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Drying Process of Garlic and Allicin Potential-A Review

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ABSTRACT

To obtain dehydrated garlic in high quality, the drying process should allow effective retention of flavor, color, appearance, taste, and nutritive value, comparable to a fresh one. Garlic is a precious product among agricultural products and contains several bioactive compounds that present antioxidant, anti-inflammatory, antibacterial, antifungal, immunomodulatory, antidiabetic, anticancer, hepatoprotective, digestive system protective, anti-obesity, and cardiovascular protective properties. Therefore, choosing the right method of drying garlic is of important significance to maintain its post-harvest processing. In this review, the drying processes of garlic were evaluated and allicin potential in garlic was highlighted. In this context, the freeze-drying method is better in terms of allicin potential in the drying process of garlic.

Keywords: *Garlic, allicin potential, drying method, postharvest processing*

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1. INTRODUCTION

The botanical name of garlic which is one of the members of the lily family is *Allium sativum*. Block, (1985) reported that garlic is one of the oldest plants cultivated and its origin has been based on most likely central Asia. Garlic has been used as a folk medicine plant for thousands of years, besides being edible food (Corzo-Martinez et al, 2007; Block, 1985). Even today, to treat a variety of diseases, garlic is continued to make use of folk medicine over all the world (Ali et al., 2000). Beneficial effects of garlic on health are associated with phenolic components, especially flavonoids, and several organosulfur compounds (Fredotović ve ark. 2017). Moreover, according to Martins et al., (2016); Alorainy, (2011), Banerjee, et al., (2003), Borlinghaus, et al., (2014), Capasso, (2013), Chen et al., (2013), Harris, et al., (2001), Higuchi, et al., (2003), Khanum, et al., (2004), Kopec, et al., (2013), Kumar et al., (2013), and Lanzotti et al., (2014) reported that bioactive components in garlic are liable for medicinal properties of garlic.

When evaluated physical properties of garlic, the diameter of whole garlic (mm), the weight of whole garlic (g), segment number of whole garlic, length of garlic cloves (mm), the width of garlic cloves (mm), the thickness of garlic cloves (mm), the mass of garlic cloves (g), the geometric mean diameter of garlic cloves (mm), sphericity of garlic cloves, the projected area of whole garlic (cm^2), volume of whole garlic (mm^3), bulk density of whole garlic (kg m^{-3}), segment density of whole garlic (kg m^{-3}), the porosity of whole garlic (%), the terminal velocity of whole garlic (m s^{-1}), hardness of whole garlic (N), and 1000 segment mass (g) were 46.51, 32.81, 17.56, 27.24, 14.46, 9.25, 2.25, 15.15, 0.559, 4.54, 2245.64, 478.75, 1054, 54.16, 7.24, 13.78, and 2383.8, respectively at 66.32 % d.b. of moisture content. Also, values for static and dynamic coefficients were found to be 0.416–0.352, 0.472–0.406, and 0.541–0.481 on galvanized, iron, and plywood surfaces, respectively. (Haciseferogullari et al., 2005). Results of some physical properties of garlic determined by Bahnasawy, (2007) and Rahman et al., (2009) were similar to that of Haciseferogullari et al., (2005).

On the other hand, potential active chemical constituents of garlic as follows: sulfur compounds (aliin, allicin, ajoene, allyl propyl disulfide, diallyl trisulfide, s-allyl cysteine, vinyldithiines, S-allylmercaptocystein, and others), enzymes (allinase, peroxidases, myrosinase, and others), amino acids and their glycosides (arginine and others), and selenium, germanium, tellurium, and other trace minerals (Kemper, 2000). Garlic also contains the other compounds having a bioactive property such as phenolic compounds, saponins, sapogenins, flavanoids. More than 20 phenolic compounds such as β-resorcylic acid, pyrogallol, gallic acid, rutin, protocatechuic acid, and quercetin are contained in garlic (Nagella et al., 2014, Shang et al., 2019). Moreover, the presence of fructose, glucose, and galactose in garlic was stated by Hang, (2005), Shang, et al., (2019).

