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The Effects of a Gum-Based Edible Coating on Apple Slices Characteristics during Infrared Heating

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ABSTRACT: Edible coatings used for food products before drying is a procedure that can certainly enhance the appearance and sensorial properties of dried food products. In this research study, it is aimed to determine the influences of some edible coatings, namely basil seeds gum and xanthan gum, on the colour and surface shrinkage of apple slices throughout drying time by infrared dryer. The colour parameters include $a*$ (redness: green to red), $b*$ (yellowness: blue to yellow), $L*$ (lightness), and ΔE (total colour difference) were used to calculate colour changes during infrared heating. $L*$ index values of untreated and treated apple slices with xanthan and basil seeds gums decreased from 85.90 to 38.19, from 81.38 to 46.76, and from 83.00 to 66.13, during infrared heating, respectively, however the ratio of the lightness index changes was lower for the treated samples. The redness of dried untreated and treated apple slices increased during the initial period of drying. The results illustrated that radiation power has a considerable effect on the colour parameters (P-value<0.05). As the radiation intensity increased from 150W to 250W, the lightness of apple slices reduced from 65.11 to 61.11. The lowest colour change value (19.06) was for the apple slices treated by basil seeds gum. Power equation, quadratic equation and sigmoidal equations (Gompertz, Logistic, Richards, Morgan-Mercer-Flodin (MMF) and Weibull) were used to fit the experimental drying data and the results illustrated that the MMF equation was the best equation to explain the colour change of untreated and treated apple slices (r>0.986). The lowest surface shrinkage change value was for the apple samples treated by basil seeds gum and dried in 375W (47.47%).

Keywords: Apple, Colour Indexes, Image Analysis, Infrared Heating.

Introduction

Heat and mass transfer can occur throughout drying time and cause physico-chemical changes including the colour and surface shrinkage of the dried products. In addition, process variables including dryer type, drying condition, sample pre-treatment and edible coating are expected to influence the colour and surface area of the dried products (Hawlader *et al.*, 2006; Artnaseaw *et al.*, 2010; Salehi & Satorabi, 2021). Edible coatings can improves the shelf life and quality of food products, and act as a low O_2 barrier and low H_2O vapor barrier, they have appropriate O_2 and CO_2 barrier properties via reducing oxidative reaction in food samples during drying and reducing H_2O loss or controlling H_2O adsorption. They are applied to food samples before drying as a technology that can improve the nutritional value and sensory qualities of the dehydrated food

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samples (Fakhouri *et al.*, 2007; Garcia *et al.*, 2014; Silva *et al.*, 2015). Rahman *et al.* (2020) indicated that the coatings material including alginic acid and polygalacturonic acid causes high water loss (17% and 7.5%, respectively) and low solid gain (4% and 8%, respectively), compared to untreated potato samples after a typical 90 min osmotic dehydration process. Also, the edible coating improved the physico-chemical and nutritional characteristics of the dried fruits and vegetables by decreasing O_2 diffusion into the food.

Among the natural polymers used to formulate edible coatings; seeds gums have been deemed the most promising materials, mostly because their high accessibility, low price, and good performance (Salehi, 2020a). Basil (*Ocimum basilicum* L.) seeds containing significant content of mucilage (gum), when soaked in water, and it will give some favored functional properties for numerous food products (Amini *et al.*, 2021).

The infrared heating technique can be used as a succession to the present drying technique for the production of higher quality dried products (Salehi, 2020b). Satorabi *et al.* (2021b) investigated on the effects of polysaccharide coating on the drying kinetics of apricot slices and used genetic algorithm–artificial neural network (GA-ANN) and adaptive neuro-fuzzy inference system (ANFIS) approaches for forecast of drying time and moisture content of treated apricot slices in an infrared dryer. They reported that the both GA-ANN and ANFIS approaches predictions agreed well with experimental data sets and they can be beneficial for modelling and controlling the factors affecting the drying kinetics of the untreated and treated apricot slices in the infrared dryer. Dadali *et al.* (2007) investigated colour change kinetics of Turkey spinach undergoing microwave drying. The authors reported that drying with microwave technique changed colour indexes (L^*, a^*, and b^*), that causing redness colour shift toward the redness section. Also, the values of lightness and yellowness indexes reduced, while values of redness index and ΔE increased during drying by microwave dryer. In another study, the effect of solar drying technique on colour kinetics of dates were studied by Seerangurayar *et al.* (2019). It was found that the most suitable equation to explain the colour change kinetics of dates at the 3 ripening periods was the fractional conversion equation. In addition, at the end of drying, Rutab and Tamr period dates turned to red–brown colour for all solar drying techniques.

