# How does the consumption of processed food affect the pathogenesis of various diseases? - literature review

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**ABSTRACT**

**Introduction and purpose:**

With the development of civilization, the amount of technology enabling food processing increases. Due to the implementation of these procedures, food can gain new properties that will make it more attractive in the eyes of the consumer. The aim of our work is to collect information on the relationship between the consumption of processed and ultra-processed food and the development of various diseases, with particular emphasis on civilization diseases.

**State of knowledge:**

Processed food often contains non-nutritive ingredients, for example, artificial food additives, which have a negative impact on health. Numerous studies demonstrate the correlation between the consumption of ultra-processed food and the development of various diseases. Scientific research suggests that ultra-processed foods may lead to addictive behavioral and biological responses through their reinforcing effects. It also influences the development of various conditions, including obesity, type II diabetes, cardiovascular diseases, depression, and anxiety. Furthermore, its components pass through the placenta.

**Summary:**

In light of the research discussed, we are convinced that we cannot remain indifferent to the role of ultra-processed food in the pathogenesis of many diseases. Its multidirectional negative effects show that it is worth conducting further research to discover more consequences of its mechanisms. At the same time, consumers should become more aware of food composition data to be able to make conscious choices and countries should strive to change the food policies.

**Key words:** Ultra-processed food, UPF, obesity, type 2 diabetes, cardiovascular diseases, inflammatory bowel diseases, pregnancy, depression, NOVA

**INTRODUCTION:**

Food consumption constitutes one of the fundamental physiological functions essential to sustaining life. Therefore, it accompanies people from birth until death, every day. With the development of civilization, the amount of technology enabling food processing increases. Thanks to this treatment, food can gain new properties. Food additives therefore imitate certain features that do not occur naturally in a given product, such as smell, color, taste or durability. Despite the possibility of seeing advantages in introducing such food, such

as an increase in trade efficiency, it actually generates huge economic losses [1]. Awareness of the significant increase in lifestyle diseases and the role of the processed food we consume does not allow us to remain indifferent to this topic. Ultra-processed food (UPF) dominates the diet of people around the world [2]. It accounts for between one fifth and one third of total dietary energy in middle-income countries, and more than half of total dietary energy in high-income countries. The average growth in sales of these products is up to 10% per yearin middle-income countries and about 1% per year in high-income countries [3].

Numerous studies demonstrate the association between the consumption of processed food and the development of various diseases. The aim of our work is to collect this information and thus increase awareness of this problem.

## WHAT IS PROCESSED FOOD?

To understand the definition and division of processed food, we must first realize that almost every food product is processed in some way and subjected to some processes that make it suitable for entering the market. Therefore, overusing this word seems pointless. Many classifications of processed foods have been created, of which, according to a systematic review, NOVA seems to be the most accurate [4].

The NOVA classification takes into account all biological, chemical and physical processes used in food production, as well as the use of additives. Food is divided into four groups, depending on the nature, scope and purpose of processing used. Below we will present definitions and examples of foods belonging to each group [5].

Group 1. Unprocessed or minimally processed food

Unprocessed food or natural food, includes edible parts of plants, fungi, algae and animals. Minimal food processing means subjecting natural food to processes that make it preserved, more pleasant to consume, safe, edible, or simply more suitable for storage. These include removing inedible or undesirable parts and drying, crushing, grinding, fractionating, filtering, baking, cooking, non-alcoholic fermentation, pasteurization, chilling, freezing, placing in containers and vacuum packaging [5].

Group 2. Processed culinary ingredients

Processed culinary ingredients include products that come from Group 1 foods or from nature and are subjected to processes such as drying, grinding, pressing, refining, for example oils, butter, sugar, salt. Through these processes, durable products are produced, which are usually not consumed alone, but with food from group 1 [5].

Group 3. Processed food

Processed food is subjected to preservation, cooking and non-alcoholic fermentation processes, often produced by adding salt, oil, sugar or other substances from group 2 to group 1 in order to increase durability or improve its sensory value. It often consists of two or three ingredients and is eaten with other products or on its own. These will include, for example, bottled vegetables, canned fish, fruit in syrup, cheese and fresh bread [5].

Group 4. Ultra-processed food

The latter group, called ultra-processed food, often includes ingredients used in processed food (including salt, sugars, fats). However, in the case of ultra-processed food, its composition includes other energy sources, which may be produced from food or as a result of further processing of food ingredients. The first group includes, for example, gluten, whey, lactose, and casein. The second one includes, among others, invert sugar, high-fructose corn syrup, soya protein isolate, hydrolyzed proteins, maltodextrin, dehydrogenated or interesterified oils.