According to previous researches, bioactive components in garlic changed during post-harvest processing. In this context, Liang et al., (2015) reported that when raw garlic was subjected to the thermal process to obtain black garlic, thirty-eight components investigated showed variability. Besides, saccharide content in black garlic was different than in fresh garlic because of polysaccharide degradation (Lu et al., 2018). Contents of polyphenols and total flavonoids in black garlic enhanced depending on increasing temperature and decreasing humidity (Kim et al., 2013).

One of the post-harvest processes, which agricultural products are subjected to the thermal process is the drying process as well. Likewise, the preservation of fruits and vegetables by the drying process can prevent both the huge wastage and make them available in offseason. Because agricultural products are highly seasonal and therefore they are available in plenty in particular times of the year.

To obtain far better results in terms of quality of the dried product, researchers have been working on different drying methods such as microwave drying, infrared drying, microwave-assisted hot air drying, microwave vacuum drying, especially in the last decades. The fundamental aim of the drying process is to reduce the moisture content of the product to delay adverse biological, chemical, and enzymatic processes. Major issues during the drying process is a substantial loss of color, appearance, flavor, taste, and chemical components. The objective of this study is to evaluate how different methods of drying affected the quality of garlic, besides allicin potential in garlic.

2. ALLICIN IN GARLIC

Garlic ranks the first among agricultural products such as onions, broccoli, cauliflower, turnip in terms of organosulfur compounds (Holub et al., 2002, Prati et al., 2014). The characteristic odor of garlic and its most biological activities are due to organosulfur compounds which it has (Diretto et al., 2017). Intact garlic contains two main classes of organosulfur compounds named as alk(en)yl cysteine sulfoxides (ACSOs) and γ-glutamyl-L-cysteine peptides, which they have neither possess pungent odor nor biological activities (Higdon, 2008).

Intact garlic does not contain thiosulfinates (TSs) in its nature until garlic tissues are mechanically damaged (Mansor et al., 2016). When garlic tissues are disrupted, organosulfur compounds especially cysteine sulfoxides and γ-glutamyl-L-cysteines convert into TSs by enzymatic hydrolysis (Ilic et al. 2011; Mansor et al., 2016; Ramirez et al., 2017). In this context, S-allyl-L-cysteine sulfoxide (ACSO) stored in the cytoplasm, which is a dominant compound with approximately 80% in cysteine sulfoxides is converted to pyruvic acid, ammonia and alk(en)yl sulfenic acid by alliinase located in the vacuoles (Higdon, 2008; Mansor et al., 2016; Yamaguchi and Kumagai, 2020). Following this process, sulfenic acid will undergo rapid condensation to form thiosulfinates, RS(O)-S-R1 (Mansor et al., 2016). Allicin occurred in the highest amount among the thiosulfinates formed with 70-80% of the total of TSs and responsible for typical garlic odor, besides many different biological activities (Block et al. 1985; Ellmore and Feldberg, 1994; Borlinghaus et al., 2014; Ramirez et al., 2017).

Allicin which gives characteristic odor to garlic, as indicated above, is bright yellow and an oily liquid (Ilic et al. 2011). Also, it is a remarkable organosulfur compound considered a quality indicator of commercial garlic. Likewise, British pharmacopeia (1998) indicated that to ensure the pharmaceutical and economical viability of garlic powder products, allicin content should be at least 4.5 mg g^{-1} (Baghalian et al., 2005). It has been stated by Iberl et al. (1990) that preservation of allicin is complicated owing to its unstable and thermo-labile compound, therefore its decomposition to other organosulfur compounds occurs readily even at room temperature (Ilic et al. 2011; Aware and Thorat, 2011).

