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Black Garlic: Production Possibilities, Physicochemical Changes During the Production Process and Effects on Health

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ABSTRACT

The benefits of garlic for human health have been known for centuries. Due to its valuable compounds, many people avoid consuming it due to its pungent odor and bitter taste, although experts recommend that people add it to their diet lists and consume it persistently. In order to change this disadvantage and increase consumption, black garlic has been produced by developing different production techniques. Black garlic is produced by fermenting fresh garlic in a controlled environment at 45-90°C and 50-90% relative humidity until it turns black, and during this process, physicochemical properties such as color, pH, dry matter, reducing sugar and nutrient content change with the effect of Maillard and enzymatic reactions. With this fermentation process, the alliin and allicin substances that give fresh garlic its characteristic odor and taste are reduced, so that the undesirable bitter taste and odor disappear. The fact that black garlic has higher antioxidant activity compared to fresh garlic has made this product more preferable in terms of health, not only in terms of taste and smell, but even with this feature. Although black garlic has been consumed in Asia and Europe for many years, our country has met this product very recently. In this review, we will focus on black garlic production technology, techniques used to increase production efficiency, changes that occur during the production process and health effects.

INTRODUCTION

Garlic (*Allium sativum* L.) is a plant belonging to the Alliaceae family, native to Asia, and is considered a miraculous plant. It is used both for medicinal purposes and as food. Today, there are 500-600 garlic varieties identified worldwide, and this number is increasing. It is widely produced all over the world and used in various fields (Akan, 2014; Martínez-Casasve et al., 2017; Abe et al., 2020). Also being used as a spice in meals for centuries, it is also used in traditional medicine due to its beneficial effects on health; it is known as the 'death-defying plant' in mythology and maintains its importance in health, economy, science and social fields with its 5000-year history (İbret, 2013). Garlic has been used for medicinal purposes for centuries due to its bioactive properties, such as antimicrobial, antidiabetic, anticancer, antiallergic, and antioxidant effects (Farhat et al., 2021; Mondal et al., 2022; Saikat et al., 2021; Kim et al., 2012). Scientific studies on this plant started in the 19th century when Louis Pasteur discovered the antibacterial properties of garlic in 1858, and in 1932 Albert Schweitzer used garlic to treat amoebic dysentery in Africa (Lanzotti, 2006; Kim et al., 2012).

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Although onions, which are related among Allium species, are consumed more by consumers, garlic, which has a bad reputation due to its smell and taste, attracts the most attention of researchers; Garlic has been described as a natural antibiotic due to its richness in terms of the compounds it contains, its calming properties, improving the function of white blood cells that play an active role in the immune system, cleaning toxic metals such as mercury that disrupt the immune system, antimicrobial, antiprotozoal, virucidal, antibacterial, painkiller, anticarcinogenic properties, as well as its ability to treat skin diseases, respiratory and digestive diseases and cardiovascular diseases. The number of commercial medicines that have been used as medicines for centuries in the treatment of diseases and derived from this valuable vegetable is increasing day by day (Kemper, 2000; Losling 2003; Erşahin, 2020). However, despite the availability of many garlic-based drugs, it is strongly recommended to consume in moderation due to the toxicity reported as a result of overdose (Shashikanth et al., 1986; Lembo et al., 1991; Agusti, 1996; Kodera, 1997).

