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Review Article

Vitamins and Minerals: A Review on Processing Losses and Strategies to Control It

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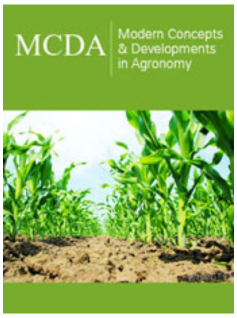

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Abstract

The objective of this review paper is to discuss the impact of food processing methods on nutritional value of vitamins and minerals and to focus on the ways of reducing the processing losses of these nutrients. The major reason for processing foods is to preserve them so that man is no longer completely reliant on geography and environment to meet his nutritional needs and desires. Processing makes food healthier, safer, tastier and more shelf stable. While there are various advantages to processing, it can also be harmful to food quality. Blanching, for example, prior to freezing or drying is used primarily to inactivate enzymes that can lead to quality deterioration of vitamins and minerals. During processing, milling and extrusion can also result in the physical removal of minerals. Non thermal techniques have been identified as suitable for retention of micronutrients.

Keywords: Vitamins; Minerals; Reduction strategies; Processing losses

Introduction

Over the last several decades, India has achieved significant progress in ensuring food security for its citizens and has become mostly self-sufficient in agriculture. The Food Processing Industry (FPI) has added value to output by generating new work opportunities, enhancing exports, and reinforcing the domestic supply chain [1]. As per Ministry of Food Processing of India (MOFPI), several segments of processing are responsible for the growth of the industry [2]. To increase the shelf life of fruits and vegetables, the food industry employs a range of preservation, or processing, technologies. Different processing methods can lead to a change in colour, texture, flavour and nutritional quality [3]. It can change them both in a positive and negative way [4]. All foods which undergo processing are subject to some degree of loss of nutrients. Among all nutrients, micronutrients are most affected by the processing. Minerals can be lost during cooking processes due to their solubility in water or heat. Minerals leach out during processing, but at a lower rate than vitamins. Furthermore, food processing and cooking processes can alter the content of food (vitamins, proteins, or fatty acids), resulting in changes in the composition and bioavailability of micronutrients. It is critical; therefore, all efforts should be made to restore the nutritional value of foods during preparation [5]. High temperature exposure causes undesirable changes such as a reduction in organoleptic quality as well as in heat-sensitive nutrients [6-8]. Common food technologies including pasteurisation, high-temperature sterilisation, drying, and evaporation can ensure the microbiological safety or stability of their products, but they can also destroy some of the food ingredients, particularly heat-sensitive vitamins and polyphenols, which are linked to food quality [9,10]. With the increasing demands for high-quality foods with 'fresh-like' characteristics, the non-thermal technologies introduced to the food industry, such as low processing temperatures with a short treatment time, exert minimal or no changes on food flavours and essential nutrients such as vitamins and minerals [11-14]. This review paper provides information on different processing methods affecting vitamins and minerals as well as techniques to overcome the reduction losses.

Effect of Processing on Vitamins

Vitamins are organic molecules that, in very small amounts, are required in the diet. They provide specialised and distinct tasks in the promotion of development and reproduction, as well as in the maintenance of health and life. Vitamins are divided into two main types according to solubility: fat-soluble vitamins (A, D, E, and K) and water-soluble vitamins (B-complex including B1, B2, B3, B5, B6, B7, B9, B12, C, D, E, and K). Vitamins in food are not stable. Vitamin disintegration depends on the different parameters during the processing, e.g., temperature, oxygen, light, moisture, pH, and length of exposure [15-17]. The loss of vitamins could be attributed to trimming and removing the skins of fruits and vegetables. Nutrients, particularly vitamins, found in cereal seed coats and germ are lost during milling. Thermal processing is the most detrimental to food vitamins, results in the degradation of water-soluble vitamins such as vitamin B complex and vitamin C, and the degree of thermal damage follows time/temperature relationship. Vitamins that are fat-soluble have a longer shelf life. Temperature, time, pH, moisture content, water activity, and oxygen concentration are all factors that influence the quantity of vitamins lost during food preparation [18].