Additives to ultra-processed foods include those that hide unfavorable aspects of the final product and those that enhance or imitate certain good characteristics of the food. These include, among others, flavors, flavor enhancers, non-sugar sweeteners; dyes and other colors, color stabilizers; and processing aids such as firming, bulking and anti-bulking, emulsifiers, carbonating, de-foaming, sequestrants and humectants, anti-caking and glazing agents. Additives also include those used in processed foods, for example antioxidants, stabilizers and preservatives.

The path to creating an ultra-processed product is therefore not short, and many processes are sometimes required, such as hydrogenation and hydrolysis, extrusion and forming, or pre-processing for frying. Ultra-processed food is prepared with very little

or no natural substances. These will include, for example, sweet and salty packaged snacks, reconstituted meat products, pre-prepared frozen meals, and non-alcoholic drinks [5].

Below is a table with more examples of foods belonging to each of the groups discussed.

**Table 1**: NOVA food groups with examples, based on the article [3].

| NOVA group | Examples |
|---|---|
| **1) Unprocessed or minimally processed foods** | Fresh, squeezed, chilled, frozen, or dried fruits and leafy and root vegetables; grains such as brown, parboiled or white rice, corn 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, filets and other cuts, fresh or chilled or frozen; eggs; fresh or pasteurized milk; fresh or pasteurized fruit or vegetable juices (with no added sugar, sweeteners or flavors); grits, flakes or flour made from corn, wheat, oats, or cassava; tree and ground nuts and other oily seeds (with no added salt or sugar); herbsand spices used in culinary preparations, such as thyme, oregano, mint, pepper, cloves and cinnamon, whole or powdered, fresh or dried; fresh or pasteurized plain yogurt; tea, coffee, and drinking water. Also includes foods made up from 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 corn flour fortified with iron and folic acid. |

| 2) Processed culinary ingredients | Vegetable oils crushed from seeds, nuts or fruits (notably olives); 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 corn and other plants, and salt mined or from seawater, vegetable oils with added antioxidants, and table salt with added drying agents. Includes products consisting of two group 2 items, such as salted butter, and group 2 items with added vitamins or minerals, such as iodized salt. |
| --- | --- |
| 3) Processed foods | 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 (with or without added antioxidants); freshly made unpackaged breads and cheeses. |
| 4) Ultra-processed foods | Carbonated soft drinks; sweet or savory packaged snacks; chocolate, candies (confectionery); ice-cream; mass-produced packaged breads and buns; margarines 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 milks, other baby products; 'health' and 'slimming' products such as meal replacement shakes and powders. Many ready to heat products including pre-prepared pies and pasta and pizza dishes; poultry and fish 'nuggets' and 'sticks', sausages, burgers, hot dogs, and other reconstituted meat products, and powdered and packaged 'instant' soups, noodles and desserts. |

The purpose of creating ultra-processed products is to create products that are attractive to the consumer and will replace other foods. This attractiveness is built through convenience and ease of preparation, low price and, of course, good, in some sense unique taste [3].

## ULTRA-PROCESSED FOOD AND ADDICTION

Ultra-processed food poses a great threat to public health because in addition to having the above-mentioned features, such as low price, good taste, and quick preparation, it is also heavily advertised and widely available. [3, 5, 6, 7, 8].

Scientific research suggests that ultra-processed foods may lead to addictive behavioral and biological responses through their reinforcing effects. Interestingly, it is even compared to drugs, by comparing their features and functions [9].

First of all, it should be noted that neither drugs nor highly processed food are necessary for human survival. Secondly, the similarity of food processing to the processing of certain naturally occurring substances to create alcoholic beverages, cigarettes or illegal drugs was taken into account. The addition of flavor enhancers, refined carbohydrates and fats to food was compared with adding menthol to cigarettes or sugar to alcoholic beverages. In both cases, these combinations deepen the addictive potential by increasing their desired effects. A third point to mention is the important role of individual and genetic risk factors in both cases. This includes, among others, exposure to depression, trauma, cognitive disorders, and the occurrence of addictions in the family [9]. This also highlights the fact that not every person who eats such foods or uses potentially addictive substances will actually become addicted [9, 10]. The fourth common feature of addictive substances and highly processed foods is their rapid absorption by the body. This feature can also be seen in processed foods. This happens by removing ingredients from food, such as water, protein or fiber, which prolong the absorption of substances that provide quick satisfaction, such as sugar, and make the "effect" of their action faster [9]. This enhances the effectiveness of activating the reward and motivation system in the brain [11]. Interestingly, even neuroimaging studies support similar patterns of reward system dysfunction and inhibitory control deficits. The last issue common to processed food and drugs that we want to mention are certain symptoms that accompany addiction, such as, among others a strong desire for a given substance, taking it in larger amounts than planned, or consuming it despite the visible negative consequences of consuming it [9].