In a research carried out by Prati et al., (2014), allicin potential of fresh garlic varieties determined ranged from 20.79 to 24.31 mg g^{-1} d.b. However, Ribak et al., (2004) obtained lower values as compared to Prati et al., (2014) since they used different methods to determine allicin potential. In previous researches, allicin values of fresh garlic varieties were also stated to be 9.69 mg g^{-1} w.b. and 24.84 mg g^{-1} d.b. (Rahman et. al., 2009; Aware and Thorat, 2011). A similar result for allicin potential in fresh garlic was published by Ratti et al., (2007). Based on allicin values mentioned above, it may be concluded that the potential of allicin may differ depending on garlic variety and growing conditions.

Garlic in fresh form is widely consumed and allicin which is the main compound in fresh garlic is considered its predominant bioactive compound. However, there are currently many garlic-based products on the market, which they are needed to be dried such as garlic powder and dried garlic slices (Tsai et al., 2012; Calín-Sánchez et al., 2014). As mentioned above, since the allicin compound is quite responsive to temperature, choosing the right method of drying is of important significance.

3. DRYING PROCESS OF GARLIC

A common method used to dry garlic has been the convective hot air-drying process (Ratti et al., 2007). Moreover, garlic drying studies using different drying methods such as microwave drying, freeze-drying, infrared drying are also available in the literature. In hot air drying, heat applied reaches the outer layer of the product by convection and heats it, the remainder of the product is heated by conduction as well. Moisture starts to be removed from the surface of the product, thus a moisture gradient which is the main mechanism of outward liquid flow occurs (Bouraou et al., 1994). Bouraou et al., (1994) also presented the report of Fellow, (1988) as follows: the most important disadvantages of hot air drying are long drying durations, damage to sensory characteristics and nutritional properties of products, oxidation of pigments and vitamins by hot air, and solutes migration from the interior of the product to the surface. On the other hand, a very rapid drying without overheating atmosphere or surface is obtained by microwave heating. Microwave heating prevents case hardening since little solute migration in the liquid phase occurs. Mechanisms of dipole rotation and ionic polarization are governed during microwave heating of dielectric materials. When a wet solid is subjected to microwave heating, its temperature may reach the boiling point of the liquid. Vapor generated owing to internal evaporation of moisture causes a gas pressure gradient that can rapidly expel the moisture from the interior of the solid (Metaxas and Meredith, 1983; Knutson et al. 1987; Bouraou et al., 1994). Freeze drying is another drying method and involves stages of freezing of product, reducing pressure, and then removing frozen water in the product through sublimation. Compared to the other techniques, existing properties of the product such as appearance, shape, taste, color, flavor, texture, biological activity are preserved more and high rehydration capacity of the freeze-dried product is obtained. However, a major issue with the freeze-drying process is drying duration (Hammami and Rene, 1997). In the infrared drying process, infrared wavelength radiation from a source interacts with the internal structure of the product, thus the temperature of product increases and evaporation of moisture content of the product is contributed (Celma et al., 2008). The infrared drying process has some advantages as compared to convective drying. Those advantages were stated as follows: responsible quality of the final dried product, coefficients of heat transfer are high, the process time is short and the cost of energy is low (Nowak and Lewicki, 2004; Riadh et al., 2015). Besides, interest in hybrid drying methods has increased in recent years to enhance the quality of the dried product.

