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Food processing can save lives: how bioactive compounds defy oversimplification

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Abstract

In many instances, the term processed foods is used interchangeably with ultra-processed foods (UPF), which may lead to the former group being mistakenly perceived as unhealthy. In reality, the term food processing encompasses a range of treatments and operations aimed at ensuring food safety, preservation, and availability. Bioactive compounds found in raw foods can be used to examine the complex nature of processing. Factors such as processing type (e.g., thermal treatments, non-conventional processes) and operational conditions (e.g., temperature, pressure) significantly affect the final product and can either increase the levels and bioavailability of bioactives or diminish their concentration leading to reduced functional properties. Criticism directed toward UPFs should not overshadow the boundaries separating them from healthy and nutritive processed foods. Food processing continues to be a tool to produce foods that are stable and free from microbiological and physicochemical hazards, ensuring their availability in underserved areas of the world.

Keywords: Ultra-processed foods; NOVA system; Non-conventional processing; Polyphenols; Lycopene.

1. Introduction

The distinction between processed foods and ultra-processed foods (UPF) has been the subject of recent debates about the influence of UPF consumption on poor health outcome. Several hypotheses have been formulated to help explain such relationship, with many scientists pointing out sugar, unhealthy fats (e.g., saturated, trans fats), salt, and synthetic additives as the culprits and suggesting a shift toward the consumption of minimally-processed whole foods (Shahidi, 2009, Marti, 2019, Luiten et al., 2016, Barbosa et al., 2022). Amidst all the controversies surrounding this topic, not enough attention has been paid to drawing a line separating processed foods from UPF, which causes misconceptions and generalization. The definition of ultra-processing can be confusing and lead consumers to believe that processed food is synonymous with junk food when in reality food processing is an umbrella term comprising a nuanced set of distinct treatments and operations serving many purposes and initially developed to guarantee the consumption of safe foods, while also ensuring its preservation and availability, especially in impoverished regions.

2. Food processing from a bioactive compounds standpoint

Food processing is an essential operation performed with the objective to convert raw material to food or one form of food to another with desirable sensory properties in terms of texture, color, flavor, and taste. Most importantly, food processing is sometimes essential to achieve microbiological safety and stability of food products. Several types of treatments are available for this purpose, with the most common being thermal processing in the form of boiling, pasteurization, grilling, barbecuing, drying, frying, and baking. They are often accompanied by changes in the physiochemical properties of the food and may alter its nutritional value, not necessarily in a negative way. According to the US Department of Agriculture (USDA, 2023), any food that has undergone treatment that altered the fundamental nature of an agricultural

Table 1. Effect of different processing types on the bioactive compounds of selected foods

Food Product	Processing Type	Processing Conditions	Effects on Bioactive Compounds	Reference
Tofu	Fermentation	Strains: L. *casei* and L. *acidophilus*; Co-inoculation in soymilk (6 log CFU/mL); Incubation at 32 °C for 15 h to reach pH 5.5	↑β-sitosterol and total phytosterols compared to unfermented tofu; Tocopherols levels remained unaltered; ↓Isoflavone glycosides; ↑Isoflavone aglycones and bioavailability	Riciputi et al. (2016)
Gluten-free bread enriched with onion by-products	Baking	180 °C/60 min – internal temperature of 95 °C	↓Quercetin glycosides, dimers, and trimers after baking; ↑Quercetin aglycones after baking; ↑*in vivo* antioxidant activity in the blood of human subjects after consuming the baked bread	Bedrníček et al. (2020)
Crushed tomatoes	Pasteurization in glass bottles	80, 90 or 100 °C for 120 min	The 100 °C treatment reached the highest retention rates for lycopene (74.76%) and ascorbic acid (86.68%) with the 80 °C treatment showing the worst performance in the same parameters (18.35 and 36.13%, respectively)	Badin et al. (2023)
Tartary buckwheat bran	Steam explosion	Pressure: 0.32 - 3.2 MPa; Time: 15 - 90 s	↑release of bound polyphenols (15.23–120.81%); ↑release of free quercetin (4-6-fold); ↑antioxidant capacity	Li et al. (2022)
Soybean/ soybean milk	Ultrasound pre-treatment	Temperature: 35–55 °C; Time: 5–25 min; Frequency: 6–24 W/cm^2	↑release of isoflavone aglycones; ↑Antioxidant activity; ↓Level of inflammation markers	Falcão et al. (2019); Falcão et al. (2018); Silva et al. (2019)

product can be considered a processed food, including minimally processed horticultural products. Under this definition, it is clear to notice that processing is not confined to the industrial context, with home cooking also being characterized as a form of food processing (Zhang et al., 2019).

Depending on the material used and the extent of processing, the physicochemical and nutritional properties of foods can be either increased or decreased. From this standpoint, bioactive compounds are perfect examples of the benefits and the drawbacks of processing foods, exposing how oversimplification fails to capture the significance and complexity of these operations, as can be observed in the examples given in Table 1.

Tomato paste, which undergoes a high-temperature treatment, has been shown to increase lycopene bioavailability when compared to fresh tomatoes. Lycopene is a carotenoid with antioxidant activity that is associated with a lower risk of cardiovascular diseases and certain types of cancer (Sharma et al., 2021). Fermentation has been reported to promote a higher release of bioactive compounds and consequently increased levels of health-promoting benefits. For example, fermentation of whole soybean flour with *Lactobacillus casei* significantly enhanced hydroxyl radical scavenging activity compared to the unfermented flour. Such effect was attributed to the conversion of bound polyphenols to their free forms by the enzymes synthesized by the microorganism (Li et al., 2020).