The percentage loss of nutrients from fruits and vegetables is also affected by the amount of time they have been stored and amount of chemical added. Refrigerated storage can be accomplished using plastic wraps, bags, net bags, paper bags, or airtight containers [19]. The vitamin content of cereals (rice and wheat) remains relatively stable as long as the moisture content does not exceed 10%. If good storage conditions are used, the vitamin B content of stored bread and breakfast cereals remains stable. During processing and storage, vitamin C is highly susceptible to oxidation [20,21]. Postharvest nutritional quality losses, particularly vitamin C content, can be significant, and are magnified by physical damage, extended storage duration, high temperatures, low relative humidity, and chilling injury of cold-sensitive commodities [22,23]. The factors that affect vitamin degradation are the same whether the vitamins are naturally occurring in food or added to food from synthetic sources. However, the form in which a synthetic source is used (e.g., a salt or ester) may improve its stability. For example, vitamin E (tocopherol) esters are more stable than the tocopherol form [24].

Different Methods

High-pressure preservation

Total carotenoids in fruits and vegetables are relatively resistant to HPP and thermal processing. The majority of researchers discovered that high-pressure preservation had no effect on the total carotenoid content of fruits and vegetables, or even boosted it [25,26]. Depending on the fruit or vegetable product form, the effects of HPP on individual carotenoids varied (e.g., pieces, puree or juice). B vitamins in particular are extremely resistant to high-pressure storage. Sancho et al. [27] discovered that HPP had no effect on vitamin B1 and B2 retention in strawberry ‘coulis,’ and that retention was higher than when the strawberries were heated. Vitamins B1, B2, B6, and C (ascorbate) were similarly better preserved in high-pressure treated (400-600MPa/25 °C/30 min) model solutions than in thermally processed solutions. The majority of investigations have revealed that HPP has little effect on vitamin C. Vitamin C was reported to be unstable at high pressure levels paired with temperatures exceeding 65 °C by Oey et al. [25] and Barrett DM [3].

Freezing

Freezing is a method of preservation because it lowers water activity to a level that prevents microbial activity and reduces the rates of chemical reactions. While the heat exposure in frozen vegetables and fruits is limited, depending on the pace and temperature at which each is applied, the freezing and thawing process causes significant tissue structure damage. This degradation of plant tissue may allow for the loss of cellular integrity and the interaction of enzymes and nutrient substrates, resulting in nutrient loss as well as texture, colour, and flavour deterioration [2,3]. Vitamin C losses have been observed at temperatures as low as -23 °C [24].

Pasteurisation

Pasteurization is the process of destroying microorganisms by heating liquid foods like milk and fruit juices at specific temperatures. Milk’s nutritional value is unaltered in most cases. Some vitamin C loss might occur in pasteurised fruit juices [2].

Dehydration

Drying fruits can reduce the amount of vitamin C they retain, but it can also concentrate other nutrients, especially fibre in plant foods. Dehydrating food also increases the energy density of food, which may contribute to weight gain. When a dehydrated food is reconstituted and cooked with water, additional nutrients are leached out and lost in the cooking water [2]. According to research on the dehydration of blanched vegetables, the dehydration process can result in additional losses. Dehydration of blanched (unsulphited) cabbage resulted in an additional 30% reduction in vitamin C content, a 5 to 15% reduction in niacin content, and a 15% reduction in thiamine content [24].

Preparation of vegetables

Before cooking, most vegetables are peeled or trimmed to remove the tough skin or outer leaves. However, because most nutrients, such as vitamins, tend to be concentrated near the skin’s surface, excessive trimming can result in a significant reduction in a vegetable’s nutrient value [2].

Cooking

Some vitamins dissolve in water, so if you prefer to boil your vegetables, you will lose some of your vitamins to the cooking water. Boiling a potato, for example, can cause much of the potato’s B and C vitamins to migrate into the boiling water. You can still benefit from these nutrients if you consume the liquid, for example, by making a soup with the potato and the liquid. Alternative cooking methods, such as grilling, roasting, steaming, stir-frying, or microwaving, generally preserve more vitamins and other nutrients [2]. Lipophilic vitamins are released when green fresh vegetables are cooked. In contrast, a decline or no change occurs in a red vegetable fruit or frozen veggies that have undergone a blanching procedure [4].

Canning

Although the initial thermal treatment of canned products can result in loss, nutrients are relatively stable during subsequent storage due to the lack of oxygen. Frozen products lose fewer nutrients during blanching because of the short heating time, but they lose more nutrients during storage due to oxidation [3].