In a research carried out on drying of garlic, since part of alliinase, which is responsible for the production of allicin would be inactive at high temperatures during the drying process, presence of allicin decreased with increasing drying temperature (Cui et al., 2003; Rahman et. al., 2009). Garlic samples dried at 60 °C and higher through hot air dryer statistically caused an increase in allicin potential loss as compared to the sample dried at 50 °C. The values of allicin obtained from garlic sliced 5 mm thick at 50 °C, 60 °C, 80 °C, and 90 °C of drying temperature through hot air dryer were 4.932 mg g^{-1} w.b., 4.731 mg g^{-1} w.b., 3.808 mg g^{-1} w.b., and 3.845 mg g^{-1} w.b., respectively. The other dryer methods named vacuum oven and nitrogen atmosphere gave more or less similar results with a hot air drying method in terms of allicin potential. Effect of slice thickness on the loss of allicin potential in garlic by hot air dryer at 60 °C statistically was significant as well (Rahman et. al., 2009). Another study emphasized that the values of allicin in garlic samples dried which were in 1 mm thick through hot air dryer at 40 °C, 50 °C, and 60 °C were 20.625 mg g^{-1} d.b., 20.283 mg g^{-1} d.b., and 15.928 mg g^{-1} d.b., respectively. In addition to the hot air drying method, researchers had also investigated the other drying methods to compare drying kinetics, allicin content, and color analysis in dried garlic. Those methods were heated pump dryer, hot air dryer, solar cabinet dryer, infrared dryer, vacuum dryer, freeze dryer, and fluidized bed dryer. They reported that drying processes through heat pump dryer, vacuum dryer, freeze dryer, and heat pump cum fluidized bed dryer showed lesser color change and excellent allicin retention compared to the other methods (Aware and Thorat, 2011). In research carried out by Ratti et al., (2007), the effect of hot air drying and freeze-drying processes on allicin content in garlic was investigated. According to the authors' report, the maximum allicin retention was obtained through the freeze-drying process at 20 °C in whole cloves and however higher drying temperatures might cause allicin loss in garlic. To measure and model changes in garlic flavor during dehydration as a function of temperature, research was carried out by Pezzutti and Crapiste, (1997). It was stated in this research that partial inactivation of alliinase enzyme during drying could be attributed to the loss of pyruvic acid. Pyruvic acid is a result of alliin-alliinase reaction; therefore, the loss of allicin potential could be explained similarly. Lilia et al., (2017) who carried out drying of garlic using a hot air dryer at 50 °C and 60 °C of drying temperatures stated that 60 °C of drying temperature could induce more rapid shrinkage and dense structures and partially inactivate the enzyme alliinase.

On the other hand, dried garlic cloves were lighter in color when dried by a combined microwave-hot air-drying process as compared to the hot air drying process. It was found that with an increase in air temperature, color became darker implying that more browning of the cloves occurred. The microwave-assisted hot air drying process contained more compounds that were responsible for flavor as compared to the hot air drying process. Therefore, microwave-assisted hot air drying process gave superior quality dehydrated garlic cloves (Sharma and Prasad, 2001). Shade, solar, oven, and microwave drying methods were used to dry garlic. Proximate composition and mineral content ranged from 0.78% to 8.87% and from 0.29 to 86.50 mg/100g, respectively depending on the drying method. Although polyphenol content was almost similar in all dried garlic powders, β-carotene and ascorbic acid contents were at the maximum level for shade-dried garlic powders i.e. 0.69 and 5.39 mg/100 g, respectively (Sangwan et al., 2010). Calin-Sanchez et al., (2013) studied on garlic drying process to investigate drying kinetics, energy consumption, and quality properties. In this context, garlic slices were dehydrated by convective drying (CD) and by a combined method consisting of convective pre-drying (CPD) followed by vacuum-microwave finishing drying (VMFD). Total antioxidant capacity generally was higher in dried garlic whereas the potential of total phenolic compounds presented the opposite trend. Also, the combined CPD-VMFD drying method gave brighter samples with color. In research, the sample was exposed to microwave-vacuum drying until %10 w.b. of moisture content reached, and then continued to be exposed to hot-air drying at 45 °C of temperature to a final moisture content less than %5 w.b. Quality of garlic slices dried by the combination of microwave-vacuum drying and air drying was close to that of freeze-dried product. However, it was much better than that dehydrated by conventional hot-air drying. That microwave-vacuum+air drying was a better way for drying garlic slices and other vegetables were reported (Cui et al., 2003). The research investigated the effects of the drying process on allicin-forming potential. In this context, the kinetics of enzymatic activity loss during drying by temperature cycling or by constant temperature were evaluated and compared. Protection of the enzymatic activity under conditions of cyclical occurred mainly with exposure to low temperatures for drying periods longer than those of constant drying conditions (Lagunas and Castaigne, 2008).