On the other hand, cooking fruits and vegetables for too long or at too high temperature can cause certain heat-sensitive vitamins, such as vitamin C and thiamin, to be partially destroyed or leached out into the cooking water. Similarly, overcooking meats and fish can cause the loss of certain B vitamins and minerals such as iron and zinc. Some processing techniques may also lead to the development of undesirable compounds such as polycyclic aromatic hydrocarbons, acrylamide and heterocyclic amines, as well as other potentially undesirable compounds (Tincheva, 2019).

Alternatively, non-conventional processing may also be adopted, and these include ultrasound-assisted processing, high-pressure processing (HPP), moderate pulsed electric field, steam explosion, among others. Many of these are classified as non-thermal processing and may preserve the nutritional value of heat-sensitive molecules present in food. Besides, such techniques can help in the development of clean label products by enhancing processing efficiency while reducing the need for synthetic additives. Case in point, high-pressure processing has been successfully used as a cold pasteurization technology for milk, an alternative to classic pasteurization and ultra-high temperature processing. Stratakos et al. (2019) applied HPP to milk at pressures of 400–600 MPa for 1–5 min, achieving a 5 log CFU/mL reduction of *E. coli*, *Salmonella*, and *L. monocytogenes* and prolonging the microbiological shelf life by one week as opposed to pasteurized milk. It should be noted that many of the food products treated by such techniques still need to be subjected to food regulation before widespread commercialization due to their novelty.

In some instances, non-conventional processing may help release key compounds from the food matrix, increasing their bioaccessibility and bioavailability. Steam explosion is a promising technique that involves subjecting raw materials to high temperature and pressure within a cylinder. Steam is generated and forced into the interior of the materials, filling the pores of the tissue with steam. The saturated steam then undergoes a sudden release of high pressure, which causes it to expand rapidly and create small micropores on the cell walls of the material. These micropores help to release small molecules from the cells, making them more accessible for use (Wan et al., 2022; Shahidi et al., 2021). Research suggests that steam explosion can enhance the release of insoluble-bound polyphenols from their food sources, increasing their availability for intestinal absorption and bioactivity levels as a whole (Li et al., 2020; Chen et al., 2016). Nevertheless, this process can also lead to polymerization of say phenolic compounds and other forms of molecular modification, as well as thermal degradation and oxidation (Wan et al., 2022). Therefore, the operational conditions need to be studied and optimized on a case-by-case basis.

Regardless of the type, food processing often saves lives and promotes food security for underprivileged populations by allowing food products to be preserved for longer periods and travel longer distances. Moreover, genetic manipulation of food crops can also be a powerful tool for guaranteeing food security. As an example, salt-tolerant and draught-resistant rice allows the cultivation of this crop in areas where rice cultivation would not be possible (Rasheed et al., 2020). Other genetically modified crops may reduce or eliminate the need of herbicides and pesticides.

From a food safety standpoint, processing leads to the elimination of microorganisms and other harmful compounds that may otherwise cause discomfort, illnesses, and even death. This has been observed for vegetables and improperly prepared meat. Moreover, the elimination of toxicants in certain commodities, such as cassava and lima beans that contain linamarin, a cyanogenic glycoside, can be achieved with processing. When linamarin reaches the human gut, it decomposes to the toxic hydrogen cyanide. This compound can be eliminated by successive boiling and draining of the liquids before consumption (Zhong et al., 2021).

In contrast to processed foods, ultra-processed foods belong to a different category as suggested by the NOVA system (Monteiro et al., 2016). Both the NOVA classification and the term ultra-processed foods have been coined by Dr. Carlos Monteiro's research group, a Brazilian pediatrician and Professor of Nutrition and Public Health at University of São Paulo. The term is usually used to describe foods that have been extensively subjected to a number of processing operations and often contain additives such as synthetic flavors, colorants, preservatives, and emulsifiers. They are typically high in calories, added sugars, unhealthy fats, and salt, while being low in essential nutrients such as fiber, vitamins, and minerals. Examples of ultra-processed foods include packaged snacks, sugary drinks, certain ready-to-eat meals, and some fast food. The consumption of these foods has been linked to an increased risk of obesity, type 2 diabetes, heart disease, and other chronic health conditions (Monteiro et al., 2019).

The major issue regarding this definition is that differentiating processed and ultra- processed foods is not an easy task for those unfamiliar with food science, technology and/or engineering, thus becoming a matter of individual perception. In the NOVA classification, aspects such as the presence of sugar, oil, fats, salt, antioxidants, stabilizers, and preservatives in the formulation overlap in the definitions of processed and ultra-processed foods. The description of the latter group explicitly mentions fortified foods and products carrying ingredients that increase palatability as being ultra-processed (Monteiro et al., 2016). In this context, ultra high-temperature (UHT) milk is considered a processed food (NOVA's Group 3) but adding chocolate to it would make it fall into the ultra-processed category (NOVA's Group 4). This unclear distinction can cause confusion in the general public and may lead to mistakenly equating all processed foods to junk food, which is inaccurate and can even reflect on industrial and regulatory issues.

Better terms and education are necessary to describe and/or fully understand the many existing categories of food processing. This would allow a clear distinction between beneficial processing and over processing. Appropriate processing refers to techniques that are used to promote food safety and stability while maintaining or improving the nutritional value and sensorial properties of products. This is different from processing used to create food analogs with low level use of healthful raw ingredients and devoid of nutritional value, with the potential of increasing the risk of non-communicable diseases.

3. Conclusion

Food processing is a legitimate and most desirable strategy to provide safe and sustainable foods for consumption with extended shelf-life, and to make them available in underserved areas. As any tool, food processing can be misused in order to increase profit margins while neglecting the health of consumers. Therefore, it is important to be familiar with state-of-the-art food processing techniques, be aware of the correct terminology and use the classic and novel processing methods to feed the world population.

Conflict of interest

The author declares no conflict of interest.

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