Effects of drying methods on the composition of volatile compounds in fruits and vegetables

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Abstract

The mixtures of different volatile and non-volatile compounds create the unique aroma and taste of foods. Aroma, derived from combinations of volatile components, is essential for determining the quality of foods. Aroma profile of dried foods may be affected by loss, destruction, change or improvement of unexpected flavours during drying processes. The Maillard reaction and autoxidation are the main chemical reactions responsible for the formation of new compounds during drying. These reactions have considerable effects on the flavour of dried fruit and vegetables. The Maillard reaction derived compounds are classified in three groups which are sugar dehydration/fragmentation products (furans, pyrones, cyclopentenes, carbonyl compounds and acids), amino acid degradation products (aldehydes, sulphur compounds and nitrogen compounds) and volatiles produced by further interactions (pyrroles, pyridines, pyrazines, imidazoles, oxazoles, thiazoles and thiophene). Some of the flavour compounds (aldehydes and esters) might be formed through lipid oxidation or biosynthesis of alcohols and acids. The concentration of volatile compounds and activity of volatile forming enzymes are affected by drying methods and conditions. Besides that, loss of the precursors may also cause the loss of volatile compounds after drying. Conventional drying techniques adversely affect colour, aroma and flavour due to increased temperature and long exposure to heat and oxygen. On account of the negative effects of conventional drying processes, freeze drying and vacuum drying have been alternatively used in recent years. These technologies are expensive and time consuming; even they preserve flavour better than conventional drying. This review highlights the effects of drying methods on the volatile compounds of fruits and vegetables.

Introduction

Fruits and vegetables are readily perishable foods because of their high moisture content [1]. Drying of fruits and vegetables are important in preserving food quality, forming suitable option for economic postharvest management, increasing food safety and shelf-life. In the drying process, water is removed to slow down or stop the existent chemical reactions, in addition to inhibit growth of spoilage microorganisms [2]. However, drying leads to loss and change in volatiles (e.g. stripping process, oxidation and thermal degradation), formation of new volatile compounds (e.g. enzymatic reactions, Maillard reaction and lipid oxidation), and negative impact on colour, texture and nutritional value [3, 4, 5].

Different drying methods are commercially utilized to remove moisture from fruits and vegetables. These methods are basically divided into three subgroups; solar drying, atmospheric drying (e.g., tunnel, cabinet, fluidized bed, spray and microwave drying) and sub atmospheric drying (e.g. vacuum and freeze drying) [6]. In order to maintain the characteristic aroma of fruits and vegetables during drying, novel or improved drying methods have been developed [3]. Therefore, this study is aimed to collect recent information on volatile flavour compounds of dried fruits and vegetables.

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Drying methods

Sun and solar drying: In sun drying, sunshine is used to dehydrate fruits and vegetables which are spread out under the sun and dried. It is widely used in tropical and semitropical countries due to its low cost by using free renewable energy source, whereas there are adverse effects of this method such as inapplicability in all seasons and hygiene problems [6]. The different solar drying methods use equipment to gather sunrays in a unit. Compared to sun drying, the temperature in solar unit is usually 20-30°C higher. The handicap of these methods is that fruits and vegetables that are dried outdoors must be covered during cool nights because air condenses and can moisturize foods back [2].

Conventional drying: Drying times in conventional driers change remarkably, depending on room temperature, humidity, the amount of food and its moisture content. Air temperature and circulation are important aspects which should be controlled during drying. When the temperature is too low, the food will dry slowly and microbial growth may occur, but if the temperature is too high, a hard shell can develop and the inside of product remains wet [2].

Tunnel dryers: The tunnel driers consist of fans, heaters and wagons in which products are carried. During drying the wagons are moved in the tunnel. Tunnel dryers decrease the drying time and enable closer control of moisture content [7, 8, 9].

Drum dryers: Drum dryers consist of a cylinder which is heated on the inside and turns continuously. During drying, the product is carried out in a thin film on the outside of the drum and dries quickly. After every rotation, the dry solid is scraped off the roll, which is revolving slowly. This method is convenient for highly or low viscous foods [10].

Spray drying: Spray dryers are used to remove moisture from foods especially those in puree or liquid forms. In this method, atomization and evaporation of water are carried out when the dispersed / sprayed material passes through the drying chamber. Higher drying rates, low energy consumption, preservation of food quality and prevention of oxidation are the main advantages of spray drying [2, 10].