Fresh garlic; flavanoids, acidic compounds, sulfur compounds such as diallyl sulfate, allicin, ajoen, alliin, which give garlic its unique smell and flavor; protein, fiber, free amino acids, enzymes such as allinase, myrosinase; carbohydrates (especially sucrose and glucose), phenolic compounds; vitamins A, B, C and E; minerals such as potassium, phosphorus, calcium, selenium, germanium tellurium and iron (Khuda-Bukhsh et al. , 2014; Ichikawa et al., 2006; Lanzotti, 2006; Beato et al., 2011; Turfan et al. 2016). Garlic is not only one of the vegetables consumed raw or cooked on the tables, but it is also used by consumers to flavor foods. In addition, the fact that it is preferred in spices, meals and alternative medicine today shows that it has a wide range of uses (Vural et al., 2000). Allicin and disulfide compounds in garlic, which are extremely important for human health, are formed by the breakdown of alliin, a sulfurous amino acid, into allicin by the enzyme alliinase and into allicin allyl disulfide in the presence of water vapor or water, and this compound is known as the essential oil that gives garlic its special smell and flavor. However, due to the undesirable taste and smell of garlic, its consumption by consumers is quite limited. For these reasons, various techniques such as heat treatment, fermentation, water vapor applications are used to eliminate these negativities of garlic and to increase its flavor, nutritional value and product variety. Although there are differences in its use among consumers, it is consumed as fresh garlic, dried garlic, black garlic, garlic powder, garlic juice, garlic tablets, deodorized garlic powder tablets, soaked garlic in oil, garlic oil, encapsulated garlic oil or juice, garlic puree, garlic juice and frozen garlic (Kang, 2016; Medina et al., 2019; Özaydın et al., 2020).

With the recent developments on black garlic, the scientific community has started to focus on the potential health benefits/harms of this new product. Black garlic is produced by natural fermentation of fresh garlic at controlled temperature and humidity. Some researchers have reported that black garlic can be produced directly or by yeast fermentation in a controlled environment with a temperature of 45-90°C and a relative humidity of 60-90% (Jang et al., 2008; Wang et al., 2010; Lee et al., 2011). During the fermentation period of black garlic produced under specific temperature and humidity conditions, significant changes occur in its physicochemical properties such as pH value, dry matter, color, reducing sugar content, and nutritional value. In particular, the increase in antioxidant activity compared to fresh garlic makes this product medically preferable (Colín-González et al., 2012; Czompa et al., 2018). The biochemical event that occurs during this ripening process is the Maillard reaction, a non-enzymatic color transformation that occurs under the influence of heat treatment. The darkening of the color of the garlic during the fermentation period consists of sugars and amino acids due to this reaction, and the demand for black garlic is increasing day by day due to the rich compounds released during this process and the medicinal benefits it provides, as well as the consumption of black garlic as teeth, It has also enabled the opening of different commercial branches with product types such as capsules obtained from 100% black garlic flour, black garlic paste, black garlic flour obtained by drying and machine grinding after extraction of black garlic with ethanol, and black garlic gels obtained from this flour (Akan, 2014; Lee, et al. , 2009; Wang et al., 2010; Erol and Ersus, 2022). The use of black garlic in various foods (candies, ice cream, such as beverages, sausages, tofu, bread, yogurt, vinegar, alcohol and jam) is very popular in Asia, Europe and America, and it is also used in products such as shampoo, cosmetics, skin protectant, face cream, soap, etc. due to its high antioxidant potential (Lee et al., 2009; Sim et al., 2016; Kim et al., 2013).

Due to its high antioxidant activity, black garlic has become a more preferred food product compared to white garlic, whose consumption is socially restricted, and is also used to prevent age-related diseases. S-allyl cysteine (SAC) is the main antioxidant component in black garlic, which makes black garlic more valuable due to its low toxicity, easy absorption, disease prevention effect, and rapid bioavailability compared to other sulfur compounds (allicin, diallyldisulfite) in white garlic (Colín-González et al., 2012; Kimura et al., 2017). In recent years, black garlic has attracted a great deal of attention from both consumers and scientists and has been recognized as a functional food of natural origin and named as a 'Superfood' due to its health beneficial properties incomparable to other processed foods and fresh garlic (Najman et al., 2020).

In this review, it is aimed to investigate the production method of black garlic, which has functional properties and positive effects on human health, changes in the structure and physicochemical properties of black garlic during the production process, nutrient content and health effects.

