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Latest Apple Drying Technologies: A Review

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Abstract

Drying is known as one of the oldest preservation methods and can be applicable to many fruits. Sun drying of apple has been known from ancient times. However, this technique is weather-dependent and has contamination problems such as dust, soil, sand particles and insects. Hot air drying of apples has low energy efficiency and requires longer drying period. The desire to eliminate these problems, prevent quality loss, and achieve fast and effective thermal processing has resulted in an increase of researches on other techniques. In recent years, drying technology is being developed and designed to reduce the nutrient loss as much as eliminating the possible any pre-treatment residues. Also, these new methods ensure food safety, increase the quality of dried apples and reduce drying time, risk factors and product losses. In this way, during drying facilities undesirable chemical reactions, microbial growth and mycotoxin formation are eliminated by the new drying technologies. Microwave, osmotic and infrared dehydration, calcium pre-treatment application before irradiation and combined drying methods are the new drying techniques studied in recent years. The aim of this work is to explicate the latest apple drying technologies with their advantages and disadvantages.

Key words: Apple drying, dehydration, microwave drying, osmotic drying, drying pretreatment

Elma Kurutmada Son Teknolojiler Üzerine Bir Derleme

Özet

En eski muhafaza yöntemlerinden birisi olarak bilinen kurutma, birçok meyveye uygulanabilen bir işlemdir. Elmaların güneşte kurutulması çok eski yıllardan beri bilinen bir muhafaza yöntemidir. Ancak bu yöntem toprak, taş, çöp ve böcek başta olmak üzere birçok kontaminasyona neden olabilmektedir. Elmanın sıcak hava ile kurutulması ise düşük enerji verimliliğine ve uzun kurutma süresine sahip olan bir yöntemdir. Günümüzde ise kurutma sırasında elmanın besin öğelerinde gerçekleşecek olası kayıpları en aza indirecek, ön işlem kalıntısı içermeyecek, mikrobiyal gelişim ve mikotoksin oluşumu gibi sağlık risklerini elimine edecek kurutma teknikleri üzerine araştırmalar yürütülmektedir. Mikrodalga, ozmotik ve kızıl ötesi ışınla kurutma, kalsiyum ön işlem uygulaması ve kombine kurutma sistemlerinin kullanılması gibi işlemler elma kurutma süreçlerinde araştırılan yeni teknolojiler arasında bulunmaktadır. Bu araştırmada elma kurutma amacıyla geliştirilen son kurutma teknolojileri üzerine yapılan çalışmalar derlenerek, olumlu ve olumsuz yanları ortaya konacaktır.

Anahtar Kelimeler: Elma kurutma, dehidrasyon, mikrodalga kurutma, ozmotik dehidrasyon, kurutma ön işlemi

INTRODUCTION

The fruits contain a high percentage of their fresh weight as water. Accordingly, they exhibit relatively high metabolic activity. This metabolic activity continues after harvesting, thus making most fruits highly perishable commodities [1]. Drying is a classical method of food preservation and it is a difficult food processing operation mainly due to undesirable changes in quality of dried product [2]. Drying of moist materials is a complicated process involving simultaneous heat and mass transfer [3]. The basic objective in drying agricultural products is the removal of water in the solids up to certain level, at which microbial spoilage and deterioration of chemical reactions are greatly minimized [4]. Water is removed to a final concentration, which assures microbial stability of the product and minimizes chemical and physical changes of the material during storage [1].

Theoretically, the microwave drying technique can reduce drying time and produce a high quality end-product so as to offer a promising alternative and significant contribution to the apple [5]. Also a two-stage drying process involving an initial forced-air convective drying followed by a microwave final drying has been reported to give better product quality with considerable saving in energy and time [6]. Several mathematical modelling and experimental studies have been done about drying characteristics of apple products, such as apple slices [7,8,9,10], apple cylinder [11], and rectangular shaped apple [12].

Numerous publications indicate that drying strongly affects rheological properties of the dried material. Wet materials are viscoelastic, while at low water content they become brittle, hence rheological properties of dried plant tissue are related either to water content or water activity [13, 14, 15]. Pre-drying treatments, subsequent drying and re-hydration perse induce many changes in structure and composition of plant tissue, which result in impaired reconstitution properties. Hence, rehydration can be considered as a measure of the injuries to the material caused by drying and treatments preceding dehydration [16]. The purpose of this work is to explicate the latest apple drying technologies with their advantages and disadvantages.

