Phenolic Compounds in Fermented Quinoa

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Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal crop, indigenous to the Andean region, increasingly singled out as a healthy food with an excellent nutritional profile. Fermentation can be used to increase phenolic compound content in quinoa seeds and flours. The use of fermented quinoa flours allows obtaining bread and pasta richer in phenolic compounds and with a greater antioxidant capacity. Fungi are the main starters used in quinoa seed fermentation, while Lactobacillus strains have been applied to produce sourdoughs. Quinoa has been also fermented to obtain yogurt-like beverages with a higher content in phenolic compounds and a greater antioxidant activity. Strains of Lactobacillus sp. and Bifidobacterium sp. have been used as starters.

Keywords: quinoa ; pseudocereals ; phenolic compounds ; fermentation

1. Background

Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal crop, indigenous to the Andean region, increasingly singled out as a healthy food with an excellent nutritional profile. It has recently attracted a lot of attention, as it is rich in proteins of excellent quality, with a balanced essential amino acid profile similar to milk and close to the ideal balance recommended by the Food and Agriculture Organization of the United Nations (FAO); it is a good source of minerals (e.g., calcium, iron, and zinc), vitamins, and also natural antioxidants. In addition, it is a gluten-free (GF) crop, and its seeds have been milled and widely used to overcome the technological challenges of GF breadmaking [1].

Phenolic compounds (PCs) are the most studied antioxidants in quinoa [2], so far. They are a diverse group of phytochemicals ranging from simple phenols to complex polyphenols, sharing the presence of one or more hydroxyl groups on aromatic ring(s). They have been mainly quantified by spectrophotometric methods as Total Phenolic Content (TPC) and a great variability in TPC has been observed among studies investigating quinoa samples originating from different regions worldwide.

A great deal of evidence has shown that consumption of fermented foods can have a preventive effect towards non-communicable diseases, due to the presence of bioactive molecules, which can have antioxidant capacity, cholesterol-lowering effect, or antidiabetic activity [3]. Fermentation of grains and derivatives thereof specifically determines the production of health-promoting components, such as γ-aminobutyric acid, conjugated linoleic acid, folates, and phenolic compounds [3]. The latter are mainly present in bound form (conjugates with sugars, fatty acids, or proteins) in non-fermented grains. Upon fermentation, phenolic bound forms are bio-converted into their free forms, which are more bioavailable and bioaccessible [4].

2. Fermentation and Phenolic Compounds

Food fermentation is a processing technology based on the growth and metabolic activity of microorganisms (i.e., bacteria, yeasts, and mycelial fungi, and their enzymes) for the stabilization and transformation of food matrices [5]. It can occur because microorganisms are indigenously present in the substrate or in the processing environment, or because they are added as a starter culture. In the first case, foods are referred to as wild ferments or spontaneous ferments; in the second case, foods are known as culture-dependent ferments [6]. In both cases, food fermentation occurs, provided that a suitable substrate, appropriate microorganism(s), and proper environmental conditions, such as temperature, pH, and moisture content, coexist.

During the fermentative process, several biochemical changes occur in the food matrix, and nutritive and anti-nutritive components are modified in terms of bioactivity and digestibility. In non-fermented grains, phenolic compounds are mainly present in bound form, that is, conjugates with sugars, fatty acids, or proteins.

During fermentation, bound phenolic compounds are bio-converted from their linked or conjugated forms to their free ones, because of the (i) breakdown of the bonds with the grain cell wall components; (ii) activities of enzymes, such as β-glucosidase, decarboxylases, esterases, hydrolases, and reductases; and (iii) metabolic activity of fermenting microorganisms [3]. In their free form, phenolic compounds have a greater bioaccessibility, and the released free aglycones have the potential for increasing antioxidative activity [7]. On the other hand, upon fermentation, a decrease of free phenolic compound content can occur, because they may bind with other molecules present in the food matrix, they might be degraded by microbial enzymes, and they might be hydrolysed by specific microbial strains [8].

Since phenolic compounds act as antioxidants, they also contribute to food antioxidant capacity. Hence, changes in phenolic compound content or profile, upon fermentation, can modulate antioxidant capacity. In addition, many lactic acid bacteria themselves possess enzymatic and non-enzymatic antioxidative mechanisms [7].

In grains, fermentation can increase or reduce phenolic compound content and antioxidant capacity [9]. The effect and the degree of influence depend on the species of microorganisms involved in the process [7]. It is pivotal to choose an adequate microorganism able to ferment the food matrix and outcompete contaminating flora [10].

3. Phenolic Compounds in Fermented Quinoa

Phenolic compounds have been the most investigated non-nutrient phytochemicals in quinoa [2]. A great variability in their content and profile has been observed among studies analyzing quinoa samples originating from different regions worldwide. Such variability is due to several factors, such as genetic traits, growing conditions, post-harvest processing of quinoa seeds, and also analytical procedures for phenolic extraction.

Quinoa processing, such as milling, cooking, fermentation, can modulate the dietary intake of PCs [11][12].

As regards fermentation, its application to quinoa seeds and/or flours, as well as the incorporation of fermented quinoa in bakery products, pasta or yogurt-like beverages proved to have multiple effects on phenolic compounds, such as modifications of their content and/or profile, as well as formation of metabolites.

Fungi (e.g., Helvella lacunosa X1, Fomitiporia yanbeiensis G1, Agaricus bisporus AS2796, Rhizopus microspores var. oligosporus, Aspergillus oryzae and Neurospora intermedia) were mainly used as starters to ferment quinoa seeds, while Lactobacillus strains (e.g., Lactobacillus casei CICC 20995, Lactobacillus paracasei A1 2.6, Pediococcus pentosaceus GS B, Lactobacillus plantarum DSM2648 and KX881779, Lactobacillus reuteri KX88177) were applied to both ferment quinoa seeds and to produce sourdoughs. In general, fermentation determines an increase in phenolic compounds, especially of free forms. However, it has emerged that any positive or negative effect is generally related to the strain used in the fermentative process and the fermentation conditions (e.g., duration, temperature).

The effect of fermentation on phenolic compound profile has been also investigated. Hydroxybenzoic and hydroxycinnamic acids derivatives, as well as flavonoids were identified in fermented quinoa and quinoa-based products. Among hydroxybenzoic acid derivatives, gallic, protocatechuic, and vanillic acids were mainly identified, and depending on fermentation duration an increase was observed after the process. Regarding hydroxycinnamic acid derivatives, caffeic, chlorogenic, ferulic, and p-coumaric acids were found in fermented quinoa. As regards flavonoids, catechin, kaempferol, quercetin were the main compounds identified in fermented quinoa and/or quinoa-based products.

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