Practices to Reduce the Production Process

Black garlic production for more than 20 days results in high energy consumption, time loss and reduction of important bioactive compounds. Therefore, it has led researchers to find ways to use emerging technologies, different pre-processing and production techniques to produce products with desired quality characteristics (Li et al., 2020). Jung et al. (2011) fermented fresh garlic using yeast (S.cerevisiae) and investigated the hypolipidemic, hypoglycemic, nephroprotective, antiobesity and antioxidant effects of black garlic on mice. As a result of the research, they reported that black garlic fermented with yeast contained higher rates of obesity, hyperlipidemia, nephropathy and antioxidants than heat-treated black garlic, and that black garlic bioactivity can be used as an adjunct to diabetic drugs by enhancing its bioactivity with yeast fermentation. Pakakaew et al. (2022), in order to find the shortest processing time that keeps the S-allyl cysteine (SAC) level, which is considered as a quality indicator of black garlic, fresh garlic was pretreated with $CaCl_2$, then frozen and heat treated at 60 °C 65% relative humidity and 80 °C 80% relative humidity for one week. As a result of the study, they determined 874.26 mgSAC/100g dry weight with 5390 mgTrolox/100 g antioxidant and 25,421 mgTrolox/100 g antioxidant activity for DPPH and ABTS analyses, respectively. They reported that $CaCl_2$ treatment shortened the processing time of black garlic by about 4 times, garlic processed for 1 week at 60 °C and 65% RH provided the highest SAC content of about 1772 mg/100g dry weight, which was 2 times higher than garlic processed for 1 week at 80 °C and 80% RH, and the color of this garlic was golden and called 'golden garlic'. In order to shorten the production process of black garlic, the raw material is stored in the freezer for a while as a pre-process before production and then subjected to fermentation. Kandemirli et al. (2020), kept fresh garlic at -16 °C for 30 hours as a pre-treatment application and found that the antioxidant activity, total phenolic, total flavanoid and HMF ratios of black garlic produced after freezing were higher and the fermentation period was reduced to 20-35 days. Ding et al. (2021), stored black garlic in kraft paper bags (KPB), polyethylene terephthalate bottles (PETB) and aluminum laminated polyethylene bags (ALPB) for 90 days, at 4°C and 20°C and investigated the metabolite levels, volatile compounds and antioxidant activities of black garlic. A total of 27 water-soluble substances and 96 volatile compounds were detected using nuclear magnetic resonance (NMR) and gas chromatography-mass spectrometry (GC-MS). Antioxidant levels decreased in the order ALPB < KPB < PETB, and storage at 20°C stimulated enzymatic hydrolysis and the Maillard reaction, while storage at 4°C maintained antioxidant activity and inhibited the Maillard reaction. They also reported that the sucrose content was higher when black garlic was packed in PETB and KPB. Chen et al. (2020) reported that 300MPa high pressure pretreatment of fresh garlic for 15 minutes increased the SAC ratio in black garlic obtained from γ-glutamyltransferase (γ-GTP) by about 8 times.

Black Garlic Production and Changes During Production

The exact origin of black garlic is unknown and still the subject of controversy. It has been consumed in South Korea, Japan and Taiwan for many years, but has been consumed in European countries for the last 20 years and in our country for the last few years (Bradley, 2009). The first partial production of black garlic was realized by Kamimura in 1999, but thanks to the fermenter device developed by Japanese and Korean scientists in 2003, black garlic production from fresh garlic was fully achieved. However, as a result of subsequent researches, black garlic is defined as a fermented product obtained by heat treatment of fresh garlic cloves at controlled temperature and constant humidity for an average of 40-45 days (Figure. 1), and it varies according to factors such as the variety of garlic, the conditions of the growing region, temperature, relative humidity of the environment and processing time (Ergin, 2019; Jing, 2020; Kimura et al., 2017; Martínez-Casasas et al., 2017). The lack of a quality index of black garlic and its products or the lack of a standardized black garlic production method hinders the growth of the black garlic industry.

