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EFFECT OF BASIL SEED AND XANTHAN GUMS COATING ON COLOUR AND SURFACE CHANGE KINETICS OF PEACH SLICES DURING INFRARED DRYING

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The article presented conducts the research of infrared radiation power effect on the colour and surface changes of peach slices coated with basil seeds gum (BSG) and xanthan gum during drying. The colour indices include redness (a^*), yellowness (b^*), lightness (L^*), and total colour difference (ΔE), which were used for the purposes of colour change calculation. As the IR radiation power increased from 150 W to 375 W, the average values of L^* , a^* and b^* of uncoated and coated peach slices decreased from 67.45 to 65.41; 7.95 to 5.89; and 49.21 to 38.52, respectively. The lowest ΔE and surface change values were observed in peach samples coated with BSG. The modelling results showed that the MMF model was the best model to describe the total colour difference of uncoated and coated peach slices (the average correlation coefficient was equal to 0.991 and the average standard error was equal to 1.791). The surface area change (%) of uncoated and coated peach slices increased with the progression of drying time, but the rate of changes was lower for the coated peach slices with BSG. The current research indicated that BSG coating has the potential to improve surface colour and appearance quality of dried peach slices.

Keywords: coatings; colour indices; image analysis; MMF model; surface area change

The drying technique is one of the most frequently utilized preservation methods due to its efficiency and low cost. It is a process in which 80–95% of water within the agricultural products is decreased to 10–20% and maintained for a long time. However, the quality aspects, e.g., appearance, colour, taste, etc., should change as little as possible. Furthermore, by adding water, they should be able to absorb the water as close as possible to the original fresh state as well (Ozgen and Celik, 2019; Salehi, 2020d, 2021). The surface colour and appearance quality of the dried fruits and vegetables represent one of the most important quality factors for the acceptance of these products. Process variables, such as dryer type, drying conditions, sample pre-treatment, and edible coating, are anticipated to have the impacts on the colour and surface of dried products (Salehi, 2020c).

Food drying is an energy consuming process even though it is the most efficient method to preserve food products (Bouhjdjar et al., 2020). Considering the conventional thermal drying techniques, there occur flavour, colour, and nutritional losses (vitamin degradation and loss of amino acids) due to thermal degradation, which decreases the drying rate and rehydration ratio. Therefore, new methods should be employed for the purposed of attaining better quality dried food products (Aksoy et al., 2019). One of the best techniques for dehydration time reduction is to provide heat using infrared radiation (IR), which can serve as a substitution to the current drying technique for producing dried food products of high quality. In contrast to convective heating, its advantages are high heat transfer coefficients, short process times, and low energy costs (Salehi, 2020d).

Edible coatings can be applied to fruits and vegetables surfaces in a form of thin layer edible film. These can potentially extend the product shelf life and enhance its quality by the control of mass transfer, moisture and oil diffusion, gas permeability (O_2 , CO_2), and flavour and aroma losses, as well as by maintaining its mechanical, rheological characteristics, colour and appearance (Lacroix and Vu, 2014). Moreover, application of edible coatings maintains the surface appearance of dried food products (Lai et al., 2013; Lacroix and Vu, 2014; Salehi, 2020a; Satorabi et al., 2021), e.g., the effect of edible coating (prepared from pectin) and blanching pre-treatments on the air drying (60 and 70 °C with air velocities of 0.85 and 1.70 m·s⁻¹) kinetics of pumpkin slices was studied by Molina Filho et al. (2016), who reported that the coating did not show any significant impact on the drying kinetics of pumpkin slices, and this technique was recommended for using as pre-treatments of drying.

Basil (*Ocimum basilicum* L.) is the mucilaginous native plant, and its seeds have a high amount of mucilage (gums) with outstanding useful properties that are comparable with marketable food gums (Amini et al., 2021). Basil seeds gum (BSG) is a mucilage extracted from basil seeds using cold water extraction (Zameni et al., 2015). Application of seed gums as edible coatings for protection and preservation of food products is especially significant in terms of biodegradability, eco-friendliness, accessibility and a suitable price (Salehi, 2020a, b). The effect of BSG coats (0.3 and 0.6%) on the kinetics of osmotic dehydration of apple slices was examined by Etemadi et al. (2020). Coated apple

slices showed 18% lower sucrose absorption in contrast to samples without coating.