Blanching

Vitamin retention is better with a high temperature and a short water-blanch time than with a low temperature and, consequently, a long blanch period. Steam blanching is superior to water blanching in most cases. Sulphite added to blanching water has been shown to have a significant impact on thiamin levels in fruits and vegetables. -Carotene was discovered to be the most resistant to blanching. Under ideal conditions, riboflavin retention ranged from 80 to 95 percent; vitamin C retention ranged from 70 to 90 percent; and niacin retention ranged from 75 to 90 percent [24-27].

Milling

Milling grains causes significant losses of thiamine, biotin, vitamin B6, folic acid, riboflavin, niacin, and pantothenic acid (in descending order); there are also significant losses of calcium, iron, and magnesium [28,29]. Because most of the bran and some of the germs are removed during the refining process, refined grains are higher in starch. The germ and bran part of grains contains the majority of vitamins and minerals (44.45%). When wheat is milled into wheat flour, about 70 percent of vitamins and minerals (range 25-90 percent) and fibre are lost, along with 25 percent protein, 90 percent manganese, 85 percent zinc, and linoleic acid, and 80 percent magnesium, potassium, copper, and vitamin B6 [30-32].

Microwave drying

Microwaving resulted in vitamin C losses of up to 57 percent and increases of 10-260 percent in fruits and vegetables. Total vitamin C concentration in apple puree was similar before and after the microwave procedure, according to Picouet et al. [33]. However, ascorbic acid content reduced (43 percent retention) and dehydroascorbic acid increased (57 percent). Microwaving was found to be less harmful to vitamin C, and fruits and vegetables retained more vitamin C after microwaving than following a comparable heat procedure. The orange juice trial was an outlier, with microwave-processed juice having the lowest vitamin C level [3].

Microwave vaccum drying

Clary et al. [34] investigated the effects of microwave vacuum drying on whole grapes and compared the levels of vitamins A, B, and C in fresh and sun-dried grapes. The removal of water resulted in a concentration of the initial nutritional content in the microwave-dried product ranging from 50 percent to over 700 percent higher values in all conditions.

Irradiation

Irradiation can influence vitamin levels in food, and the losses are usually proportional to the exposure. The losses for most vitamins are negligible at low dosages (e.g., up to 1kGy). Vitamin losses have been observed in foods exposed to air during the irradiation and subsequent storage at higher doses (3-10kGy). When employing the highest allowed radiation doses, special care must be taken to preserve the food by using airtight packing and performing the irradiation procedure at a low temperature. The fat-soluble vitamins A, E, and K, as well as the water-soluble thiamin, have been shown to be the most sensitive to irradiation, while niacin, riboflavin, and vitamin D are reasonably stable. If nutrition claims for irradiated foods are to be made, research on the content and stability of vitamins after treatment with ionising radiation are recommended [24].

Effect of Processing on Minerals

For humans, food is the primary source of minerals. Major essential elements are Ca, Cl, Mg, Na, K, and P; minor essential elements are Co, Cu, Cr, F, Fe, Mn, Mo, Ni, Se, I, and Zn; and important elements in very small quantities are Li, B, Si, V, As, Sn, and Pb. The amount of these minerals in food is determined by a variety of factors, including the type of food (animal or vegetable), genetic origin, farming practises, and geographic location. Industrial processing and cooking processes are also key determinants in food mineral content. Cooking improves the palatability of food. Different cooking methods can be utilised, such as frying, boiling, baking, or grilling. In some circumstances, additives are added to food during processing, resulting in a higher mineral concentration. Minerals can be combined with other food components and become unavailable for digestion when food is cooked, processed, or stored. Natural changes in raw food products and cooking procedures also result in variances in the final mineral composition of foods, just as they do with vitamins [3].

Mineral stability and availability in foods are often less impacted by processing than other macro- and micronutrients within a diet. It's prone to leaching into the water used for processing or cooking. If the liquid is not consumed, more than half of the manganese, cobalt, and zinc in spinach, beans, and tomatoes may be lost during canning. In many cases, processing improves a food's digestibility, which increases mineral availability. Acidification, for example, can increase the solubility of mineral complexes, making certain metal ions more accessible. Food processing losses are typically associated with leaching or the formation of insoluble metal complexes, which reduces absorption. Thermal processing has no effect on the availability of minerals associated with proteins unless there is significant thermal destruction of the protein [18].