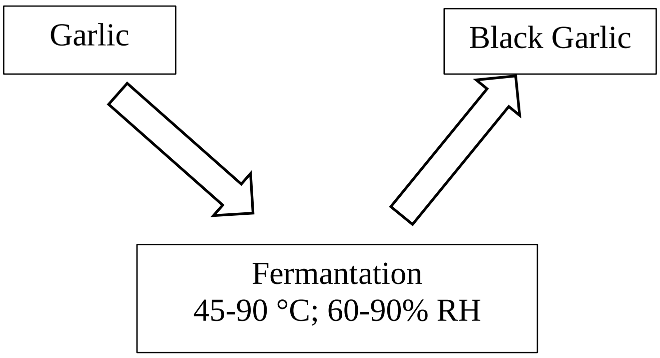

Figure 1. Black Garlic Production

Therefore, a quality index should be established for the black garlic sector, taking into account beneficial compounds, physical, and functional properties. Increased antioxidant activity, S-allyl-cysteine (SAC) and browning during the black garlic production process are used as quality factors in black garlic. However, information on browning products is very limited and many parameters affect black garlic quality (Manzocco et al., 2000; Bae et al., 2014). The characteristics that affect the physical and chemical properties in the black garlic process include the changes or interactions between carbohydrates, free amino acids, volatile sulfur compounds, polyphenols and other antioxidant compounds, and the extent of these changes is mostly related to production parameters (Bae et al., 2014; Rios-Rios et al., 2019). Garlic, which has a hard and watery structure during the fermentation process, has a gelatinous and soft texture and is more suitable for consumption when the moisture content is in the range of 40-50%. However, when the moisture content falls below 35%, chewing will be more difficult as it will have a hard structure due to its dryness. During the production of black garlic, many reactions occur, the main reaction being the Maillard reaction, and the Maillard reaction changes the color, texture, nutrient content and taste of fresh garlic (Bae, 2014; Lei et al., 2015). Maillard reaction plays an important role in the process of changing the color of garlic from white to black and this reaction is a non-enzymatic browning reaction between reducing sugars and amino acids that occurs in heat treatments during the black garlic production process (Wang et al., 2011).

During the transformation of fresh garlic heads into black garlic, enzymatic breakdown of the sulfur content takes place in a temperature and humidity controlled atmosphere, while the characteristic odor decreases, the conversion to alliin allicin is prevented as a result of the inactivation of the allinase enzyme with temperature, so that there is no undesirable odor and taste, and a fragrant product with sour-sweet aroma or partially prune or apricot taste is formed (Montano et al., 2004; Akan, 2014). Looking at the changes in the taste profile during the fermentation process, it has been determined that while fresh garlic contains sulfur volatile compounds and butenal derivatives that give bitterness, black garlic has a roasted taste arising from sweetness-sourness and Maillard reaction products, especially furfural compound (Zhang et al., 2016; Molina-Calle et al., 2017; Erol and Ersus, 2021). Black garlic has sour, sulfur, fruity, fruity, sugary flavors other than roasted flavors. The brown compounds formed as a result of the Maillard reaction depend on thermal processing parameters, pH value, and the quantitative ratio of amino acids to reducing sugars. This reaction results in the formation of a brown color in foods, and the importance of Maillard browning in processed foods in terms of consumer acceptance is clearly understood from the fact that “we eat with our eyes.” (Martıns-Sara and Van Boekel Martinus, 2000).

Due to the intermediate products formed as a result of the Maillard reaction, it has a color scale from white to dark brown and black. The reason for this color is the melanoidin pigment formed in the final product towards the end of the Maillard reaction. With the formation of this pigment, a bitter, burnt taste begins to form. However, in addition to these properties, melanoidins also have antimicrobial, prebiotic and hypertensive effects (Yuan et al., 2018; Vhangani and Van Wyk, 2016; Wang et al., 2011; Yang et al., 2019). Abe et al. (2020) used the sensomic approach to determine the effect of heat treatment time on black garlic flavor and compared the results with fresh garlic results. In the results of the research, 13 odor compounds, 39 aroma compounds, esters, aldehydes, phenols, pyrazines and sulfur-containing compounds of aroma compounds and lactones were found in black garlic and the concentration of allicin was higher in fresh garlic than in black garlic. They also reported that changes in the chemical reactions of heat treatment time may lead to differences in black garlic flavors. Molina-Calle et al. (2017), investigated the aroma compounds of fresh garlic and black garlic using Headspace gas chromatography mass spectrometry. They found furfural as the most concentrated aroma compound in black garlic, 2-ethyl-2-butenal with pungent aroma only in white garlic and 2-methylpropanal with spicy aroma only in black garlic.