The colour and surface changes data are applicable in prediction of physical, chemical and quality properties of food products. In addition to this, they are useful for determining the consumer acceptability. The skin colour plays an important role in drying process controlling. Potential of BSG utilizations in food ingredients, and lack of scientific data on its usage for the edible coating of fruits and vegetables as a pre-treatment in IR drying make it essential to examine the behaviour of this mucilage as coating pre-treatment for the IR drying process. Therefore, this paper aimed to examine the impacts of IR drying on the colour parameters and surface changes kinetics of coated peach slices with BSG and xanthan gum and determine the kinetic model coefficients for these changes.

Material and methods

Peach samples preparation

Slice samples of peach (5 mm thickness) were prepared using a cutter and a cylindrical steel-made cutter. The initial moisture content (MC) of the peach slices was 90% (measured at 105 °C for 5 h).

Gum extraction

Basil seeds were examined and cleansed from all impurities. Subsequently, the pure basil seeds were immersed in water for 20 min at a seed/water portion of 1:20 at 25 °C. The extracted mucilage was separated from the inflated seeds using an extractor (Bellanzo BFP-1540 Juicer, China) with a rotating disc that scratched the mucilage layer on the seed surface (Amini et al., 2021; Salehi and Satorabi, 2021). The initial MC of the BSG was 99.4% (wet basis).

Coating of peach slices

Xanthan gum and BSG were used for the purposes of coating the fresh peach slices. A solution with 0.6% (w/w) xanthan gum and BSG was prepared at temperature of 25 °C. Subsequently, peach slices were immersed for 1 min in this aqueous solution (Salehi and Satorabi, 2021).

IR drying

Considering the thickness of products to be dried, drying methods can be classified as either a thin-layer, or deep bed. In terms of the former, products with thickness less than 20 cm are exposed to drying air, and drying conditions are considered constant. Regarding the latter, the product thickness can reach up to 45 cm (Odewole and Falua, 2021). In this study, the coated peach slices with 5 mm thickness were dried in an IR dryer. The distance of samples from IR lamp surface was 10 cm. The impacts of IR radiation power at three levels (150, 250, and 375 W) on the colour and surface changes kinetics of peach slices were examined. The drying was performed to reach the final MC of 10% from initial MC of approx. 90%. The total drying times of peach slices were 80 min, 45 min, and 30 min by using the 150 W, 250 W, and

375 W IR radiation lamps, respectively. All drying periods and conditions were conducted in triplicate.

Colour measurement

The colour was assessed based on the determination of Hunter values L^* (lightness/darkness), a^* (redness/greenness), and b^* (yellowness/blueness). Image analysis was carried out by Image J software version 1.42e, USA. The samples' photos were acquired using HP Scanjet-300 scanner (Salehi, 2017).

For the purposes of description of the changes in colour values of samples, the total colour difference (ΔE) values were calculated as follows:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

The higher the ΔE value, the greater the difference between the fresh and dried slices (Aksoy et al., 2019).

Surface area measurement

The changes in the surface area of peach slices during drying were estimated as follows:

$$\Delta A = \frac{A_0 - A_t}{A_0} \times 100 \quad (2)$$

where:

ΔA – surface changes (%); A_0 – surface of the fresh peach slices (cm^2); A_t – surface of the dried peach slices (cm^2); t – drying period (min)

Mathematical modelling

Power, quadratic and sigmoidal models (Gompertz relation, Logistic model, Richards model, MMF (Morgan-Mercer-Flodin) model and Weibull model) were selected to characterize the total colour difference within the IR drying process of uncoated and coated peach slices with BSG and xanthan gum (Hyams, 2005; Khamis et al., 2005; Salehi, 2019):

Power model:

$$\Delta E = at^b \quad (3)$$

Quadratic model:

$$\Delta E = a + bt + ct^2 \quad (4)$$

Gompertz relation:

$$\Delta E = ae^{-e^{-t}} \quad (5)$$

Logistic model:

$$\Delta E = \frac{a}{1 + be^{-t}} \quad (6)$$

Richards model:

$$\Delta E = \frac{a}{(1 + e^{b-ct})^{1/d}} \quad (7)$$

MMF model:

$$\Delta E = \frac{ab + ct^d}{b + t^d} \quad (8)$$

Weibull model:

$$\Delta E = a - be^{-ct^d} \quad (9)$$

where:

ΔE – total colour difference (%); t – IR drying time (min); a , b , c , d – coefficients of these models

Results and discussion

IR drying shows great potential in terms of dried food production due to drying time reduction without causing any deterioration in product quality. A reasonable drying

process and pre-treatment can ensure the product quality. Figure 1 shows colour and surface changes of peach slices coated with BSG during IR drying. The lightness (L^*) represents a significant parameter in the dehydrated products because it is usually the very first quality aspect evaluated by consumers when determining product acceptance. The loss in L^* gives the darker colour and appearance to the dried products (Seerangurayar et al., 2019). Low L^* value is demonstrated by a dark colour and associated with the enzymatic browning reaction. The effect of edible coatings on L^* during IR drying of peach slices (150 W) is provided in Fig. 2; the L^* index values of dried peach decreased during IR drying, however, the rate of changes was lower for coated samples. Krokida et al. (1998) studied the influence of drying conditions on colour changes of specific fruits and vegetables (apple, banana, carrot and potato) during drying by conventional-dryer and vacuum-dryer. The Hunter colour scale parameters a^* , b^* and L^* were utilized for the calculation of the colour changes during drying at 50–90 °C. The authors reported that the air temperature and humidity influenced a^* and b^* values, but L^* values remained unaffected. The reduction in the L^* index values with an increase in the darkness-brownness of agricultural products and pigment destruction were also observed by Chong et al. (2008) and Seerangurayar et al.

Fig. 1 Colour and surface area changes of dried peach samples coated with BSG (150 W and 80 min)

Fig. 2 Impacts of edible coatings on the L^* , a^* and b^* parameters during IR drying of peach samples (150 W)

Table 1 Colour parameters of uncoated and coated peach slices during IR drying

Coating	IR power (W)	b^*	a^*	L^*
Uncoated	150	45.39	10.38	62.42
	250	41.65	10.96	62.02
	375	34.93	8.19	59.42
Xanthan	150	52.75	7.58	67.39
	250	48.61	6.27	69.89
	375	38.96	7.03	63.89
Basil	150	49.50	5.90	72.53
	250	51.67	3.96	76.83
	375	41.66	2.45	72.91

(2019). The a^* index values of uncoated and coated peach slices increased during IR drying, however, the rate of changes was lower for the coated ones. It was recorded that the a^* index value was an indicator of browning (colour changes) during drying of peach slices, which is in consistency with the observations made by Bingol et al. (2012) for colour changes of grapes during drying, Askari et al. (2008) for colour changes of apple slices during drying and Krokida et al. (2000) for colour changes of apple, banana, and potato.

The colour parameters were affected by IR radiation power, coating type and drying time (Table 1). The IR radiation power negatively influenced the L^* of dried peaches. In addition, the change in b^* values was less at lower IR radiation power (150 W). With increase in IR radiation power from 150 W to 375 W, the average L^* and b^* values of uncoated and coated samples decreased from 67.45 to 65.41 and 49.21 to 38.52, respectively. Generally, reduction in the L^* index is not desirable, since it leads to darker dried products, which is unacceptable for dried peach slices. The a^* value indicates redness for dried products and the variation in the a^* values during IR drying of peach slices is presented in Table 1. The results showed that the radiation power intensity had a significant impact on the a^* parameter. As the IR radiation power increased from 150 W to 375 W, the average a^* index values of uncoated and coated peach slices decreased from 7.95 to 5.89.

The total colour difference was reported as functions of dehydration time, edible coatings and IR radiation power (Fig. 3). As given in Fig. 3, the ΔE values increased during the early stages of drying. The ΔE values got more intense at higher IR radiation power. Moreover, Fig. 4 depicts the impacts of edible coatings on average total colour difference (ΔE) of dried peach samples. The lowest total colour difference value was showed by samples treated with BSG. Dadali et al. (2007) studied the influence of microwave output power and sample quantity on colour change kinetics of Turkey spinach using the microwave drying method. The microwave drying process caused changes in L^* , a^* , and b^* , causing a^* colour shift toward the darker region.