Latest Apple Drying Techniques

Osmotic dehydration is effective at ambient temperature with minimal damaging effect on food quality, achieving product stability, retention of nutrients and improvement of food flavour and texture. It results also in less discoloration of fruits by enzymatic oxidative browning; it satisfies consumers' demand for minimally processed products while additionally facilitates the industrial processes requiring reduced drying times [17]. However, because it is a time consuming process, supplementary ways to increase the mass transfer are needed without affecting the product quality [18]. Air-drying following osmotic dehydration was proposed for fruits and vegetables by many authors (especially for apples the use of air-drying after osmotic pre-treatment) [19]. Mass transfer during osmosis depends on operating variables such as concentration and solute type of the dehydration solution. Therefore, the solute molecular weight can be a determinant factor influencing solute uptake during osmosis [18]. In recent years there has been increased interest in the investigation of the physical characteristics of fruits, and especially apples, after osmotic pre-treatment and drying.

Osmotic pre-treatment had a beneficial effect on the firmness of the rehydrated apples that had been air-dried at 50^{o}C. In addition, osmotic dehydration before microwave- assisted air-drying increased the final overall quality of the product, but a negative correlation between apple texture and sugar diffusion [20]. Porosity can be related to the degree of water loss and solid gain in osmotic dehydration, to the immersion time during osmosis, to the fruit moisture content or to the microstructure changes of the tissue during drying. Moreover, changes in fruit porosity result in changes of its texture, influencing its firmness [11, 21]

The influence of different osmotic pre-treatments on apple air-drying kinetics and their physical characteristics during drying were investigated in a study. Apple samples were immersed in glucose or sucrose solutions of 30%, 45% (w/w) at different times. Apples osmosed in glucose showed a large moisture decline in the early drying periods and similar drying rates to untreated samples for the same moisture change. Osmosed apples in sucrose showed lower drying rates ascribed to sugars concentration on the outer layers of apple tissue and their crystallization during drying. Samples pre-treated in 45% sugar solutions had greater porosity and better colour retention during drying. In glucose osmosed samples a greater texture hardening rate was observed, in sucrose just the opposite occurred [19].

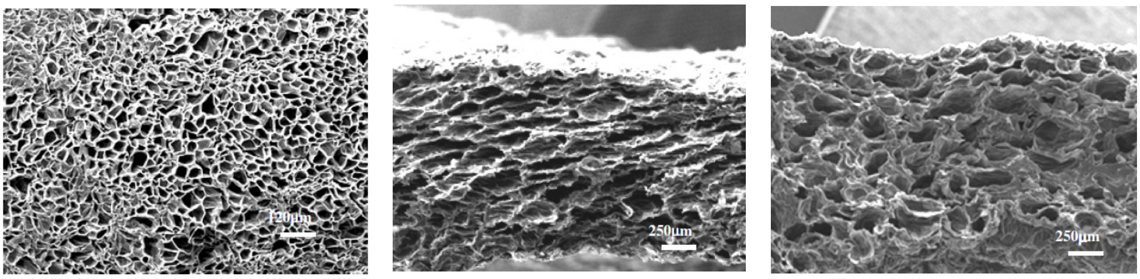
Using an osmotic pre-treatment can prevent bulk density reduction because of less shrinkage occurred during treatment due to solid penetration. Conversely, solid gain can lead to the lack of porosity in products. Using a microwave stage as complementary step after air drying produces more porous samples [22]. However, some researchers mentioned that bulk density was not affected by the process conditions or increased by using a microwave stage [7, 23]. This divergence is due to the sequencing of microwave treatment. When the microwave energy was used as complementary step after air drying, un-removed water is heated suddenly then vapours exits from apple texture. As we observed during heating, samples puffed and gained volume, but after drying, when product was cooled, a small collapse was observed [22].

In a microwave drying system, the microwave energy has an internal heat generative capacity and can easily penetrate the interior layers to directly absorb the moisture in the sample. The quick energy absorption causes rapid evaporation of water, creating an outward flux of rapidly escaping vapour, thus, both thermal gradient and moisture gradient are in the same direction [5].

Microwave drying is one of the emerging food-processing methods when incorporating microwave radiation in a conventional air drying [24]. Microwave drying utilizes very fast nearly instantaneous volumetric heating due to the microwave energy coupling with foods, while conventional drying relies on slow transfer of heat from the surface to the interior of the food, the presence of air at a certain flow in addition to improve the product quality is used to carry away the moisture from the surface of the product [25, 26]. Some researchers reported that using microwave reduces drying time (25-90%) and applying energy at lower level improves quality of final products, such as colour, rehydration capacity, density and porosity [27, 23]

Dehydration of apple cylinders applying microwaves (3 and 10W/g initial incident microwave power) combined with forced air (40^{o}C air temperature) was performed in a study. Experimental results showed the effect of temperature raise on internal evaporation phenomena producing both plasticization of sample matrix and an increase of internal pressure. As a consequence changes in sample temperature and volume, as well as the drying rate and dissipated power showed a common pathway [24].