Due to its unstable sulfoxide bond, alliin in fresh garlic converts to the more stable compounds S-allyl cysteine, S-allylmercaptocysteine or diallyl sulfide, diallyl disulfide, diallyl trisulfide, dithiin and ajoene during fermentation. SAC is one of the most abundant sulfur-containing amino acid compounds in black garlic and SAC is formed by the hydrolysis of γ-glutamyl-S-allyl cysteine (GSAC) with the enzyme γ-glutamyl transpeptidase (Bae et al., 2014; Medina et al., 2019; Amagase et al., 2001). In a study conducted to determine the changes of alliin at different temperatures, it was found that the amount of alliin in fresh garlic exposed to 90°C decreased faster than those at 60, 70 and 80°C (Zhang et al., 2016).

The term antioxidant, which has been used very frequently in the scientific world in the last three decades, includes compounds such as vitamins A, C and E, β-carotene, bioflavanoids and selenium, which help us protect against oxidizing agents or free radicals that have the potential to damage the cells in our body. In other words, antioxidants are molecules that prevent cell damage by preventing the formation of free radicals or by clearing existing radicals and generally carry phenolic functions in their structures (Kahkonen et al., 1999; Kozan, 2012). During the fermentation process of black garlic, reducing sugar content and total polyphenol content increase. The main phenolic acids in black garlic are hydroxynamic acid derivatives and gallic acid; the main flavonoids are flavanols such as catechin, epicatechin, epigallocatechin gallate and these compounds increase approximately 5-8 times during fermentation (Bae et al., 2014; Kim et al., 2013). In a study, in order to determine the phenolic compounds in black garlic, it was extracted with methanol and p-hydroxybenzoic acid, chlorogenic acid, vanillin and p-coumaric acid from phenolic acid class and quercetin from flavonol group were found in the extract (Özaydın et al., 2020). Studies have shown that the amount of total phenolic substances and flavonoid substances is higher in black garlic compared to fresh garlic with the heat treatments applied. Sato et al. (2006) heat-treated fresh garlic at 60°C - 70°C and 85 - 95% relative humidity for 40 days and examined the anti-oxidative properties and total phenol content of 80% ethanol extracts. They determined that superoxide dismutase (SOD) activity increased 10-fold and total phenol content increased 7-fold. The valuable compounds of garlic vary according to the conditions to which it is exposed, which shortens the shelf life of garlic (Rabinkov et al., 1998; Banerjee et al., 2003). For these reasons, the use and storage methods of garlic and cooking techniques are of great importance in terms of preserving the chemical components, nutritional value, odor and flavor of garlic and especially in terms of preventing the accumulation of carcinogenic mycotoxins, malondialdehyde and reactive oxygen that will lead to food poisoning (Akan and Halloran, 2012; Saldamlı, 2007; Cantwell and Suslow, 2003; Li et al., 2015). However, it should be noted that a decrease in the amount of phenolic compounds has been reported to occur when the heat treatment time of fresh garlic is kept longer (Kumar et al., 2017; Yuan et al., 2016).