Edible coatings have barrier features that decrease fruits' surface permeability to oxygen and carbon dioxide, resulting in a change in internal gas composition that reduces oxidative metabolism and increases product shelf life (Salehi, 2020a). The goal of this study is to investigate the effect of an edible coating based on basil seeds and xanthan gums on the colour change kinetics and shrinkage of treated apple slices throughout drying time by infrared dryer.

Materials and Methods

- Samples preparation

Slices of apple (*Golden delicious*) with 0.5 cm thickness were sliced with the aid of a sharp knife and a cylindrical shape mold. The initial moisture content of the apple slices was 86% w.b. (was calculated at 105°C for 5 h).

- Treatment of apple slices

Basil seeds were immersed in H_2O in the ratio of 1:20 in an beaker at 25°C for 20 min. Then, the basil seeds gum was extracted from the basil seeds by passing the swollen samples through an experimental extractor (Bellanzo BFP-1540 Juicer, China). The total solid of the extracted basil seeds gum was 0.6% (w/v). Xanthan gum powder of food-grade was acquired from FuFeng Co., China. Xanthan gum solution at 0.6% (w/v) was arranged by dissolving 6 g of xanthan gum powder in 1 L of H_2O. The solution of xanthan gum was agitated with low heat at 25°C for 20 min using a stirrer. Finally, the apple slices were immersed in these coating solution for 1 min in a beaker.

- *Infrared heating*

The treated apple slices were dried in an infrared dryer (Figure 1, length 0.44 m, width 0.20 m, and height 0.40 m). The distance of apple slices from infrared lamp (Noor Lamp Company, Iran) surface was 0.10 m. The influence of the radiation intensity at 3 levels of 150, 250, and 375 watts was examined on the colour and surface shrinkage changes of the apple samples.

- Surface colour and appearance

In order to examine the influence of infrared heating on colour indexes of the untreated and treated apple slices, a computer vision technique was used. Image analysis was carried out using Image J software (V.1.42e, USA). The apple slices' photos were captured with a scanner (HP Scanjet-300). The L^* (lightness: ranges from 0 (black) to 100 (white)), a^*(redness: ranges from green (<0) to red (>0)), and b^* (yellowness: ranges from blue (<0) to yellow (>0)) values determined (Salehi, 2019). The total colour difference (*ΔE*) was calculated using equation 1:

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

The change in the surface area of the apple slice throughout drying time was calculated using equation 2:

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

Where, *ΔA* is the shrinkage of sample surface (%), and A_0 and A_t (cm^2) are the surface area of the fresh apple slices and the dries products at drying duration of *t*, respectively.

- *Kinetic modelling*

Power equation, quadratic equation, and sigmoidal equations (Gompertz, Logistic, Richards, Morgan-Mercer-Flodin (MMF), and Weibull) were utilized to describe the colour changes during the infrared heating procedure of the untreated and treated apple slices with the basil seeds and xanthan gums (Salehi & Satorabi, 2021).

