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INFORMATION PROCESSING IN AGRICULTURE XXX (2017) XXX–XXX

journal homepage: www.elsevier.com/locate/inpa

Innovative superheated steam impingement blanching (SSIB) enhances drying rate and quality attributes of line pepper

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ARTICLE INFO

Article history:
Received 14 May 2017
Received in revised form
10 July 2017
Accepted 13 July 2017
Available online xxxx

Keywords:
Line pepper
High-humidity hot air impingement blanching
Air impingement drying
Drying characteristics
Quality attributes

ABSTRACT

Blanching is an essential step before processing of agricultural products as it can inactivate enzymes that cause undesirable changes. In current work the effects of superheated steam impingement blanching (SSIB) time and temperature on drying characteristics and red pigments content of line pepper were investigated. Results showed that after a 3-min SSIB pretreatment at 110 °C the pepper epidermis covered with wax coat was damaged. In addition, the drying time was extensively decreased and the loss of red pigments of dried products was reduced. Results showed that the whole drying process took place in the falling rate period, which indicated that diffusion was the dominant physical mechanism governing moisture movement in the samples. Therefore, the second Fick's law of diffusion was used to determine the effective moisture diffusivity (D_{eff}) of line pepper, which increased from 1.193×10^{-10} to 3.128×10^{-10} m^2/s with increasing of the drying temperature and air velocity. The drying activation energy (E_a) of pretreated samples was 34.31 kJ/mol, which decreased by 3% compared with the non-pretreatment group. The findings of this work indicate that SSIB is very promising pretreatment technique as it not only enhances drying process but also improves bioactive substance preservation of red pepper.

1. Introduction

As one of the most frequently consumed vegetable spices worldwide, line pepper (*Capsicum annuum* L.) is a rich source of health-promoting compounds such as vitamin C, red pigments, carotenoids [1,2]. Frequent consumption of red pepper has many benefits for human health as it can promote glucose and lipid metabolism, stimulate the immune system, delay the aging, even prevent cancers [3–5].

The worldwide chillies and peppers production reached 3.32×10^7 tons and China produced about 1.61×10^7 tons according to Food and Agriculture Organization statistics for 2014 (FAO, 2016). However, due to its high moisture content and perishable tissue, the shelf life of fresh line pepper is very short [6]. Drying is one of the most frequently used method for pepper preservation as it can remove water to the level at which microbial spoilage and deterioration reactions can be minimized [7].

Currently, in China and other developing countries, the most common drying methods for peppers and other spices are the natural open sun drying and shade drying without technical aids [8]. Although the capital investment is low

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Peer review under responsibility of China Agricultural University.
https://doi.org/10.1016/j.inpa.2017.07.004

Please cite this article in press as: Yang X-H et al. Innovative superheated steam impingement blanching (SSIB) enhances drying rate and quality attributes of line pepper. Info Proc Agri (2017), https://doi.org/10.1016/j.inpa.2017.07.004

Nomenclature

A_{460}	spectrophotometer reading (absorbance)	c	total content of naturally coloring matter for line pepper powder (g)
D_{eff}	effective moisture diffusivity (m^2/s)	D_0	effective moisture diffusivity base (m^2/s)
DR	drying ratio (g moisture/g dry matter. h)	E_a	activation energy (kJ/mol)
f	calibration factor of UV VIS spectrophotometer	G	dry matter weight (kg)
H	moisture content (%, Wet basis)	L	the Flesh thickness of line pepper (m)
m	sample's weight (kg)	MR	moisture ratio (dimensionless)
M_o	initial moisture content (kg/kg, dry basis)	M_e	equilibrium moisture content (kg/kg, dry basis)
M_t	moisture content at any point in time (kg/kg, dry basis)	r	correlation coefficient
R	universal gas constant (J/mol·K)	t	drying time (h)
T	temperature (°C)	W_t	samples' weight at any time (kg)