Using the combined drying method has beneficial effects on structural properties of dried products, comparing to conventional drying. Using microwave heating as final stage of drying may increase the porosity of samples. However, with this combined method can not produce a completely puffed product. So, it will be of advantage to add $CaCl_2$ into the osmotic solution. Its diffusion to the apple tissue can improve the firmness of dried apple and prevent the collapse of tissue during cooling period after microwave treatment [22].



a: Fresh apple tissue (25×) b: Air dried (75ºC) apple tissue (40×) c: Microwave–assisted air dried apple tissue (40×)

Figure 1. Microstructure of fresh, air and microwave dried apple samples

It was observed that using either hot air or combined method (coating, hot air and microwave drying), the porosity of samples can be increased by about 19.38 and 15.38% (according to their coating material starch, pectin and CMC solution (2%w/w) containing $CaCl_2$ (1%w/w)) compared to hot air dried samples. Adding $CaCl_2$ to the coating solution increased the porosity of samples by 18.31%. Investigations by SEM microscopy showed that the starch and pectin coated samples along with $CaCl_2$ exhibited completely porous structures while microwave heating caused some cellular damages. Using hot air drying led to a significant amount of shrinkage [28].

Infrared heating offers many advantages over conventional drying under similar drying conditions. These may include decreased drying time, high energy efficiency, high quality finished products, uniform temperature in the product while drying, and a reduced necessity for air flow across the product [29]. Infrared drying has been investigated as a potential method for obtaining high quality dried foodstuffs, including fruits, vegetables and grains [30, 31]. Infrared drier was tested and compared with the oven-drying technique for the determination of the dry matter % (dm%) of apple (Malus domestica Borkh.) pomace. Lighter apple slices will be obtained by maintaining a low drying air temperature. The suitable drying air temperature was observed in the temperature range of 40–50^{o}C. Higher drying air temperature also resulted in a darker slice. Increase in browning with increasing drying air temperature has been reported from researchers [10, 32]. They show that infrared drying of apple is to be an alternative, giving the same level of accuracy as oven drying but with a much reduced determination time [33]. The effect of infrared drying temperature on drying rates of apple slice almost doubled when the drying temperature was increased from 50 to 80^{o}C [34].

CONCLUSION

Apple is cultivated and consumed fresh or dried all over the world. Also by-products of apple juice processing reaches to enormous amounts. So that, it is very important to define optimal drying conditions to increase the shelf life, and final product quality of dried apples and apple pomace. Unsuitable drying techniques cause losses in apples and product quality. The use of combined drying methods, microwave or infrared dehydration has beneficial effects on quality and structural properties of dried apples in comparison with conventional apple drying techniques. Therefore, apple drying studies should be carried out about the integration of different drying techniques and new pre-treatment facilities and their effects on final product quality should be investigated.

REFERENCES

[1] Atungulu G, Nishiyama Y, Koide S, 2004, Electrode configuration and polarity effects on physiochemical properties of electric field treated apples post harvest, Biosystems Engineering, 87(3):313–323.

[2] Sacilik K, Elicin AK, 2006, The thin layer drying characteristics of organic apple slices, Journal of Food Engineering, 73:281–289.

[3] Yilbas BS, Hüseyin MM, Dincer I, 2003, Heat and moisture diffusion in slab products to convective boundary condition, Heat and Mass Transfer, 39:471–476.

[4] Krokida MK, Marinos-Kouris D, 2003, Rehydration kinetics of dehydrated products, Journal of Food Engineering, 57(1):1–7.

[5] Wang Z, Sun J, Fang Chen, Xiaojun Liao, Xiaosong Hu. 2007. Mathematical modelling on thin layer microwave drying of apple pomace with and without hot air pre-drying Journal of Food Engineering 80 (2007) 536–544

[6] Maskan A, Kaya S, Maskan M, 2002, Hot air and sun drying of grape leather (pestil), Journal of Food Engineering, 54(1):81–88.

[7] Funebo T, Ohlsson T, 1998, Microwave-assisted air dehydration of apple and mushroom, Journal of Food Engineering, 38(3):353–367.

[8] Ramaswamy HS, Nieuwenhuijzen NH, 2002, Evaluation and modeling of two-stage osmo-convective drying of apple slices, Drying Technology, 20(3):651–667.

[9] Wang J, Chao Y, 2002, Drying characteristics of irradiated apple slices, Journal of Food Engineering, 52(1):83–88.

[10] Wang J, Chao Y, 2003, Effect of ^{60}Co irradiation on drying characteristics of apple, Journal of Food Engineering, 56(4):347–351.

[11] Andre´s A, Bilbao C, Fito F, 2004, Drying kinetics of apple cylinders under combined hot air-microwave dehydration, Journal of Food Engineering, 63(1):71–78.