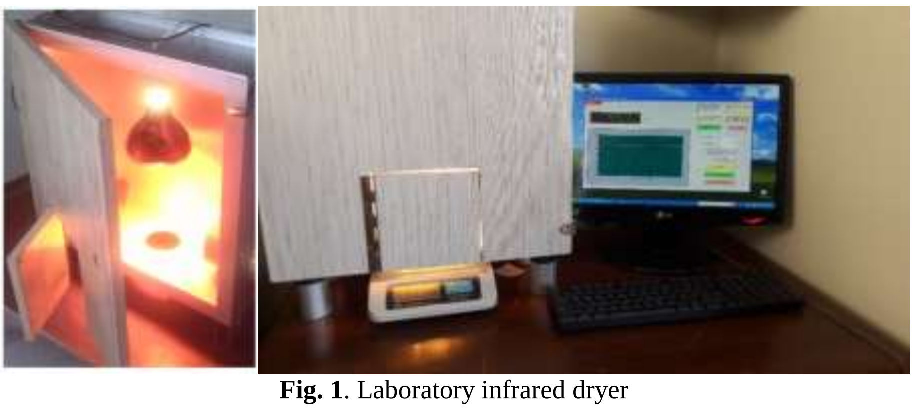

Fig. 1. Laboratory infrared dryer

Regression analysis was carried out using Curve Expert software (Version 1.34, Hyams, D. G., Microsoft Corporation) to estimate equations parameters. Correlation coefficient (r) and standard error (SE) were calculated to evaluate the accuracy of models.

- Statistical analysis

This experiments were assembled in a wholly randomized design with 3 replicates and consisting of two factors: coating treatments and radiation power. This experiment was analyzed as a factorial experiment. The effects of coating treatments (coating with basil seeds gum and xanthan gum) and infrared radiation power (150, 250, and 375 W) on several properties were statistically analyzed by ANOVA using the SAS statistical software (SAS 9.1, SAS Institute Inc., Cary, NC, USA). Comparisons among means were done by Duncan's multiple range test (DMRT) at probability ≤ 0.05.

Results and Discussion

Edible coatings have been spotlighted by many researchers because this technique offers better protection for food products. Figure 2 shows colour and surface shrinkage of the apple slices treated with basil seeds gum during infrared heating (150 W). Also, Figure 3 shows the effect of the coating type on the colour and surface shrinkage of the infrared dried apple slices.