Freeze drying: Freeze drying technique uses extreme cold temperatures as low as -50°C in a wide variety of products [11]. In regards to low processing temperatures applied in this method, thermal degradation reactions are excluded, high aroma retention and high quality product is attainable with excellent rehydration properties [12].

Microwave drying: Microwave drying is an another alternative method with various advantages like providing higher drying rate, shorter drying time, homogeneous energy delivery on the material and better process control [13, 14, 15, 16].

Vacuum drying: Vacuum drying is used under reduced pressure, which enables food to be dried at lower temperatures. With this method, oxidation reactions are inhibited due to the absence of air while the flavour, colour and texture of the dried foods are maintained [10, 17].

The volatile flavour compounds of dried fruits and vegetables

More than a few hundred volatile compounds are present in fruits and vegetables. Many vegetables contain aroma compounds such as allicin in garlic [18] terpenes, sesquiterpenes, styrene, alkanes and a few alcohols in carrots [1], sulphur compounds, alcohols and esters in shiitake mushrooms [19] and sesquiterpene lactones in chicory and lettuce [20, 21]. Moreover, citrus fruits such as lemon and orange are abundant in terpenoids, while aroma compounds of the other non-citrus fruits such as banana, apple, apricot and cranberry are described by esters and aldehydes [22]. These volatile compounds may change, be lost or form new compounds during drying with some reactions such as stripping process, oxidation, thermal degradation, enzymatic and non-enzymatic reactions.

Nunes et al. [23] reported that among thirty-one volatile compounds of fresh guava fruit, terpenes were predominant even after oven (55°C, 22 h) and freeze drying (50°C, 0.025 mbar, 48 h) processes. However, aldehydes and esters were other main compounds diminished by dehydration of guava fruit.

Allicin, which is the principal volatile of organosulfur compound in garlic, was affected by drying time and temperature when dried convectively at 50 and 60°C, respectively, with airflow of 1.5 m/s. Allicin retention after drying was significantly affected by temperature and variance in the structural properties of garlic. Researchers reported that drying at 60° C lowered loss of allicin content [18].

Rajkumar et al. [1] showed that freeze drying is an extremely useful technique for higher aroma retention in carrots. They also indicated that terpenes had a greater effect in giving aroma to the samples. The key flavour components of fresh carrots were mostly kept during drying.

Narain et al. [24] evaluated the retention of volatile compounds in tomato juice and its products (A: prepared with 5% maltodextrin, B: prepared with 5% tapioca flour) dehydrated by a forced air circulation dryer (temperature: 60°C, relative humidity: 25%, air velocity: 5 m/min). The volatiles, mostly sulphur compounds, were more retained in product A than product B. The concentration of dimethyl sulphide, hydroxymethyl furfural, acetaldehyde, 2-ethyl furan and α-terpineol in tomato powder rose with drying, whereas ethanol and geranyl butanoate decreased during dehydration.

In another study reported by Huang et al. [25], aroma composition of apple slices dried by a combination of freeze drying and microwave-vacuum drying (A) was evaluated and compared with only freeze dried (B) samples. They also indicated that volatile compounds in apple slices were classified as esters (principal compounds in apple), aldehydes, alcohols and acids. From the results of aroma retention between drying methods applied, researchers observed that dried apple slices by B application were retained aroma better than A application.

Shiga et al. [26] studied the influences of spray drying on powdery encapsulation of shiitake flavours. It was reported that flavour retention increased with the rise of drying air temperature and solid content and decreased with the rise of dextrose equivalents of maltodextrin. Lenthionine concentration was increased with heat treatment but other flavours were not affected by heat treatment.

The study of Jeyaprakash et al. [27] was attempted to identify the effects of heat pump dehumidifier dryer on flavour retention of tomato samples and compared with fresh, freeze dried and commercial spray dried samples. The quality parameters were determined as volatile, non-volatile and odour intensity. Heat pump dried tomato showed better retention with regard to volatile and sensory profiles of tomatoes than freeze drying. However, loss of the fresh aroma compounds (*E*)-2-hexenal, 1-penten-3-one, 1-hexanol) and the availability of heat induced compounds (dimethyl sulphide, furfural, pyrrole) were identified in spray dried tomato samples.

Conclusion

Consumers demand processed products, which retain their original properties. During drying, important flavour components could degrade and be lost due to high temperatures and long drying times. Among the drying technologies, freeze drying, vacuum drying and heat pump drying offer great scope for the dried products retaining aroma components.