Different Methods

Cooking

Squeezing after boiling lost the most minerals from spinach, followed by boiling in tap water, 5 percent sodium acetate, 1 percent salt solution, steam heating, microwave heating, and parching. Cooking losses of minerals in spinach were largest in iron and magnesium, followed by in potassium, sodium, zinc and phosphorus. Magnesium and manganese were the most lost in rice during cooking, followed by phosphorus, copper, and potassium. In addition to boiling, soaking in water and washing caused a considerable portion of the cooking loss in rice. Cooking losses in these minerals ranged from 0-85%, and iron concentrations were sometimes higher than pre-cooked values. Squeezing after boiling and thin slices soaking in water, followed by parching, frying, and stewing, resulted in the greatest loss of minerals in vegetables [4].

Microwave vacuum drying

Clary et al. [34] examined mineral and fibre content in microwave vacuum-dried grapes. Microwave vacuum-preserved grapes had higher levels of minerals and crude fibre in all cases, most likely due to concentration in the dried product.

Extrusion cooking

The iron diffusibility increased just slightly during extrusion cooking. The reaction products of depolymerization processes under high temperature and shear could modify the chemical form of iron and make it more soluble. Studies on baking with iron-enriched flour yielded similar outcomes [35].

Milling

The bran and germ fractions of grains typically have a high concentration of minerals, and their removal by milling yields a pure endosperm with a low mineral content. Iron, zinc, copper, magnesium, and selenium are lost between 16 and 86 percent when whole wheat flour is converted to white flour (Miller, 1996). Although significant mineral losses occur during milling, mineral bioavailability can improve if the phytic acid/bran concentration of the grain is reduced [36].

Fermentation

Fermentation increases mineral bioavailability by lowering phytate levels and producing lactic acid, which promotes mineral solubility. Zinc availability was enhanced from 6.3 percent to 12.5 percent by fermenting milk with *Staphylococcus thermophilus* and *Lactobacillus bulgaricus*. The increase in zinc solubility was attributed to lactose to lactic acid fermentation, which either enhanced zinc solubility or reduced zinc binding to casein [37].

Strategies for Reducing Vitamins and Minerals Losses

A. To decrease mineral loss during cooking, take the following steps [4]:

a) consume the cooked food with the soup

b) add a tiny quantity of salt (approximately 1% NaCl) to the boiling water

c) avoid excessive boiling

d) use a cooking method that causes less mineral loss (stewing, frying or parching)

B. Microencapsulation: Although fortification is an important strategy for combating vitamin deficiency, many vitamins are susceptible to degradation during food processing. Microencapsulation can improve their stability, help them survive food processing and storage, and ensure they are released in the most beneficial part of the human digestive system [38]. Vitamins for food can be provided in encapsulated or coated forms to improve their stability. Some of these preparations, however, are only suitable for low-moisture foods [24].

C. Use of hard water for processing and cooking can result in an increase in the calcium or magnesium content of foods, while use of softened water can result in an increase in the sodium content [39].

D. Heat is generated locally during electric field processing, reducing the quantity of heat required. As a result, advanced methods reduce the temperature gradient (and thus maintains the quality) in the product while also reducing the amount of time it takes to complete the process [3].

E. Incorporation of purified dietary fibers which are essentially low or free from anti-nutritional factors like phytic acid, oxalic acid etc. to dairy products (a rich source of minerals like calcium) can be performed as it does not adversely affect the bioavailability of minerals [40].

F. All phases of product processing, handling, and storage must be examined for all products with vitamin claims to ensure that the vitamins are not degraded. This can be accomplished by limiting or eliminating exposure to light and oxygen, as well as keeping residence durations at high temperatures to a minimum. De-aeration of the solution, for example, during the processing of fruit juices, fruit squashes, and fruit drinks, can have a protective effect on the vitamin C levels in the product by lowering or eliminating oxygen [24].

Conclusion

It is concluded that nutrient losses occur in all processed foods. 'Advanced' technology may have a positive, neutral, or negative influence on nutrient retention depending on the fruit or vegetable of importance, preservation conditions, and particular nutrient(s). Processing, on the other hand, can improve nutrient absorption by inactivating antinutritive molecules. To summarise, food processing procedures can typically be good in terms of boosting mineral availability, but they can sometimes have negative consequences, particularly when it comes to vitamins. There is no perfect way of cooking that preserves all of the nutrients. Each has its own set of advantages and disadvantages. Last, for best outcomes the following conditions should be considered: Cook for shorter periods of time, at lower temperatures, with little or just enough water, and with minimal by-product waste.

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