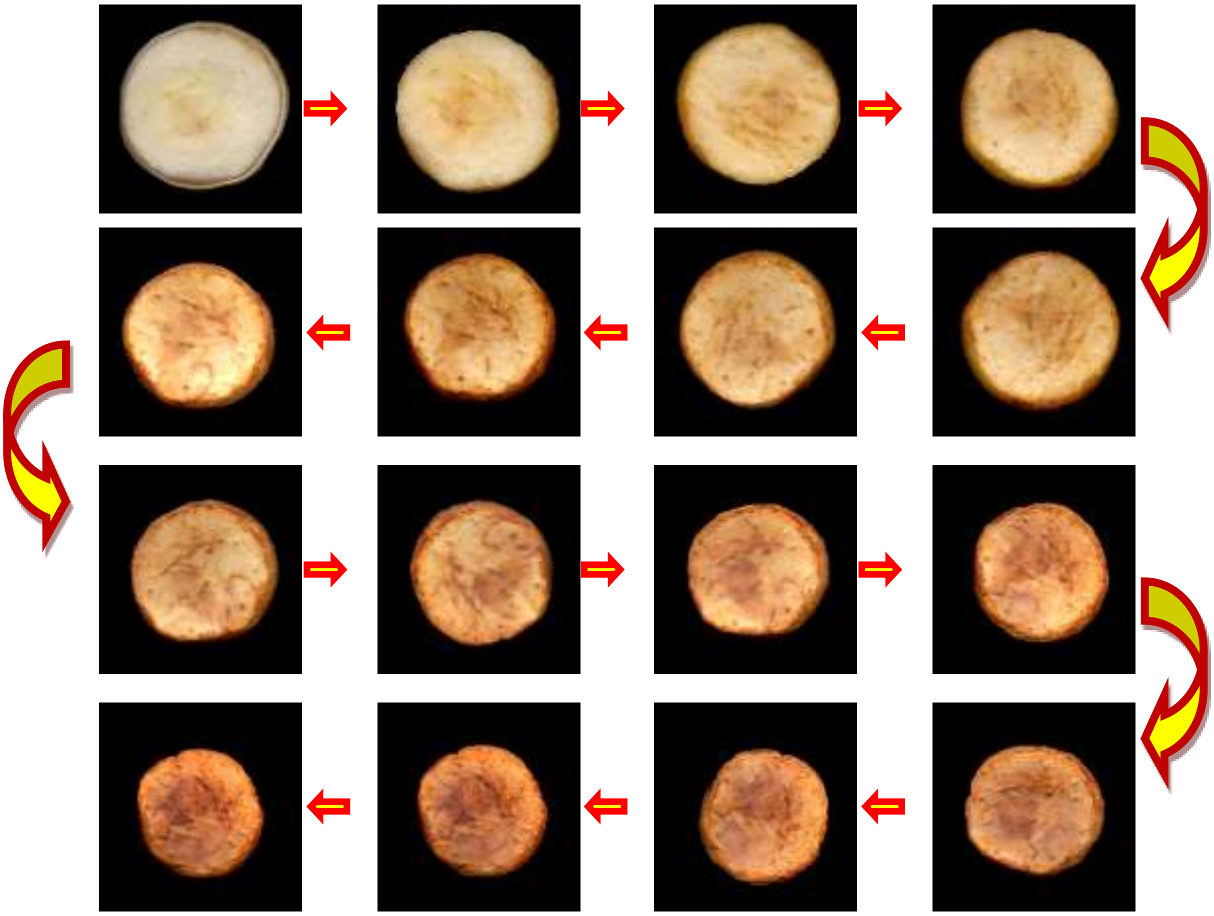

Fig. 2. Colour and surface shrinkage of apple slices treated with basil seeds gum during infrared heating (150 W).

Fresh apple slice

Untreated sample Treated with basil gum Treated with xanthan gum

Fig. 3. Effect of the coating type on the colour and surface shrinkage of infrared dried apple slices (150 W).

The $L*$ (lightness parameter) is a main indicator in the dried products as it is generally the first quality element considered by customers when evaluating product approval. Low $L*$ value demonstrates a dark colour and it is attributed to the enzymatic browning reactions. The $L*$ is the index of brightness of samples and the Figure 4 illustrates the effect of coating treatments on the $L*$ during infrared heating of the apple slices (150W). As expected, the $L*$ value of all the dried apple reduced throughout heating time, but the speed of change was lower for the treated samples. Similarly, the decreases in the $L*$ index value with an increases in the darkness of food samples was reported by some researchers (Chong *et al.*, 2008; Seeranguravar *et al.*, 2019).

The colour indicators were influenced by radiation intensity, coatings treatments and drying duration (Table 1). Infrared heating intensity has a negative effect on the lightness of dried apples ($P<0.05$). The change in lightness values were less at the lowest infrared radiation power (150W). As the infrared radiation intensity was increased from 150 to 250W, the lightness of apple slices decreased from 65.11 to 61.11. The variation in the redness values during infrared heating of apple slices is shown in Table 1. The redness index values of the untreated and treated apple slices increased during infrared heating but the rate of the changes were lower for the treated samples.

In Figure 5 the colour change (ΔE) is presented as function of the drying duration, edible coatings, and infrared radiation intensity. As shown in Figure 5, the ΔE increased during the early stages of drying. This may be due to decomposition of some pigments. The total colour difference (ΔE) gets more intense at higher infrared radiation power. The average values of ΔE for the control sample, treated with xanthan gum and treated with basil seeds gum were equal to 38.32, 29.70 and 19.06, respectively. The lowest total colour difference value was for the apple slices treated by basil seeds gum (19.06) ($P<0.05$). Satorabi *et al.* (2021a) used xanthan and balangu seeds gums for edible coating of apricot slices before drying by infrared system. The authors reported that the treated apricot slices with balangu seed gum showed the lowest colour changes throughout drying time and the average values of ΔE for the control sample, treated with xanthan gum and treated with balangu seeds gum were equal to 21.30, 16.89 and 13.92, respectively.

In Table 2 the MMF equation constants for total colour difference of apple slices were reported. High correlation coefficient (r) and low standard error (SE) values of the approximation of fitting demonstrated that the colour change throughout drying time of the untreated and treated apple slices could be modeled by the MMF equation.

