with an increased risk of multimorbidity of cancer and cardiometabolic diseases (including type 2 diabetes). Seven groups of UPF, including plant-based substitutes for meat and dairy, for example, did not demonstrate a significant association with multimorbidity. A high consumption of UPF products of animal origin and artificial and sugar-sweetened drinks were associated with a higher risk of multimorbidity.

AI indications (from overview articles containing a number of meta analyses) for the above links between UPF consumption and health risks originate from epidemiological (cohort) research and have a reputation, as mentioned above, for not providing evidence of cause and effect[5,31]. With UPF, its heterogeneity also makes it difficult to isolate any effect of UPF. The consumption of UPF is related to numerous other factors, including the existing guidelines for a healthy diet, as well as socioeconomic status. These are disruptive factors that must be corrected statistically. That is not always sufficiently possible because the disruptive factor has not been (adequately) measured. This correction was carried out in different ways in the various studies. In addition, the questionnaires used (usually food frequency questionnaires) in cohort studies are not designed to classify products according to their processing degree, which means that unvalidated assumptions are needed[3,31,32]. The results from the various studies are therefore uncertain.

In the ideal situation, the dietary guidelines are based on epidemiological research, controlled clinical studies and mechanism data. Epidemiological studies provide hypotheses that be confirmed by clinical studies. A proven mechanism of action makes an identified effect in a clinical study biologically plausible.

Controlled clinical studies

Thus far, there has only been one intervention study, which was carried out by the American Kevin Hall[33]. In this study, randomly assigned participants were given a diet of UPF or unprocessed foods for two weeks followed by the opposite diet for another two weeks. The meals were comparable in terms of calories, energy density, macronutrients, sugar, sodium and dietary fibre. The participants were allowed to consume as much as they wanted. The energy intake was greater during the ultra-processed diet (508 ± 106 kcal/d) due to a higher intake of carbohydrates (280 ± 54 kcal/d) and fat (230 ± 53 kcal/d), but there was no difference in protein intake (−2 ± 12 kcal/d). Weight changes were strongly correlated with energy intake (r = 0.8) in the participants, who had a weight gain of 0.9 ± 0.3 kg during the ultra-processed diet and weight loss of 0.9 ± 0.3 kg during the unprocessed diet. As with any study, there are remarks to be made. The energy density of highly processed foods in solid form was nearly twice as high as in unprocessed foods. The energy intake rate of UPF was around 50% higher (48 versus 31 kcal/min). This suggests that the differences between the processing levels in the two diets were due to significant differences in food texture and energy density, and that the increase in energy intake observed with UPF was possibly associated with the softer texture/faster eating rate and higher energy density of UPF[27,34]. Both factors have been known for decades to be very important causes of obesity and associated diseases. Research into the relationship between UPF and weight gain did not provide supporting evidence for the mechanisms of palatability or a change in appetite. According to Astrup[4], the study is too short and distorted by differences in, for example, energy density to determine a causal relationship. Given that this sole clinical study had weight gain as the end point, the remainder of this factsheet focuses primarily on weight gain.

Mechanisms

Little is known with certainty about the numerous mechanisms of action that may be responsible for the link between UPF consumption and weight gain. Valicente *et al.*[35] mapped out the possible mechanisms of a potential link between the consumption of UPF and development of overweight and obesity based on 366 publications. The authors distinguish three types of mechanisms in the relationship between the consumption of UPF and body weight: food choices (low cost and palatability), food composition (added salt, sugar, fat, additives and texture) and digestive processes (eating rate, gastric emptying time and gut microbiota). These mechanisms would explain why UPF leads to weight gain. However, the results of the overview article show that the intake of UPF is not sufficient or necessary for weight gain and that the identified effects are modest (i.e. relatively minor).

No differences were found for a number of mechanisms (such as high versus low dietary fibre content or texture, gastric emptying and throughput time of food in the intestines). No data (change in microbiota, food additives) or insufficient data (packaging, food price, perishability and appetite stimulation) is available for other explanations.

The authors of the overview article concluded that it would be imprudent to give recommendations on the role of UPF in food because the causality and probability of the underlying mechanisms have not been verified.

