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Review Article

Black garlic: A critical review of its production, bioactivity, and application

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ABSTRACT

Black garlic is obtained from fresh garlic (*Allium sativum* L.) that has been fermented for a period of time at a controlled high temperature (60–90°C) under controlled high humidity (80–90%). When compared with fresh garlic, black garlic does not release a strong offensive flavor owing to the reduced content of allicin. Enhanced bioactivity of black garlic compared with that of fresh garlic is attributed to its changes in physicochemical properties. Studies concerning the fundamental findings of black garlic, such as its production, bioactivity, and applications, have thus been conducted. Several types of black garlic products are also available in the market with a fair selling volume. In this article, we summarize the current knowledge of changes in the components, bioactivity, production, and applications of black garlic, as well as the proposed future prospects on their possible applications as a functional food product.

1. Introduction

Black garlic (BG) is simply fresh garlic (*Allium sativum* L.) that has been fermented for a period of time at a high temperature under high humidity. The process turns garlic cloves dark, gives them a sweet taste, and alters their consistency to chewy and jelly-like (Figure 1). The duration of fermentation varies depending on cultures, manufacturers, and purposes [1].

The long history of the use of garlic in food and acute, chronic, and inhalation studies, although limited, reveals no credible adverse biological effects. Exact origins of BG are

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unknown and controversial. However, BG has long been consumed in South Korea, Japan, and Thailand for centuries, and was introduced into Taiwan and other countries around 10 years ago. In the past few years, high-end chefs have drawn much attention to BG, who have been using it to flavor chicken, fish, soup, and risotto [2].

When compared with fresh garlic, BG does not release a strong off-flavor due to the reduced content of allicin, which was converted into antioxidant compounds such as bioactive alkaloids and flavonoid compounds during the aging process [1]. The changes of physicochemical properties are the main reasons for enhanced bioactivity of BG compared with fresh garlic. Besides daily consumption, several studies have reported that BG extract demonstrates several functions, such as antioxidation, antiallergic, antidiabetes, anti-inflammation, and anticarcinogenic effects [3–7]. In 1990, Designer Foods Program listed garlic at the top of cancer-fighting candidates [8]. Although the Designer Foods Program no longer exists, scientists are still looking for what are now called bioactive components in different foods.

The two main focuses of this study are to summarize the current knowledge of the composition change, bioactivity, production, and applications of BG, and also to propose future prospects on their possible applications as a functional food product.

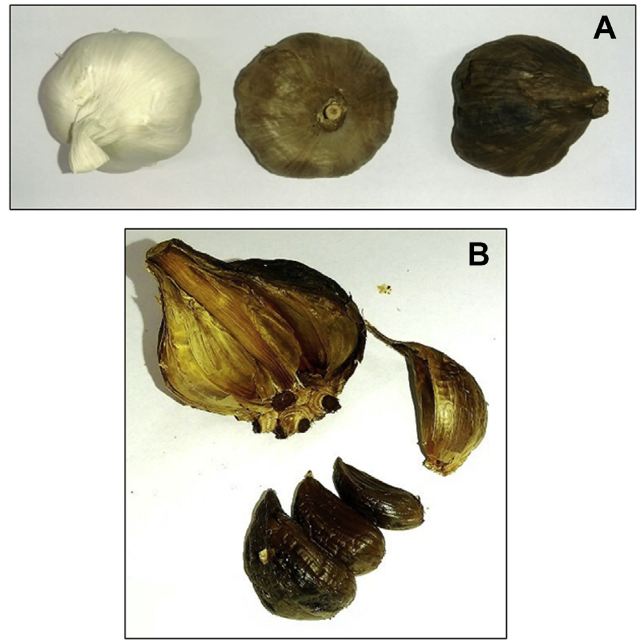

Figure 1 – Black garlic. (A) Garlic during fermentation process (left to right). (B) Black garlic cloves.

2. Nutritional content of garlic

The enhanced biological activity of BG when compared with fresh garlic lies in the conversion of phytochemical compounds during the fermentation process. In the following section, we will summarize the changes of garlic components between fresh garlic and BG.

2.1. *Comparison of the components between fresh garlic and BG*

Fresh garlic contains approximately 63% of water, 28% of carbohydrate (fructans), 2.3% of organosulfur compounds, 2% of proteins (alliinase), 1.2% of free amino acids (arginine), and 1.5% of fiber [9]. Nontreated fresh garlic also contains a high amount of γ-glutamylcysteines [10]. These compounds can be hydrolyzed and oxidized to form alliin, which accumulates naturally during the storage of garlic at a cool temperature. After processing, such as cutting, crushing, chewing, or dehydration, alliinase rapidly lyses the cytotoxic cysteine sulfoxides (alliin) to form cytotoxic and odoriferous alkyl alkane-thiosulfinates such as allicin [11]. Allicin contributes to the characteristic flavor and taste of garlic. Allicin and other thiosulfinates are immediately decomposed to other compounds such as diallyl sulfide, diallyl disulfide, and diallyl trisulfide, dithiins, and ajoene [11,12]. At the same time, γ-glutamylcysteines are converted to SAC through its catabolism pathway other than the alliin–allicin pathway [13]. SAC contributes to health benefits of garlic, such as its antidiabetic, antioxidant, and anti-inflammatory activities [14–16].

As for BG, during the thermal process, some chemical compounds from fresh garlic are converted into Amadori/Heyns compounds, which are key intermediate compounds of Maillard reaction [1]. The chemical compounds of aged BG (ABG) are complicated, and the quality of its products depends on the manufacturing process. Nevertheless, BG contains much more functional compounds such as SAC than fresh garlic.

The contents of chemical compounds of BG depend on the conditions during thermal processing. Some researchers reported that many valuable components within BG against diseases increased during the aging process, especially polyphenol, flavonoids, and some intermediates of Maillard reaction have been known as antioxidant agents [13,17]. Furthermore, the antioxidant activity of garlic varies across regions [18]; nevertheless, BG demonstrates significantly much higher biological activity, such as antioxidant properties, than fresh garlic [19].

Several studies have reported that water-soluble sugars, amino acids, total polyphenols, and flavonoids increased or decreased during thermal processing (Table 1) [13,20,21]. Three of Amadori and three of Heyns compounds in BG increased significantly—up to 40–100-fold higher than those in fresh garlic. In contrast, through the aging process for converting fresh garlic to BG, the amount of fructans decreased simultaneously, owing to the fact that fructose and glucose with some of amino acids play important roles in Maillard reaction in garlic processing.

3. BG processing

3.1. *Effects of aging temperature on the quality of BG*

It is well known that the aging period of garlic is shorter at higher temperatures [22]. In the case of aging process at 70°C, the speed of aging is two-fold faster than that at 60°C [23].