Surface area change % (surface shrinkage) is a general phenomenon throughout drying time of fruits and vegetables. In Figure 6 surface shrinkage is reported as functions of heating duration, edible coatings and infrared radiation power. As shown in Figure 6, the surface shrinkage percent of untreated and treated apple slices was increased over drying time, but the speed of change was lower for the treated sample with basil seeds gum. As the infrared radiation intensity increased from 150 to 375 watts, the surface shrinkage of treated apple slices with xanthan gum reduced from 69.61% to 55.39%, respectively. These findings are matched with those obtained by Ponkham *et al.* (2012) in infrared dried pineapple rings, as well as Rani and Tripathy (2020) in dried pineapple slice. The lowest surface shrinkage value was for the apple slices treated by basil seeds gum and dried in 375W (47.47%). The highest surface shrinkage was seen in untreated apple slices dried at 150W which may be due to lower removal of moisture. Satorabi *et al.* (2021a) also reported a similar trend of shrinkage during infrared heating of apricot slices. They reported that the coating treatments with balangu seeds gum enhanced the appearance of the dried sample and in addition the least area changes in the total drying duration and at different irradiation powers were for these samples.

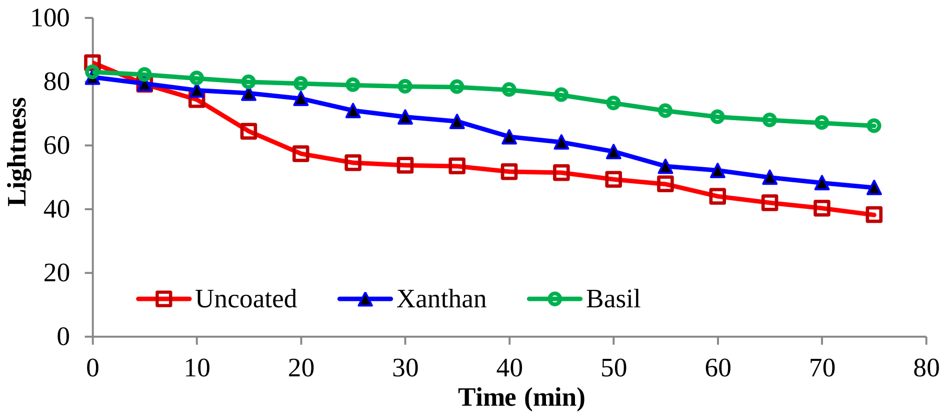

Fig. 4. Effect of edible coatings on the lightness parameter (L^*) during infrared heating of apple slices (150 W).

Table 1. Mean of colour parameters of untreated and treated apple slices throughout drying by infrared dryer

Coating	infrared power (W)	b^*	a^*	L^*
	150	36.22 ^{a}	21.40 ^{a}	55.48 ^{d}
Untreated	250	35.64 ^{a}	19.35 ^{a}	55.12 ^{d}
	375	26.97 ^{d}	11.11 ^{cd}	60.03 ^{c}
	150	36.43 ^{a}	14.49 ^{b}	64.30 ^{b}
Xanthan	250	33.51 ^{b}	19.05 ^{a}	55.00 ^{d}
	375	28.79 ^{cd}	14.28 ^{b}	58.18 ^{cd}
	150	35.34 ^{a}	11.93 ^{c}	75.54 ^{a}
Basil	250	35.69 ^{a}	12.86 ^{bc}	73.22 ^{a}
	375	29.81 ^{c}	9.03 ^{d}	73.65 ^{a}

* where, L^*, a^*, and b^* are the lightness, redness, and yellowness indexes, respectively.
Means with different superscripts in same column differ significantly (P<0.05).

