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A review on plum drying

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ABSTRACT

Plum has high consumption rates throughout the world while drying as a common way for increasing its shelf-life is inevitable. But, drying this agricultural product is highly energy-intensive since it has high moisture contents. Hence, any energy saving procedure for drying such an economic product is warmly embraced by plum drying industry. In the present review, based on perusing the plum drying-related papers, it was concluded that the conducted studies on plum drying can be generally categorized in three groups: Plum pre-treatments which highly focus on speeding the rate of drying through application of some mechanical/chemical methods mostly with energy saving perspectives; Mathematical modeling and simulation of plum drying for prognosticating the given process and also the plum drying kinetics. Fortunately, the pre-treatments used were reported to be effective in decreasing the time and the total consumed energy for plum drying.

Contents

1. Introduction

Fruits and vegetables play a very important role in our diet and nutrition and they have been mostly dried as a means of preservation for thousands of years. Hence, dehydration is probably the oldest method of preserving foodstuffs. Amongst different types of fruits, plum is one of the most important products for the drying fruit industry with 2014 production (August–September harvest, Northern hemisphere) of 88,800, 36,000, 1360 and 8700 t in USA, France, Italy and Serbia, respectively and 2015 production (February–March harvest, Southern hemisphere) of 77,000, 35,000, 1000 and 3600 t in Chile, Argentina, South Africa and Australia, respectively [1]. Many studies have been conducted to study the plum drying and its changes during the process. These studies are classified mostly in three following sectors: Treatments/pre-treatments applied to plum prior to drying; Mathematical modeling and simulation of its drying process and studying the kinetics of plum drying. The authors have tried to put these findings together and prepare a review in which the researcher can get a better and sooner picture of the plum drying.

2. Plum drying issues classification

2.1. Pre-treatments

The energy consumed for dehydration of plums constitutes almost a quarter of the total production cost. Hence, to enhance

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the drying rate of plum for reduction of drying time, some physical/chemical pre-treatments have been proposed by researchers. Besides reduction of desiccation time of plum, producing a high quality final-product (with good texture and bright color) is also very significant to the whole process. Considering the two above factors, different studies have been undertaken.

Wax layer on the surface of plums retard the rate of moisture loss and consequently drying. There for, Bain and Mcbean [2] studied the structure of the cuticular wax of prunes and its influence as a water barrier in relation to their drying characteristics. They estimated the amount of removed cuticular wax from 5–6 kg of prunes (250–300 fruits) and also calculated the average surface area of them while wax on the surface of prune was shown by electron microscopy. They mentioned the three following factors as the water loss retarders: the distance through which water must diffuse to the surface to evaporate; the high solid content and the cuticular wax. As an important factor, they mentioned that the lowest melting point of any component of wax is 56 °C. Hence, due to the high initial evaporative cooling at the surface of plums, drying temperatures up to 90 °C can be used in parallel-flow tunnel dryers with less heat damages to the tissues and shorter time period contrary to the counter-flow tunnel dryers through which the temperature of plum surface can reach 65 °C until 10–12 h after the start of drying. Anyway, both tunnel dryers lead to wax melting and it was reiterated that the destruction of the natural barrier is not the only way in which quicker drying of fruit can be achieved since it has been postulated that through dipping in emulsions (as a pre-treatment), through flooding the minute spaces in the wax layer, make the wax hydrophilic instead of being hydrophobic while the original wax structure remained unimpaired [2].

Bain and Mcbean [3] also observed the development of the wax layer or bloom on prune plums throughout the growing season. They reconfirmed the effect of temperature on the wax surface with the same results as their previous research mentioned before while they also studied the effect of sodium hydroxide on the wax layer. Based on their findings, in commercial practices, prunes are sprayed with near boiling 0.2% sodium hydroxide as a pre-treatment before drying causes splitting of the fruit surface, loss of half the wax layer, and decreases drying time by 10%. Examination of their sectioned replicas of fruit taken after dipping in sodium hydroxide showed that the hypodermal cells were severely damaged. They mentioned the loss of structure, together with the one caused by increasing temperature in the drying tunnel in the counter-flow system, must reduce the efficiency of the water barrier considerably, but the rate of diffusion of water through the flesh is the major limiting factor in the dehydration of these fleshy fruit [3].