Fresh and black garlic are very rich in carbohydrates. However, the carbohydrate profile changes significantly during the transformation of fresh garlic into black garlic (Koch and Lawson, 1996). Carbohydrates: 22-26% of fresh garlic, approximately 77% as dry matter, and mainly consist of polysaccharides and small amounts of oligosaccharides and monosaccharides (Baumgartner et al., 2000). The degradation of polysaccharides occurs at acidic and high temperatures, and it has been observed that sucrose breaks down into fructose and glucose due to the decreasing pH value and heat treatment during the advanced black garlic production process. It has been determined that more than 90% of the polysaccharide content of white garlic is fructan and galactan, which are non-reducing saccharides. Fructan in garlic provides osmotic pressure control, adaptation to lower temperatures, photosynthesis and protection against freezing stress, and the shelf life of the product is also extended by reducing pH and moisture content (Liang et al., 2015; Rios-Rios et al., 2019; Lu et al., 2018; Yuan et al., 2018). İlgün et al. (2022), investigated the total phenol, flavonoid, antioxidant and antidiabetic activities of black garlic and its peels obtained from single-clove Mürdük garlic. For this research, water and ethanol extracts of black garlic and again ethanol extracts from the peels of black garlic were prepared and as a result of the study; they determined that the extract obtained from black garlic peels had higher total phenol and total flavonoid contents compared to the extract prepared from normal garlic peels, that the antioxidant activity of black garlic peels was high, and that black garlic extracts did not show any activity against acarbose in terms of α-amylase inhibition potential.

HMF is formed by catalytic dehydration between reducing sugars and amino acids during the Maillard reaction at high temperatures or by direct breakdown of hexose in an acidic environment and contributes to the desired color, taste and aroma in foods. HMF formation varies according to processing and storage conditions and depends on the type of sugar, water activity, temperature and pH. It has been determined that when the amount of HMF in fresh garlic reaches 4 g/kg, the color of the garlic turns black (Şaşmaz, 2021; Lansalot-Matras et al., 2003). The toxicity, mutagenicity and carcinogenicity of the 5-HMF compound are still a matter of debate (Michail et al., 2007). However, although scientists have suggested that HMF has harmful effects, its beneficial properties, including antioxidant, cytoprotective and antitumor effects, have become more evident with studies conducted in recent years. In addition, the results of the latest study showed that HMF does not have significant mutagenic effects, but in fact has high antimutagenic activity (Kim et al., 1987; Kong et al., 1989). Although the results obtained have published paradoxical findings, they have shown that 5-HMF does not have carcinogenic activity and has antitumor potential (Michail et al., 2007). Kim et al. (2011) found that the chloroform extract of black garlic exhibited anti-inflammatory properties when applied to human umbilical vein endothelial cells (HUVECs). However, 5-hydroxymethylfurfural (5-HMF) is considered a compound that can adversely affect human health and is seen in heat-processed foods. Black garlic also has a high HMF content among foods produced by heat treatment. As far as is known, no limit has been set for 5-HMF by any institution/organization for black garlic (Chua et al., 2022).

Hydrolytic and oxidative changes in garlic lipids, especially during the processing of fresh garlic into black garlic, occur under conditions of high temperature (60 to 90 °C) and high humidity (60 to 90%). As a result, a series of compounds such as aldehydes, ketones, alcohols, and lactones are produced. These products participate in a series of complex chemical reactions such as hydrolysis, oxidation, and the Maillard reaction (Zamora and Hidalgo, 2005). All this explains why the lipid content in processed black garlic is lower than in fresh garlic (Qui et al., 2020; Zamora and Hidalgo, 2005). Although inconsistent and even controversial lipid components were detected during the production of black garlic, changes were found in the lipid profiles of fresh and black garlic due to their oxidation and participation in chemical reactions. Choi et al. (2008) showed that the crude lipid content increased significantly (from 0.18% to 0.58%) after processing fresh garlic into black garlic, while Lu (2017), reported the crude lipid level in fresh garlic and black garlic after heat treatment as 0.33% and 0.16%, respectively. These differences are likely due to differences in garlic type, processing procedures, extraction methods, and moisture content of the garlic (Qui et al., 2020).