One of the studies conducted was aimed at examining the addictive potential of food depending on its processing and glycemic load (GL). An important role was played by the fact that participants completed the Yale YFAS Food Addiction Scale, which

is a 25-item self-descriptive tool based on the DSM-IV substance addiction criteria. It was also checked which specific products the study participants had greater difficulty with in terms of excessive consumption and problems with its control. These products were selected according to their degree of processing. The study showed a strong relationship between the level of product processing and addictive eating behavior. Additionally, the occurrence of addictive behaviors to highly processed food was demonstrated by people who had symptoms of addictive eating in YFAS or had an increased BMI. The next positive predictors of behavioral indicators of food addiction in the study were high glycemic load and fat. The study showed that highly processed food, with the addition of fat and/or refined carbohydrates (for example sugar, white flour) and with a high glycemic index may be associated with "addiction" [11]. Another study also showed similar conclusions. Namely, it was observed that reporting more symptoms of food addiction, regardless of food addiction status, was associated with greater consumption of ultra-processed foods [12].

To summarize the relationship between ultra-processed food and addiction, it is worth keeping in mind its similarity to drugs. Looking at it through this prism, it will be easier to implement political and economic activities that will try to reduce its availability and participation in our lives.

## ULTRA-PROCESSED FOOD AND OBESITY

Obesity seems to be a natural consequence of food addiction, especially food that contains a large amount of simple sugars and saturated fats and is therefore high in calories. Numerous studies substantiate this correlation.

In the initial study scrutinized, the relation between consumption of ultra-processed food and obesity among the Australian population was examined, broken down by age group, gender and level of physical activity. The study involved 7,411 Australians aged ≥20 years. The NOVA classification was used to identify food processing, and food intake was assessed based on a 24-hour recall period. Data on body weight, height and waist circumference (WC) were used to diagnose obesity and abdominal obesity. The research results showed a significant relationship between obesity rates and the share of ultra-processed foods in the diet. A greater amount of UPF consumption translated into

a significantly higher BMI and a higher risk of obesity in all age groups, physical activity and gender [13].

Another study with the same purpose was performed on adults aged 40-69 from Great Britain. As in the previous study, the NOVA classification was used to identify food processing, and food intake was assessed by 24-hour recall. Repeated measurements of body mass index (BMI), waist circumference (WC) and percentage of body fat were performed. During the observation of the subjects, 947 incidental cases of general obesity (BMI $\geq$ 30 kg/m2) and 1900 incidental cases of abdominal obesity were detected (men: WC $\geq$ 102 cm, women: WC $\geq$ 88 cm). Again, being in the highest quartile of ultra-processed food intake was associated with the highest risk of obesity, both overall and abdominal. This risk was higher than for people in the lowest quartile [14].

Similar results were also achieved in other studies with the same purpose and similar methods. One of them involved 15,977 adult Americans, additionally showing a clearer relationship in the group of women [15].

Another study included 19,363 Canadian adults over the age of 18. It came to conclusions similar to other studies, namely that there was a significantly (32%) higher risk of obesity in people in the highest quintile of ultra-processed food consumption compared to people in the lowest quintile. Additionally, it was noted that ultra-processed food is more often consumed by men, young adults, people with fewer years of formal education, smokers, physically inactive people and people born in Canada [16].

Furthermore, a cohort study undertaken among graduates of the Spanish University of Navarra (SUN) showed that UPF consumption was associated with a higher risk of overweight and obesity. The study involved 8,451 middle-aged people, initially without signs of obesity. A total of 1,939 cases of overweight and obesity were identified during the observation period. The risk of overweight or obesity, after adjusting for potential confounding factors, was higher in participants in the highest quartile of ultra-processed food consumption compared to participants in the lowest quartile of consumption [17].