Eating rate and energy density

According to Gibney and Forde[27], the current data suggests that a high energy intake rate may be the mechanism for the link between UPF consumption and the increase in energy intake. The results of a study by Teo *et al.*[36] imply that differences in the eating rate due to differences in texture and in the energy density of meals contribute to the observed differences in energy intake between minimally processed and ultra-processed meals. The average energy intake rate is higher with UPF than with less processed foods[34]. UPF consumption has a positive correlation with the energy density of the food. Compared to unprocessed foods, UPF had a higher energy density (average: 1.1 versus 2.2 kcal/g). A high energy density turns out to be an important factor for an excessive energy intake and resulting weight gain[37].

The team of American professor Rolls at Pennsylvania State University studied the effect of energy density on energy intake in adults and children ages 3-5 years. Their research shows consumption of a consistent total weight of food and drinks, even when the energy density of these products was reduced[38,39]. Pure oil and fat, at nine kilocalories per gramme, has the highest energy density. At the other extreme end is water, with zero kilocalories. In other words, a meal rich in fat (such as fried eggs, sausage and bacon) has a relatively high energy density, while a meal with a lot of water (soup) has a relatively low energy density.
Softer foods (due to the preparation method) can be eaten more quickly than raw foods because raw foods require more chewing time. Little to no chewing of soft or liquid food increases the eating rate since this rate is affected by the texture of the food[40]. Research by Wageningen University[41] shows that beverages supply more energy per time unit than solid foods, such as 420 kcal/min for whole chocolate milk and 41 kcal/min for a boiled egg. On average, the consumed quantity of energy per minute of boiled vegetables is nearly 65% higher than of raw vegetables. Food with a slow eating rate has a solid texture, high energy density and contains little water. These characteristics do not align directly with the degree or processing, but the average higher eating rate of UPF may contribute to potential health effects, especially when a high level of energy originates from UPF.

Consumption of ultra-processed foods

Various estimates of UPF consumption are based on the NOVA classification system. In Europe, around 27% of total daily energy intake comes from UPF, with significant differences between the different countries. The lowest intake has been calculated for Italy (approx. 13 en%), while the highest calculated consumption is in Sweden (approx. 43 en%).

In Western Europe in particular, the average contribution of UPF to energy intake is high compared to countries in Central, Eastern and Southern Europe. From 2012-2016, Dutch adults derived around 37% of their daily energy intake from UPF[42]. Vellinga *et al.*[28] estimate that the percentage for the Dutch population is 61% among 1 to 79-year-olds. Children (ages 1 to 18) derive 75% of their energy from the consumption of UPF and the difference in age composition is an important explanation for the higher estimate by Vellinga *et al.*[28] compared to Mertens *et al.*[42]. SACN[3] estimates for the United Kingdom that 51-68% (for different age groups and with different socioeconomic backgrounds) of energy intake comes from UPF. Marino *et al.*[31] presented comparable results with the highest energy% for the United States (usually above 55% and the highest estimate of 65% among children aged 2-19 years) and the United Kingdom (mostly above 50 en%). Italy, on the other hand, had the lowest (aprox. 10 en%) energy intake via UPF. The results of the various studies show that in general, there are significant differences in UPF consumption.

All consumption figures should be used prudently for various reasons. A consumption comparison in different countries is limited due to methodological differences. The age composition of the samples differs, while it is known that the consumption of UPF (expressed in en%) is higher among young children and adolescents than adults[28,31]. The studies are not designed to classify products according to their processing degree. This must take place afterwards using partly incomplete information and assumptions. An unambiguous identification of UPF is difficult, making estimates indecisive.

Table 2. Average contribution in terms of percentage of UPF to energy intake in various European countries[42]

Energy%	< 20	20-30	>30
Number of countries with an UPF contribution to energy intake in terms of percentage			
Women	5	8	9
Men	6	7	9

Dietary recommendations

Guidelines for a healthy diet have shifted from recommendations on the intake of specific nutrients, such as saturated fat and vitamin C, to individual foods, such as tea, and groups of foods, such as vegetables. Foods are usually grouped according to their origin, such as dairy, meat (products) and fruit[9]. What is increasingly emphasised is that the effects of food on health should be examined based on dietary patterns because there are no good or bad foods, only good and bad dietary patterns[9]. The general guideline established by the Health Council of the Netherlands[43]": "Eat a more plant-based and less animal-based diet" is an example of this. UPF is one of the patterns in relation to health risks that has attracted interest in recent years among nutrition scientists.