[12] Velic, D., Planinic, M., Tomas, S., & Bilic, M. (2004). Influence of airflow velocity on kinetics of convection apple drying. Journal of Food Engineering, 64(1), 97–102.

[13] Gabas, A. L., Menegalli, F. C., Ferrari, F., & Talis-Romero, J. (2002). Influence of drying conditions on the rheological properties of prunes. Drying Technology, 20(7), 1485–1502.

[14] Krokida, M. K., Karathanos, V. L., & Maroulis, Z. B. (2000). Compression analysis of dehydrated agricultural product. Drying Technology, 18(1–2), 395–408.

[15] Lewick PP, Jakubczyk E. 2004. Effect of hot air temperature on mechanical properties of dried apples Journal of Food Engineering 64 (2004) 307–314.

[16] Sa´inz CB, Andre´s A, Fito P. 2005. Hydration kinetics of dried apple as affected by drying conditions. Journal of Food Engineering 68 (2005) 369–376.

[17] Velic D, Planinic M, Tomas S, Bilic M, 2004, Influence of airflow velocity on kinetics of convection apple drying, Journal of Food Engineering, 64:97–102.

[18] Rastogi, N. K., Raghavarao, K. S. M. S., Niranjan, K., & Knorr, D. (2002). Recent developments in osmotic dehydration: methods to enhance mass transfer. Trends in Food Science & Technology, 13, 48–59.

[19] Mandala IG, Anagnostaras EF, Oikonomou CK. 2005. Influence of osmotic dehydration conditions on apple air-drying kinetics and their quality characteristics, Journal of Food Engineering, 69:307–316.

[20] Prothon, F., Ahrnet, L. M., Funebo, T., Kidman, S., Langton, M., & Sjocholm, I. (2001). Effects of combined osmotic and microwave dehydration of apple on texture, microstructure and dehydration kinetics. Lebensmittel- Wissenschaft- und- Technologie, 34, 95–101.

[21] Nieto, A. B., Salvatori, D. M., Castro, M. A., & Alzamora, S. M. (2004). Structural changes in apple tissue during glucose and sucrose osmotic dehydration: shrinkage, porosity, density and microscopic features. Journal of Food Engineering, 6:269–278.

[22] Askari GR, Emam-Djomeh Z, S. Mohammad Ali Mousavi, 2004, Effect of drying method on microstructural changes of apple slices, *Drying 2004* – Proceedings of the 14th International Drying Symposium (IDS 2004), São Paulo, Brazil, 22-25 August 2004, vol. B, pp. 1435-1441.

[23] Funebo T, Kidman S, Langton M, 2000, Microwave heat treatment of apple before air dehydration effects on physical properties and microstructure, Journal of Food Engineering, 46:173-182.

[24] Sa´inz CB, Andre´s A, Chiralt A, Fito P, 2006, Microwaves phenomena during drying of apple cylinders, Journal of Food Engineering, 74:160–167.

[25] Zhang H, Datta AK, 2001, Electromagnetic of microwave heating: Magnitude and uniformity of energy absorption in an oven, In A. K. Datta & R. C. Anantheswaran (Eds.), Handbook of microwave technology for food applications, (pp. 33–67). New York: Marcel Dekker.

[26] Maskan M, 2001, Drying, shrinkage and rehydration characteristics of kiwifruits during hot air and microwave drying, Journal of Food Engineering, 48:177-182.

[27] Prabhanjan DG, Rammaswamy HS, Raghavan GSV, 1994, Microwave assisted Convective Air Drying of Thin Layer Carrots, Journal of Food Engineering, 25:283-293.

[28] Jomeh ZE, Askari GR, 2004, Air/microwave drying, as against combined method of drying sliced apple, Iranian Journal of Agricultural Sciences, 35(3):785-790.

[29] Sharma GP, Verma RC, Pathare P, 2005, Thin-layer infrared radiation drying of onion slices, Journal of Food Engineering, 67:361–366.

[30] Hebbar HU, Rostagi NK, 2001, Mass transfer during infrared drying of cashew kernel, Journal of Food Engineering, 47:1-5.

[31] Zhu K, Zou J, Chu Z, Li X, 2002, Heatand mass transfer of seed drying in a two pass infrared radiation vibrated bed, Heat Transfer-Asian Research, 31(2):141–147.

[32] Ren G, Chen F, 1998, Drying of American ginseng (Panaxquinquefolium) roots by microwave–hot air combination, Journal of Food Engineering, 35(4):433–443.

[33] Fenton GA, Kennedy MJ, 1998, Rapid dry weight determination of kiwifruit pomace and apple pomace using an infrared drying technique, New Zealand Journal of Crop and Horticultural Science, 26:35–38.

[34] Toğrul H, 2005, Simple modelling of infrared drying of fresh apple slices, Journal of Food Engineering, 71:311-323.