## ULTRA-PROCESSED FOOD AND TYPE 2 DIABETES

Type 2 diabetes (T2D) is a major public health problem worldwide, affecting 425 million people in 2017, with an estimated 629 million cases predicted by 2045 [18]. Therefore, it is very important to reduce the incidence/cases of diabetes and modify risk factors such as diet, physical activity and weight. It is also worth taking a look at the impact of diet on the development of type 2 diabetes.

The large cohort study included 104,707 people with a mean age of 42.7 years. This large, prospective observational study showed that a higher dietary intake of UPF was associated with a higher risk of T2D. These results remained statistically significant after taking into account several indicators of the nutritional quality of the diet and other metabolic comorbidities [19].

In a follow-up study lasting an average of 5.4 years and including 21,730 participants with a mean age of 55.8 years and a mean UPF intake of 22.1% at baseline, 305 cases of T2D were identified. The authors observed a significantly increased risk of T2D with a 10 percentage point increase in UPF intake, meaning that a diet high in UPF is associated with a clinically significant increased risk of T2D [20].

## ULTRA-PROCESSED FOOD AND CIRCULATORY SYSTEM DISEASES

To evaluate the association between ultra-processed foods and cardiometabolic risk factors (CMR), a study was conducted involving 5,373 adults aged 55-75. A validated food frequency questionnaire and the NOVA classification were used. In multivariable-adjusted models comparing the highest and lowest quartiles of UPF intake, associations were found for several CMR factors: body weight, BMI, waist circumference, diastolic blood pressure, fasting blood glucose, HbA1c, triglycerides, and triglycerides and glucose index. Higher UPF intake was associated with unfavorable evolution of objectively measured CMR factors after 12 months of follow-up in adults with metabolic syndrome. Further research is necessary to determine the long-term impact of UPF [21].

Another study of 60,298 adults aged 40 years and older assessed the association between UPF intake and the incidence of cardiovascular disease (CVD) and all-cause

mortality. This study also used the NOVA classification. After a median follow-up of 10.9 years, 6,048 participants (10.0%) experienced cardiovascular events, and 5,327 (8.8%) and 1,503 (2.5%) experienced coronary heart disease and cerebrovascular disease, respectively. There were 2,590 (4.3%) deaths, of which 384 (0.6%) deaths were caused by cardiovascular diseases. Higher UPF intake was associated with a higher risk of cardiovascular disease, coronary heart disease, cerebrovascular disease, and all-cause mortality. The researchers concluded that higher percentages of UPF intake were associated with higher chances of cardiovascular disease and all-cause mortality. Authors recommend limiting the consumption of UPF and including it in recommendations regarding cardiovascular diseases [22].

An additional investigation encompassing 105,159 participants aged 18 years or older also examined the association of ultra-processed foods with a higher risk of cardiovascular disease. The follow-up lasted 5.2 years. The authors also concluded that consumption of ultra-processed foods was associated with a higher risk of overall cardiovascular disease [23].

The above research allows us to conclude that ultra-processed food increases the likelihood of developing cardiovascular diseases. People predisposed to various cardiovascular diseases should therefore pay attention to their diet and, if possible, eliminate UPF.

**EFFECT OF PROCESSED FOOD ON INFLAMMATORY BOWEL DISEASE**

Nutritional intake constitutes a pivotal environmental factor and therefore remains therapy for inflammatory bowel disease (IBD). Food additives are present in processed food products as well as dietary supplements. Some artificial emulsifiers and sweeteners may induce dysbiosis associated with changes in the intestinal barrier, activation of chronic inflammation and an abnormal immune response that accelerates the onset of IBD, especially in people predisposed to IBD [24]. Preclinical studies have been conducted which prove that long-term and frequent consumption of food additives is harmful to intestinal homeostasis and may lead to the development of colitis [25].

The diet consumed by an increasing population is significantly different from the traditional diet of previous generations, when the incidence of IBD was much lower. Food in the Western diet contains large amounts of refined sugar, polyunsaturated omega-6 fats, and is heavily processed, modified, stored and transported over long distances, which may cause changes in the intestinal microflora and increased levels of pro-inflammatory cytokines. Research suggests a connection between the Western diet and the risk of IBD. Changing your eating style and introducing a Mediterranean or vegetarian diet, which is rich in many fresh fruits and vegetables as well as whole grains and olive oil, which provide nutrients such as vitamin D, essential fatty acids, minerals and fiber. Diets containing such foods help maintain homeostasis and may prevent and help treat IBD [26].