Fresh garlic contains 1.5-2.1% protein and also has a rich variety of amino acids. This variety varies depending on the type of garlic and the growing environment. Glutamine, asparagine, and glutamic acid, lysine, cysteine, tryptophan and valine are the most abundant amino acids in garlic (Lee and Harnly, 2005; Choi et al., 2014). When fresh garlic is processed into black garlic by heat treatment, protein denaturation occurs and its content decreases due to the participation of some amino acids in the Maillard reaction (Lee and Harnly, 2005; Koch and Lawson, 1996). Cysteine is one of the basic building blocks of sulfur-containing and odor compounds such as S-methyl-L-cysteine sulfoxide and S-allyl-L-cysteine sulfoxide (alliin), which are the most abundant in garlic and contain cysteine (Amagase, 2001). After processes such as cutting, crushing or dehydration, these compounds form other volatile compounds including diallyl sulfide, diallyl disulfide, diallyl trisulfide and ajoene (Corzo-Martínez et al., 2007). Choi et al. (2014) investigated amino acid changes by heat-treating fresh garlic at 70°C and 90% humidity for 35 days. They found that the amount of cysteine, threonine, serine, glycine, alanine, glutamic acid, arginine, lysine and tyrosine was lower in black garlic, while the phenylalanine content was higher. They reported that the decrease in cysteine and tyrosine in particular may be related to the Maillard reaction that occurs between the carbonyl compounds of reducing sugars of amino acids and may also be related to changes in antioxidant activity.

Effects on Health

In today's world, obesity has emerged with the decrease in mobility and changes in nutrition style, and it is increasingly emerging as a major health risk worldwide (Nomura et al., 2008; Karalis et al., 2009). Excessive food consumption and a sedentary lifestyle contribute to obesity and also increase the incidence of diseases such as liver steatosis and damage, hyperlipidemia, diabetes and heart diseases (Armitage et al., 2008). Studies have revealed that the functional components of garlic are effective in the treatment of obesity and other diseases caused by this disease, and several important natural compounds such as epigallocatechin 3-gallate, rutin, gallic acid, and o-coumaric acid are particularly effective in the treatment of obesity, and clinical studies have reported that individuals who consume garlic for an average of 4-12 weeks have decreased blood pressure, oxidative stress, and hyperlipidemia, decreased lipid profiles, and improved adipose tissue mobilization and insulin resistance (İlgün et al., 2022; Yanovski et al., 2002). Although garlic has lost its popularity in the fight against diseases with the discovery of modern antibiotics, studies have reported that garlic is more effective than antibiotics, especially against throat infections. Garlic still maintains great importance in traditional Asian medicine; It is known that garlic juice is used in typhoid and meningitis, garlic steam in whooping cough, garlic suppositories in yeast infections, and garlic soup in pneumonia. In our country, garlic is used as a traditional treatment method by applying fresh poultice on wounds (Ahsan and Islam, 1996; Bordia et al., 1977; Yoshida et al., 1998; Hanafy et al., 1994). Scientists think that this feature of garlic, which is caused by the allicin compound it contains and is especially effective against antibiotic-resistant microorganisms, should be given more place in today's medical treatments (Ayaz, 2007; Imai et al., 1994; Vural et al., 2000; Soffar et al., 1991).

Garlic, which is considered to be a cancer-fighter, has immune system-supporting properties, and carcinogens that can initiate tumor formation or support its spread are eliminated by supporting the immune system. Thanks to the properties of garlic's allinase and other compounds, this effect has been supported by various studies, and studies have shown that when mice with cancer were fed garlic extract, it stopped tumor formation and that garlic caused mutation in cancer cells. It has been determined that people who consume large amounts of garlic, especially in China, Korea, Italy and Thailand, are protected against stomach cancer (El-Mofty, 1994; Fleischauer et al., 2000; Ramakrishnan et al., 1989). It has been reported that the rate of cancer varies between regions with low and high consumption of allium vegetables such as garlic, and that people in regions with high consumption have a much lower risk of developing stomach cancer compared to those who consume low or no consumption. Although the mechanism of garlic's cancer prevention is still not well understood, it is thought to be due to its ability to block or destroy nitrosamines, which are also considered powerful carcinogenic compounds in the digestive system. Studies have determined that garlic provides protection for living tissues against carcinogens that cause breast, stomach, colon and rectum cancer (Fleischauer et al., 2000; Özçelik et al., 2006). Schmidt and Marquardt first discovered the antifungal effect of garlic in 1936 (Haris et al., 2000). It has been proven in studies that allicin is effective against microorganisms such as aspergillus, candida, torulopsis, trichophyton, cryptococcus, trichosporon and rhoodotorula due to its fungicidal properties (Yousuf et al., 2011).