4. CONCLUSION

The major quality problem faced in the garlic drying process is the loss of nutritional properties of the dried garlic. To obtain product dried in high quality, the drying process should allow effective retention of quality comparable to fresh vegetables. In the case of garlic, quality properties should consider in drying processes, allicin potential especially. Also, further research is needed to be done to preserve the potential of allicin in drying processes.

REFERENCES

1. Ali M., Thomson M., & Afzal M., (2000). Garlic and onions: their effect on eicosanoid metabolism and its clinical relevance. *Prostaglandins, Leukotrienes, and Essential Fatty Acids, 62*(2), 55–73.
2. Alorainy M.S., (2011). Evaluation of antimicrobial activity of garlic (Allium sativum) against E. coli O 157:H 7. *Journal of Agriculture and Veterinary Science*, 4, 149–157.
3. Aware R.S., & Throat B.N., (2011). Garlic under various drying study and ıts ımpact on allicin retention. Drying Technology, 29, 1510–1518.
4. Baghalian K., Ziai S.A., Naghavi M.R. Badi H.N., & Khalighi A., (2005). Evaluation of allicin content and botanical traits in Iranian garlic (Allium sativum L.) ecotypes. *Scientia Horticulturae 103* (2005) 155–166.
5. Bahnasawy A.H., (2007). Some physical and mechanical properties of garlic. *International Journal of Food Engineering, 3*(6), Article 7.
6. Banerjee S.K., Mukherjee P.K., & Maulik S.K., (2003). Garlic as an antioxidant: The good, the bad, and the ugly. *Phytotherapy Research*, 17, 97–106.
7. Block E., (1985). The chemistry of garlic and onions. *Scientific American*, 3, 94-103.
8. Borlinghaus J., Albrecht F., Gruhlke M.C.H., Nwachukwu I.D., & Slusarenko A.J., (2014). Allicin: Chemistry and biological properties. *Molecules,* 19, 12591–12618.
9. Bouraoui M., Richard P., & Durance T., (1994). Microwave and convective drying of potato slices. *Journal of Food Process Engineering*, 17, 353-363.
10. Calín-Sánchez A., Figiel A., Wojdylo A., Szarycz M., & Carbonell-Barrachina A.A., (2014). Drying of garlic slices using convective pre-drying and vacuum-microwave finishing drying: kinetics, energy consumption, and quality studies. *Food Bioprocess Technology,* 7, 398–408.
11. Capasso A., (2013). Antioxidant action and therapeutic efficacy of Allium sativum L.. *Molecules*, 18, 690–700.
12. Celma A.R., Rojas S., & Rodriguez F.L., (2008). Mathematical modeling of thin-layer infrared drying of wet olive husk. *Chemical Engineering and Processing* 47, 1810–1818.
13. Chen S., Shen X., Cheng S., Li P., Du J., Chang Y., & Meng H., (2013). Evaluation of garlic cultivars for polyphenolic content and antioxidant properties. *PLoS ONE,* 8, e79730.
14. Corzo-Martinez M., Corzo N., & Villamiel M., (2007). Biological properties of onions and garlic. *Trends in Food Science & Technology 18* (2007) 609-625.
15. Cui Z.W., Xu S.Y., & Sun D.W., (2003). Dehydration of garlic slices by combined microwave-vacuum and air drying. *Drying Technology, 21*(7), 1173–1184.
16. Diretto G., Rubio-Moraga A., Argandona J., Castillo P., Gomez-Gomez L., & Ahrazem O., (2017). Tissue-specific accumulation of sulfur compounds and saponins in different parts of garlic cloves from purple and white ecotypes. *Molecules*, 22, 1359.