Due to an increase in overweight and obesity, the Brazilian government has recommended avoiding the consumption of UPF since 2014. Their example was followed by other South American countries (Uruguay, Peru and Ecuador) a few years later. In Belgium, France, Israel, Malaysia and Canada, the population is also advised to limit the consumption of UPF[4]. The dietary guidelines established by the Health Council of the Netherlands do not contain any general recommendations related to UPF, although a number of specific guidelines point in a comparable direction: replace refined grain products with whole grain products, limit the consumption of processed meat and drink as few sugar-containing drinks as possible.

The Health Council of the Netherlands is currently reassessing the dietary guidelines and will also be devoting attention to processed foods. The Health Council of the Netherlands writes: "The 2015 dietary guidelines do not contain a specific guideline on processed foods in general. A future update of the dietary guidelines may include determining whether further evaluation is warranted based on the latest scientific knowledge on this topic." The SACN and Nordic Recommendation Committee claim that differentiating UPF does not have any added value for the existing food classifications and recommendations.

According to the British Nutrition Foundation[32], UPF does not need to be included in the nutrition policy (such as in dietary guidelines) due to a lack of a widely supported definition, the need for knowledge about mechanisms of action and concern about its suitability as a tool for identifying healthy foods. According to the British Nutrition Foundation[32], any change to the English dietary guidelines must be carefully considered, especially when there is a significant risk of confusion and unintended consequences, including a potential decoupling from other dietary recommendations. The British Nutrition Foundation[3] urges caution in relation to evidence concerning the health effects of UPF consumption because these effects are already covered by the existing guidelines.

Added value

To what extent do UPF recommendations have added value for nutrition policy and education? Various nutrition scientists question the usefulness of focusing on the degree of food processing beyond the conventional classification system, which focuses on food quality[5,9]. In terms of the plausibility of the various mechanisms studied, Valicente *et al.*[35] have concluded that none of them have a strong scientific

basis. This poses a challenge for policymakers, who need to use the best scientific data to translate complex evidence into simple and clear messages. Various experts indicate that the focus should continue to be on reduced consumption of products for which it has been proven that their consumption among an important percentage of the population has a negative effect on public health and there is a considerable overlap here with UPF[5,6,8,44]. Apart from the degree of processing, overconsumption (too much energy) should be avoided in any event. In recent years, the development and consumption of diet products has escalated significantly and many of these products fall under UPF. Due in part to the relatively high percentage of UPF in the dietary pattern in many countries, numerous unexpected effects can occur with a significant reduction in the consumption of UPF, such as food prices, food security and time constraints[9].

Conclusions

UPF is a broad and heterogenous group of foods, making it difficult to formulate a scientifically unambiguous definition. In spite of this, various cohort studies show a consistent relationship between the consumption of UPF and development of chronic diseases.

As regards the mechanism of action in these links, there is still no certainty and the same applies, although to a lesser degree, to the link between UPF consumption and weight gain. Eating rate and energy density are important factors in this.

The specific added value of UPF for the existing dietary guidelines based on existing scientific research has not yet been well demonstrated, nor has it been proven that a recommendation on UPF is more relevant for consumers than the existing recommendations. There is therefore no consensus among nutrition experts on a recommendation to limit the consumption of UPF due in part to the fact that from a nutritional perspective, food processing has a positive effect on, for example, food waste and, consequently, the sustainability of food chains.

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With its products and ingredients, Royal Cosun contributes to the growing demand for plant-based food and food ingredients. Examples include: Tendra®, a high-quality protein isolate derived from fava beans that is used in plant-based dairy and meat alternatives; Inulin, a dietary fibre that grows naturally in the chicory root that contributes to a higher fibre content and calorie reduction in a product; Fidesse®, a new functional ingredient for meat substitutes made from sugar beet pulp; Potato Cheezz, a salt and fat-free plant-based cheese substitute made from potatoes.