Fig. 3 Effects of coatings and IR radiation power on the total colour difference (ΔE) of peach slices

Fig. 4 Impact of edible coatings on average total colour difference (ΔE) of dried peach samples

The L^* and b^* values decreased, while a^* and ΔE values increased during microwave drying. Gounga et al. (2008) studied the influence of whey protein isolate-pullulan coatings on the surface colour and quality of freshly roasted and freeze-dried Chinese chestnut. It had a low, yet significant influence on decreasing moisture loss and decay incidence of fresh-roasted chestnut, delaying thus changes in its external colour.

Kinetics modelling of the total colour difference represents a necessary tool for optimization of drying conditions and controlling or improving the process in order to provide a high quality of the dried products (Yang et al., 2018). The various equations were fitted to the total colour difference data and the parameters calculation resulted from fitting models (Eqs 3–9) to the empirical data. The results of fitting the proposed MMF model to the empirical data are provided in Table 2. The highest correlation coefficient (r) and lowest standard error (SE) values of fitting suggested that the total colour difference during drying of uncoated and coated peach slices could be modelled by the MMF model. Seerangurayar et al. (2019) investigated the impacts of solar drying on colour kinetics of Khalas dates, claiming that the drying methods and ripening stages had a major influence on each colour parameter. Furthermore, the authors found that the acceptable model for description of the colour change kinetics of dates was the fractional conversion model.

Surface change (shrinkage, %) represents a common phenomenon occurring during dehydration. Based on Fig. 5, the surface change was reported as functions of dehydration time, edible coatings, and IR radiation power. As shown in Fig. 5, the shrinkage percentage of uncoated and coated peach samples increased with the progression of drying time, however, the rate of changes was lower for the coated peach slices with BSG. As the IR radiation power increased from 150 to 375 °C, the shrinkage of samples coated with xanthan gum decreased from 71.36 to 61.91% (Fig. 6). The lowest surface change value was shown by the peach slices coated with BSG and dried at 375 W (54.76%). The highest shrinkage was shown by the uncoated

Table 2 MMF model coefficients for the total colour difference (ΔE) of peach slices

Coating	IR power (W)	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	SE	R
Uncoated	150	0.00505	2099.965	2875.133	0.7221	1.031	0.995
	250	2.3712	8006.327	432.561	1.8452	3.222	0.990
	375	2.2286	22649.811	2489.392	1.8032	4.277	0.986
Xanthan	150	0.0856	41.767	33.528	1.1932	0.844	0.996
	250	1.6410	25750.914	27610.722	0.8782	2.189	0.984
	375	1.0019	10708.961	574.717	1.9752	0.979	0.999
Basil	150	2.3282	3325.251	586.196	1.1015	1.607	0.978
	250	0.0770	15.966	23.864	1.2844	0.989	0.993
	375	0.0277	104.596	407.927	0.3797	0.714	0.997

Fig. 5 Effects of edible coatings and IR radiation power on the surface area change of peach samples **Fig. 6** Effects of edible coatings and IR radiation power on the surface area change of dried peach samples

peach slices dried at 150 W (72.19%), which may be due to lower removal of moisture. Ali et al. (2019) examined the influence of Aloe vera gel coating on the postharvest browning and quality of litchi fruit. The authors reported that the Aloe vera gel coating is suitable for delaying the surface browning of harvested litchi.

Conclusion

In comparison to convective heating, the IR radiation utilization for the purposes of drying is beneficial due to high heat transfer coefficients, short process times and low heat costs. This paper investigated the effects of IR radiation power and coating type (uncoated, coated with xanthan gum and coated with BSG) on the colour and surface changes kinetics of peach slices, since these process parameters have impact on the colour indices (L^* , a^* , b^* and ΔE) during drying of uncoated and coated peach slices. The a^* index values increased during drying. The L^* index values of uncoated and coated peach slices decreased during IR drying, however, the rate of changes in the L^* index was lower for coated slices. The colour change phenomenon got more intense at higher IR radiation power. Various kinetic equations were used for fitting the empirical data and the results indicated that the MMF model was the best model for the total colour difference description with the average correlation coefficient equal to 0.991 and the average standard error equal to 1.791. The surface change (%)

of uncoated and coated peach slices increased with the progression of drying time, however, the rate of changes was lower for the coated peach samples with BSG. The lowest surface change was observed in samples coated with BSG and dried at 375 W (54.76%). Ultimately, these findings suggest that BSG coating has the capability to improve the surface colour and appearance quality of IR dried peach slices. Furthermore, these results suggest that BSG coating pre-treatment provide enough valuable advantages, making it very useful for food industry.

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