17. Ellmore G.S., & Feldberg R.S., (1994). Alliin lyase localization in bundle sheaths of the garlic clove (Allium Satıvum). *American Journal of Botany 81*(1): 89-94.
18. Fellows P., (1988). Dehydration in food processing technology. Ellis Horwood Ltd., Chichester, England, pp: 281-311.
19. Fredotovic Z., Sprung M., Soldo B., Ljubenko I., Budic-Leto I., Bilusic T., Cikes-Culic V., & Puizina J., (2017). Chemical composition and biological activity of Allium cepa L. and Allium × cornutum (Clementi ex Visiani 1842) methanolic extracts. *Molecules, 22*(3), 381.
20. Haciseferogullari H., Ozcan M., Demir F., & Calisir S., (2005). Some nutritional and technological properties of garlic (Allium sativum L.). *Journal of Food Engineering* 68, 463–469.
21. Hammami C., & Rene F., (1997). Determination of freeze-drying process variables for strawberries. *Journal of Food Engineering*, 32, 133-154.
22. Hang X., (2005). Isolation and identification of garlic polysaccharide. *Food Sci*., 26, 48–51.
23. Harris J. C., Cottrell S. L., Plummer S., & Lloyd D., (2001). Antimicrobial properties of Allium sativum (garlic). *Applied Microbiology and Biotechnology*, 57, 282–286.
24. Higdon J., (2008). Garlic and Organosulfur Compounds. Ed. Victoria J. Drake and Larry D. Lawson. Linus Pauling Institute. OSU, July 2008.
25. Higuchi O., Tateshita K., & Nishimura H., (2003). Antioxidative activity of sulfur-containing compounds in Allium species for human low-density lipoprotein (LDL) oxidation in vitro. *Journal of Agricultural and Food Chemistry*, 51, 7208–7214.
26. Holub B.J., Arnott K., Davis J.P., Nagpurkar A., & Peschell J., (2002). Organosulfur compounds from garlic. In J. Shi, G. Mazza & M. L. Maguer (Eds.). Functional foods: biochemical and processing aspects (cap. 2, pp. 213-279). Washington: CRC Press.
27. Ilic D.P., Nikolic V.S., Nikolic L.B., Stankovic M.Z., Stanojevic L.P., & Cakic M.D., (2011). Allicin and related compounds: biosynthesis, synthesis, and pharmacological activity. Facta Universitatis Series: Physics, *Chemistry, and Technology, 9*(1), 9 – 20.
28. Kemper K.J., (2000). Garlic. The Longwood Herbal Task Force, 1-49.
29. Khanum F., Anilakumar K.R., & Viswanathan K.R., (2004). Anticarcinogenic properties of garlic: A review. *Critical Reviews in Food Science and Nutrition*, 44, 479–488.
30. Kim J.S., Kang O.J., & Gweon O.C., (2013). Comparison of phenolic acids and flavonoids in black garlic at different thermal processing steps. *Journal of Functional Foods*, 5, 80–86.
31. Knutson K.M., Marth E.H., & Wagner M.K., (1987). Microwave heating of food. Lebensm. *Wiss. Technol.* 20, 101-110.
32. Kopec A., Piatkowska E., Leszczynska T., & Elzbieta S., (2013). Healthy properties of garlic. *Current Nutrition and Food Science*, 9, 59–64.
33. Kumar R., Chhatwal S., Arora S., Sharma S., Singh J., Singh N., & Khurana A., (2013). Antihyperglycemic, antihyperlipidemic, anti-inflammatory, and adenosine deaminase-lowering effects of garlic in patients with type 2 diabetes mellitus with obesity. *Diabetes, Metabolic Syndrome, and Obesity: Targets and Therapy*, 6, 49–56.
34. Lagunas L.L.M., & Castaigne F., (2008). Effect of temperature cycling on allinase activity in garlic. *Food Chemistry*, 111, 56–60.