Weitz et al. [4], analyzed the effect of some surface treatments on prunes under the particular process conditions imposed by the employment of indirect solar tunnel dryer. They programmed their experiments based on two temperature histories according to the data described by Cortes and Piacentini. Through their experiments, they prepared different dipping solutions ([Temperature history No. 1 with Pond's seedling variety: 2% K_2CO_3, 2% olive oil + 2% K_2CO_3 and 2% olive oil + 4% K_2CO_3]; [Temperature history No. 1 with D'Agen variety: 2% olive oil + 2% K_2CO_3, 2% ethyl oleate, 2% methyl oleate and 4% methyl oleate] and [Temperature history NO. 2 with D'Agen variety: 2% methyl oleate + 2% K_2CO_3, 2% olive oil + 2% K_2CO_3, 2% ethyl oleate and 2% methyl oleate]) and to make sure the contact of all the fruit surfaces with the dip chemical, applied a mechanical agitation of the prunes which took 90 s. The drying process of laid prunes in trays continued until reaching moisture content of below 24% (w.b.). They concluded the effectiveness of the olive oil emulsions and the negligible advantage of potassium carbonate dip for Pond's seedling variety and also effectiveness of fatty acid ester dips for D'Agen. The authors also reported that in spite of the smaller reduction in drying time, olive oil emulsion dips were greater commercial interest in their country (Argentina) due to its availability and cost in comparison to methyl oleate or ethyl oleate [4].

Di Matteo et al. [5] studied the effect of superficial abrasion of the plums peel as a physical pre-treatment through using an inert abrasive material to help removing the cuticular waxy layer, surrounding the fruit, being taken into account as the limiting factor for moisture loss. It was also taken into consideration by the researchers to achieve light abrasion (not peel break-ups.) on peel to avoid loss of liquid during drying. Moreover, the researchers also pre-treated the Angeleno cultivar samples of plum chemically through dipping samples into ethyl oleate and eventually compared the results with the untreated ones being used as the reference. The results of their study revealed that the abrasive pre-treatment most considerably reduced the dehydration time and the chemical pre-treatment also seemed effective in reducing the time duration of plum drying in comparison with the reference case [5].

The drying process has undoubtedly effects on quality of fruits and it is a significant objective to have it in such a way that leads to minimization of the adverse effects such as decrease in nutritional value and color changes. Parallel with the above mentioned goal, Cinquanta et al. [6] studied the effect of physical pre-treatment of superficial abrasion of the plums peel and also the chemical one (immersion into alkaline solution) (Part2 of the previous research) on the quality characteristics-skin color, sugars, Phenols etc. – of three plum cultivars namely Stanley, Angeleno and Empress. They found that both physical and chemical pre-treatments have positive effects on the final contents of glucose and fructose in Stanley and Empress prune cultivars while their proposed physical pre-treatment most importantly brought about a smaller loss of sugar in Empress and Angeleno [6].

Doymaz [7] also investigated the effect of dipping solution (alkali emulsion of ethyl oleate) on the drying kinetics of plum. He started the drying experiments using a cabinet type dryer until the moisture content of plum samples reached 20% (w/w). He reported that the treated and untreated samples both followed a similar trend of drying up to moisture ratio of 0.6 while passing 0.6, the treated samples started to dry faster (treated samples had 29.4% shorter effective time in comparison with the untreated samples). His research also emphasized on increase of diffusion coefficients of treated plum samples than those of untreated plums which is attributed to the partial chemical breakdown of the sample skins [7].

Tarhan [8] also studied the combined effect of chemical and thermal pre-treatments on plum drying. Through his research, he selected eight different pre-treatments (three chemical solutions (Ethyl oleate, Potassium hydroxide and Sodium hydroxide) plus water combined with two dipping temperatures (23 and 60 °C)). These all eight pre-treatments were applied onto plums dried through three different ways of drying i.e. laboratory tray dryer (artificial drying), greenhouse dryer (solar drying) and open sun drying (in all three methods of drying, the air temperature was below 55 °C). To make a comparison between the above mentioned combinations of pretreatments, he measured the weight loss percentage (WLP) of plum dried as the criteria through the process of drying and also applied the two-way analysis of variance and multiway factorial analysis to find the combined effects. He concluded that the temperature of chemical solution as the dipping medium is a key step for drying of plum and reported the 1% KOH with 60 °C dipping temperature as the best recommended combination of pre-treatments for all the three methods of drying while 1% NaOH took the second position. It is also worth mentioning that based on his research about color changes occurred during the process of drying, no drastic changes in color values