Many human studies are needed to obtain conclusive results, however, IBD patients should avoid processed foods and dietary consultation to use nutrition as therapy.

**PROCESSED FOODS DURING PREGNANCY**

Regrettably, the issue of the impact of processed food on health is not confined solely to adults. It can affect even the youngest children as well as extend into fetal life. Studies report that contaminants from the mother's diet pass through the placenta to the fetus. [27].

A cohort study was conducted to examine the association of maternal consumption of ultra-processed foods with newborn exposure to perfluoroalkyl substances (PFAS), which are quite commonly used in industry. They are associated with many diseases, including thyroid, liver and kidney diseases, the functioning of the immune system, regulation of insulin and lipid levels, and even cancer [28]. The research project included 131 pregnant woman-child pairs and was carried out in a maternity center in Rio de Janeiro. Over 25% of the 131 women surveyed declared regular consumption of at least two subgroups of ultra-processed food. Regularity was assessed by consumption of sausages and other processed meat products ($\geq$ 3 times per week), fast food ($\geq$ 1 time per week), and packaged ready meals ($\geq$ 1 time per week/week). Regular consumption of unprocessed foods was also assessed ($\geq$ 5 times per week for fruit, vegetables, rice and beans and $\geq$ 3 times per week for meat, eggs and fish). After the birth of the child, perfluorooctane sulfonate (PFOS)

and perfluorooctanoate (PFOA) were determined in 118 cord blood samples. The results showed increased levels of PFAS (the sum of PFOA and PFOS) in newborns whose mothers were more likely to consume ultra-processed food. [29-31] This study shows how important a pregnant woman's diet is and that she should be discouraged from eating processed products.

## ULTRA-PROCESSED FOOD AND MENTAL HEALTH

Our body is not evolutionarily adapted to consuming ultra-processed food [9], which plays a crucial role in the etiopathology of numerous somatic disorders, yet its impact on mental health cannot be ignored.

A meta-analysis was performed, which included 15 cross-sectional studies and 2 prospectively designed studies from Brazil, the USA, Italy, Great Britain, Spain, France and Belgium. The 17 eligible studies included a total of 385,541 participants of varying ages and genders. Sample sizes ranged from 33 to 100,684 participants. Food intake data were self-reported or assessed by interview and collected using food frequency questionnaires, 24-hour dietary reminders, and dietary history. Included studies examined associations between ultra-processed food consumption and common mental disorders: depression, anxiety, post-traumatic stress disorder, perceived stress, food addiction, alcohol use disorders, anorexia nervosa, bulimia nervosa and binge-eating disorder. The results confirmed that higher consumption of ultra-processed products is associated with an increased risk of depressive and anxiety symptoms. Additionally, there was an increased risk of subsequent depressive effects in people with higher UPF intake. This review suggests that the associations between the consumption of ultra-processed foods and adverse mental health are bidirectional and that more research is needed on this topic [32].

## SUMMARY:

With the development of civilization, the amount of technology enabling food processing increases. Thanks to this treatment, food can gain new properties. Processed and even ultra-processed food (UPF) consumption dominates the diet of people all over the world. Ultra-processed food is prepared with very little or no natural substances, often

containing simple sugars, saturated fats and high energy content. The purpose of creating ultra-processed products is to create products that are attractive to the consumer and will replace other foods. This attractiveness is built through convenience and ease of preparation, low price and, of course, good, unique taste. Scientific research suggests that ultra-processed foods may lead to addictive behavioral and biological responses through their reinforcing effects. It also influences the development of obesity, type II diabetes, cardiovascular diseases, depression, and anxiety, and its components cross the placenta. This shows how important a role UPF plays in our lives and that we should be especially careful when consuming such products. We are aware that in today's world it is practically impossible not to eat processed food due to the development of civilization, but it is worth remembering to make conscious consumer choices and try to eat locally and seasonally. We have great hope in the fact that the food policy of some countries is starting to change, restrictions are being introduced on the amount of additional substances in processed products, as well as the introduction of more and more organic products, which gives a great chance to improve the statistics related to lifestyle diseases.

**Institutional Review Board Statement**

Not applicable.

**Informed Consent Statement**

Not applicable.

**Data Availability Statement**

Not applicable.

**Conflicts of Interest**

The authors declare no conflict of interest

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