35. Lanzotti V., Scala F., & Bonanomi G., (2014). Compounds from Allium species with cytotoxic and antimicrobial activity. *Phytochemistry Reviews*, 13, 769–791.
36. Liang T., Wei F., Lu Y., Kodani Y., Nakada M., Miyakawa T., & Tanokura M., (2015). Comprehensive NMR analysis of compositional changes of black garlic during thermal processing. *J. Agric. Food Chem*., 63, 683−691.
37. Lilia M.L., Juan R.R., David R.V., & Anabel L.O., (2017). Changes in physical properties and relations with allicin degradation during convective drying of garlic. *Journal of Food Measurement and Characterization*, 11, 1227-1232.
38. Lu X., Li N., Qiao X., Qiu Z., & Liu P., (2018). Effects of thermal treatment on polysaccharide degradation during black garlic processing. *LWT-Food Science and Technology*, 95, 223-229.
39. Mansor N., Herng H.J., Samsudin S.J., Sufian S., & Uemura Y., (2016). Quantification and characterization of allicin in garlic extract. *Journal of Medical and Bioengineering* Vol. 5, No. 1.
40. Martins N., Petropoulos S., & Ferreira I.C.F.R., (2016). Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by pre- and post-harvest conditions: A review. *Food Chemistry*, 211, 41-50.
41. Metaxas A.C., & Meredith R.J., (1983). *Theoretical aspects of volumetric heating. In Industrial Microwave Heating*. Peter Peregrinus Ltd., London, UK, pp. 70-103.
42. Nagella P., Thiruvengadam M., Ahmad A., Yoon J.Y., & Chung I.M., (2014). Composition of polyphenols and antioxidant activity of garlic bulbs collected from different locations of Korea. *Asian J. Chem*., 26, 897−902.
43. Nowak D., & Lewicki P.P., (2004). Infrared drying of apple slices. *Innovative Food Science and Emerging Technologies* 5, 353– 360.
44. Pezzutti A., & Crapiste G.H., (1997). Sorptional equilibrium and drying characteristics of garlic. *Journal of Food Engineering*, 31, 113-123.
45. Prati P., Henrique C.M., Sonia de Souza A., Nunes da Silva V.S., & Pacheco M.T.B., (2014). Evaluation of allicin stability in processed garlic of different cultivars. *Food Science and Technology, 34*(3): 623-628.
46. Rahman M.S., Al-Shamsi Q.H., Bengtsson G.B., Sablani S.S., & Al-Alawi1 A., (2009). Drying kinetics and allicin potential in garlic slices during different methods of drying. *Drying Technology*, 27, 467–477.
47. Ramirez D.A., Locatelli D.A., Gonzalez R.E., Cavagnaro P.F., & Camargo A.B., (2017). Analytical methods for bioactive sulfur compounds in Allium: An integrated review and future directions. *Journal of Food Composition and Analysis*, 61, 4–19.
48. Ratti C., Araya-Farias, M., Mendez-Lagunas L., & Makhlouf J., (2007). Drying of garlic (Allium sativum) and its effect on allicin retention. *Drying Technology,* 25: 349–356,
49. Riadh, M.H., Ahmad, S.A.B., Marhaban, M.H., & Soh A.C., (2015). Infrared heating in food drying: an overview. *Drying Technology*, 33, 322–335.
50. Ribak M.E., Calvey E.M., & Harnly J. M. (2004). Quantitative determination of allicin in garlic: supercritical fluid extraction and standard addition of allin. *Journal of Agricultural and Food Chemistry, 52*(4), 682-687.
51. Sangwan A., Kawatra A., & Sehgal S., (2010). Chemical composition of garlic powder using different drying methods. *Asian Journal of Home Science, 5*(1), 90-93.
52. Shang A., Cao S.Y., Xu X.Y., Gan R.Y., Tang G.T., Corke H., Mavumengwana V., & Li H.B., (2019). Bioactive compounds and biological functions of garlic (Allium sativum L.). *Foods*, 8, 246.
53. Sharma G.P., & Prasad S., (2001). Drying garlic (Allium Sativum) cloves by microwave-hot air combination. *Journal of Food Engineering,* 50, 99-105.
54. Tsai C.W., Chen H.W., Sheen L.Y., & Lii C.K., (2012). Garlic: Health benefits and actions. *BioMedicine* 2, 17-29.
55. Yamaguchi Y., & Kumagai H., (2020). Characteristics, biosynthesis, decomposition, metabolism, and functions of the garlic odor precursor, S‑allyl‑l‑cysteine sulfoxide (Review). *Experimental And Therapeutic Medicine* 19, 1528-1535.