Allergy is a disease mostly related to malnutrition and stress, and the number of allergic individuals is increasing day by day. Another function of black garlic is its antiallergic effect (Wang, 2015: Ergin, 2019). Yoo et al. (2014) gave black garlic extract to rats in addition to their diet in order to investigate the antiallergic effect of black garlic, and as a result of the study, they determined that it showed an antiallergic effect and reduced IgE-related reactions, and they also reported that it would be useful as functional foods for allergic diseases.

Black garlic is rich in anti-inflammatory substances such as sulfur compounds, polyphenols, melanoidins, HMF, alkaloids, polysaccharides and 2-linoleoylglycerol and has strong anti-inflammatory activity. Black garlic exhibits higher antioxidant and anti-inflammatory activities than fresh garlic. In recent years, cardiovascular diseases and deaths from these diseases have increased all over the world. People who care about cardiovascular health have turned to fresh garlic, which is known to have a positive effect on these diseases and is also used as a traditional treatment method, but the discovery of black garlic and its positive effects on these diseases have reduced the popularity of fresh garlic. In addition to the protective effect of black garlic on the liver and heart, it has been found that it strengthens the immune system, delays arterial calcifications, and accelerates wound healing in addition to its positive effects on blood pressure and blood fat levels (Qiu et al., 2020). It has been determined that black garlic has beneficial effects on memory and the nervous system and reduces oxidative stress (Hermawati, et al., 2015; Jeong and Sim, 2020). Black garlic has antiallergic activity and antidiabetic effects (Kim et al., 2012; Jung et al., 2011).

While fresh garlic contains water-soluble allicin, black garlic contains fat-soluble SAC (S-allylcysteine), thus it is easier and faster to obtain beneficial compounds from black garlic (Chu et al., 2007). Black garlic regulates blood sugar levels, the body secretes insulin thanks to the allicin found in garlic, and facilitates the absorption of glucose in the blood with vitamin C (Wang et al., 2010). During production, allin is converted into SAC, not allicin; SAC is a water-soluble sulfur compound and also contains antioxidant activity, it is formed after the conversion of ɣ-glutamyl-SL-cysteine to SAC by ɣ-glutamyl enzyme, it is not found in fresh garlic, but is very densely found in black garlic, and is effective in preventing liver disorders and colon cancer caused by methyl hydrazine (Gorzo et al., 2007; Imai et al., 1994).

CONCLUSION

Garlic is a plant used worldwide for the prevention and treatment of various diseases including nutrition and cancer. Due to the negative taste and smell of garlic, its consumption by consumers is quite limited. For these reasons, various techniques such as heat treatment and fermentation have been used to eliminate these negativities of garlic and to increase its flavor, nutritional value and product variety. All changes that occur in the production process of black garlic depend on the applied heat treatment and the humidity of the environment. No specific method is standardized in the production of black garlic, and the processing conditions vary depending on the desired properties in the final product. The type of fresh garlic used as raw material, the growth conditions and the climate in which it is located will also differ in the final product produced. During the production of black garlic, the color darkens, pH and water activity values decrease, while dry matter, antioxidants, phenolic compounds, sulfur compounds such as S-allyl cysteine, Maillard reaction products and reducing sugar content increase. The fact that the production of black garlic takes between 25-40 days requires a lot of energy and causes loss of time, and the fact that the studies on this product are still insufficient with the efficiency of its production shows the importance of focusing on innovative studies on the development of its bioactive properties.

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