and the operation is simple, the natural open sun drying method still has several disadvantages. For example, during the natural open sun drying, the drying is not uniform and it needs to turn the products during the drying process, which is a tedious and laborious work. Moreover, peppers are susceptible to re-adsorption of moisture during night or at bad weather, which may cause rewetting, or even spoilage of the product. In addition, as long exposure to solar radiation, the quality attributes may degrade seriously [9]. It was observed that the carotenoid contents of pepper decreased as much as 80% during the natural open sun drying [10]. In addition, line pepper is more difficult to dry than other biological materials as it has a peculiar structure of a peel covered with a thin-layer of wax, which forms the main resistance to moisture transfer during dehydration process [1]. It is very common to use chemical pre-treatment methods to accelerate drying process [11]. For example, Doymaz and Pala [12] used alkaline emulsion solutions to pretreat red pepper and found that pretreated peppers dried faster and obtained better color compared with the unpretreated samples. However, the chemical additives residue in the products may lead to food safety issues and how to deal with larger quantities of corrosive chemicals is a challenge [13]. Therefore, alternative pretreatment and drying methods are necessary and very tempting for pepper drying in order to enhance the drying rate and product quality.

In fact new pretreatment and drying methods for red pepper drying have received extensive attention. In the case of red pepper pretreatment, Ramesh et al. [14] found that after 3 min steam blanching and then hot air drying, the dried red pepper contained more vitamin E and carotenoid as well as the drying rate was accelerated compared to unpretreated samples. Yong et al. [15] also observed that blanching and making perforations in the skin could enhance the drying rate of pepper by breaking the wax coat of pepper epidermis as well as keeping well the pepper's color, nutrition and flavor. Vengaiah and Pandey [16] studied drying kinetics of peppers with or without blanching in different drying temperatures and air velocities and found that blanching could enhance drying rate.

As considered red pepper drying, convective hot air drying is the most frequently used drying technique. For example, many researchers [17–20,3] explored the effect of hot air drying on drying kinetics and quality of peppers and found that the drying temperature is the most effective factor that affects the drying process of peppers compared with the air velocities and loading thickness. In addition, due to long time exposure to high air temperatures, the color, heat sensitive nutrients and rehydration capacity of the dried peppers were extensively reduced.

Superheated steam impingement blanching (SSIB) is an innovative technology, which combines the advantages of superheated steam and impingement technology, resulting in a rapid, no waste water and efficient process [21]. Xiao et al. [22] found that SSIB pretreatment could not only enhance the drying kinetics of sweet potato bars but also improve the quality of the final product in terms of color, rehydration ratio, and microstructure. In addition, Xiao et al. [23] observed that appropriately SSIB pretreatment can accelerate drying and improve the whiteness index of yam slices probably due to the absence of oxygen. Bai et al. [24] found that SSIB pretreatment is an effective pretreatment for Fuji apple quarters to inactivate PPO and meanwhile to maintain produce quality. Bai et al. [25] also observed that SSIB pretreatment could be a useful non-chemical pretreatment technology for seedless grape drying, which can not only enhance drying rate but also improve color parameters of seedless grape.

Hot air impingement drying is an efficient drying technology. With high heat transfer coefficient, impingement drying has the advantages such as better quality products, less energy consumption, shorter drying time compared to the conventional air drying [8]. Recently, it has been applied in the field of food and agricultural products processing such as chestnut de-shelling and drying [26,27], rapeseeds drying [28], apricot drying [29], carrot cubes and seedless grapes drying [30,31], shrimp drying [32], herbs drying [33–35], potato chips drying [36], Hami-melon slices drying [37].

Therefore, this study applied SSIB and hot air impingement drying to process the line pepper. The effect of the superheated steam impingement blanching (SSIB) pretreatment on drying characteristics and quality attributes of line pepper was explored. The findings of this work will contribute to better understand of the drying characteristics of line pepper after being pretreated by SSIB.

Please cite this article in press as: Yang X-H et al. Innovative superheated steam impingement blanching (SSIB) enhances drying rate and quality attributes of line pepper. Info Proc Agri (2017), https://doi.org/10.1016/j.inpa.2017.07.004