References

1. Rajkumar, G., Shanmugam, S., Galvao, M.S., Neta, M.T.S.L., Sandes, R.D.D., Mujumdar, A.S., and Narain, N. (2017) Drying Technology 35 (6): 699-708.
2. Nabais, R. (2010) In: Handbook of fruit and vegetable flavors (Hui, Y.H., ed.), John Wiley & Sons, Inc., pp.487-514.
3. Nijhuis, H.H., Torringa, H.M., Muresan, S., Yuksel, D., Leguljt, C., and Kloek, W. (1998) Trends in Food Science & Technology 9:13-20.
4. Phoungchandang, S., and Saentaweesuk, S. (2010) Food and Bioproducts Processing 89 (4): 429-437.
5. Ding, S.H., An, K.J., Zhao, C.P., Li, Y., Guo, Y.H., and Wang, Z.F. (2012) Food and Bioproducts Processing 90: 515-524.
6. Komes, D., and Ganic, K.K. (2010) In: Handbook of fruit and vegetable flavors (Hui, Y.H., ed.), John Wiley & Sons, Inc., pp.487-514.
7. Wrolstad, R.E., Lombard, P.B., and Richardson, D.G. (1991) In quality and preservation of fruits (Eskin, N.A. ed.), Boca Raton, FL: CRC Press, pp. 67-95.
8. Singh, R.P., Heldman, D.R. (2015) Introduction to food engineering. Nobel Publication, Ankara, pp.859.
9. Kutlu, N., İşçi, A., and Şakıyan Demirkol, Ö. (2015) Gıda, 40(1): 39-46.
10. Geankoplis, C.J. (2011) Transport Processes and Unit Operations, Pearson, Turkey, pp. 1052.
11. Nawirska, A., Figiel, A., Kucharska, A. Z., Sokol-Letowska, A., and Biesiada, A. (2009) Journal of Food Engineering 94 (1): 14-20.
12. Coumans, W.J., Kerkhof, P.J.A., Bruin, S. (1994) Drying Technology 12 (1-2): 99-149.
13. Maskan, M. (2000) Journal of Food Engineering 44: 71-78.
14. Zhang, M., Tang, C.J., Mujumdar, A.S., and Wang, S. (2006) Trends Food Sci Technol 17(10): 524-534.
15. Arslan, D., and Ozcan, M.M. (2010) LWT-Food Science and Technology 43: 1121-1127.
16. Incedayı, B., Tamer, C.E., Özcan Sinir, G., Suna, S., and Çopur, Ö.U. (2016) Food Science and Technology: Campinas 36(1): 171-178.
17. Zielinska, M., Zapotoczny, P., Alves-Filho, O., Eikevik, T.M., and Blaszczak, W. (2013) Journal of Food Engineering 115: 347-356.
18. Mendez-Lagunas, L., Rodriguez-Raminez, J., Reyes-Vasquez, D., and Lopez-Ortiz, A. (2017) Food Measure 11: 1127-1232.
19. Tian, Y., Zhao, Y., Huang, J., Zeng, H., and Zheng, B. (2016) Food Chemistry 197: 714-722.
20. Peters, A.M., and Amerongen, A.V. (1998) J Amer Soc Hort Sci 123 (2): 326 – 329.
21. Sessa, R.A., Bennett, M.H., Lewis, M.J., Mansfield, J.W., and Beale, M.H. (2000) The Journal of Biological Chemistry 275: 26877-26884.
22. Venir, E. (2010) In: Handbook of fruit and vegetable flavors (Hui, Y.H., ed.), John Wiley & Sons, Inc., pp.515-529.
23. Nunes, J.C., Lago, M.G., Castelo-Branco, N., Oliveira, F.R., Torres, A.G., Perrone, D., and Monteiro, M. (2016) Food Chemistry 197:881-890.
24. Narain, N., Sousa Galvao, M., Santana, K.L., and Silveira Moreira, J.J. (2010) Drying Technology 28: 232-239.
25. Huang, L., Zhang, M., Wang, L., Mujumdar, A.S., and Sun, D. (2012) LWT-Food Science and Technology 47: 183-188.
26. Shiga, H., Yoshii, H., Ohe, H. Yasuda, M., Furuta, T., Kuwahara, H., Ohkawara, M., and Linko, P. (2004) Bioscience, Biotechnology and Biochemistry 68 (1): 66-71.
27. Jeyaprakash, S., Frank, D.C., and Driscoll, R.H. (2016) Drying Technology 34 (14): 1709-1718.