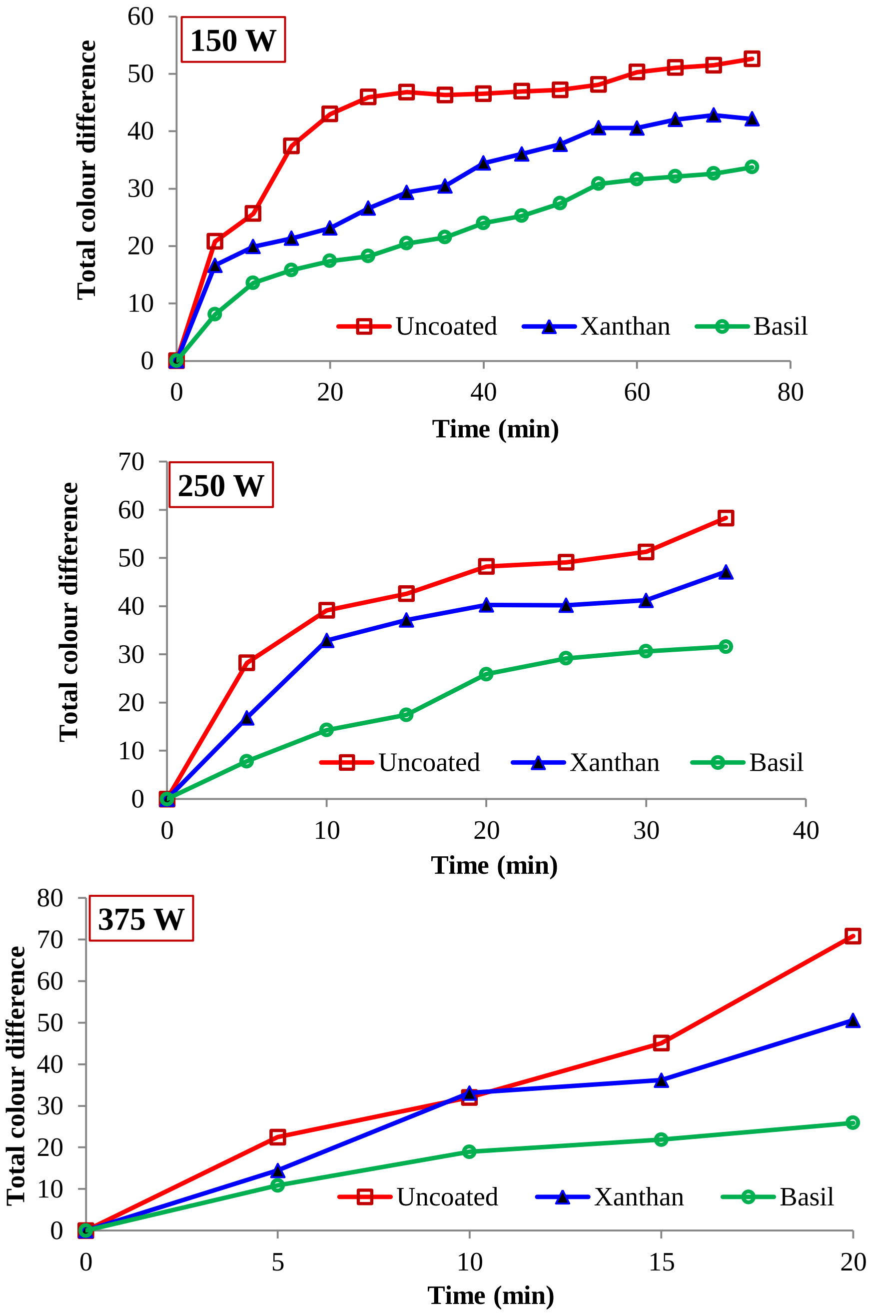

Fig. 5. Effect of coatings and infrared power on the total colour difference of apple slices during infrared heating.

Conclusion

In the present work, the effect of coating treatments (untreated, treated by xanthan gum and basil seeds gum) and infrared radiation intensity on the colour and surface shrinkage kinetics of apple slices were examined. The infrared radiation intensity and the coating type were the process parameters which affect the colour indexes (*L**, *a**, *b** and *ΔE*) throughout drying time of the untreated and treated apple slices ($P<0.05$). Overall, our findings indicated that the *L** index decreased and the redness and yellowness values increased throughout drying time ($P<0.05$). The colour change procedure

Table 2. The MMF model constants for colour change index (ΔE) of apple slices

Coating	Infrared power (W)	a	b	c	d	SE	r
	150	0.227	14.594	54.287	1.262	2.104	0.991
Untreated	250	-0.022	8.671	147.891	0.468	2.106	0.996
	375	1.698	5236887.6	15498943	1.034	8.551	0.986
	150	0.462	310.437	2149.461	0.430	1.469	0.993
Xanthan	250	-0.110	30.159	45.785	1.819	2.332	0.993
	375	-0.157	37.852	122.272	1.080	5.883	0.988
	150	0.269	515.451	1783.054	0.532	1.074	0.995
Basil	250	0.299	49.088	47.180	1.320	1.741	0.994
	375	-0.016	16.419	35.963	1.233	1.128	0.998

* where, *SE* and r are the standard error and correlation coefficient, respectively, and *a*, *b*, *c*, and *d* are the constants of the MMF model.

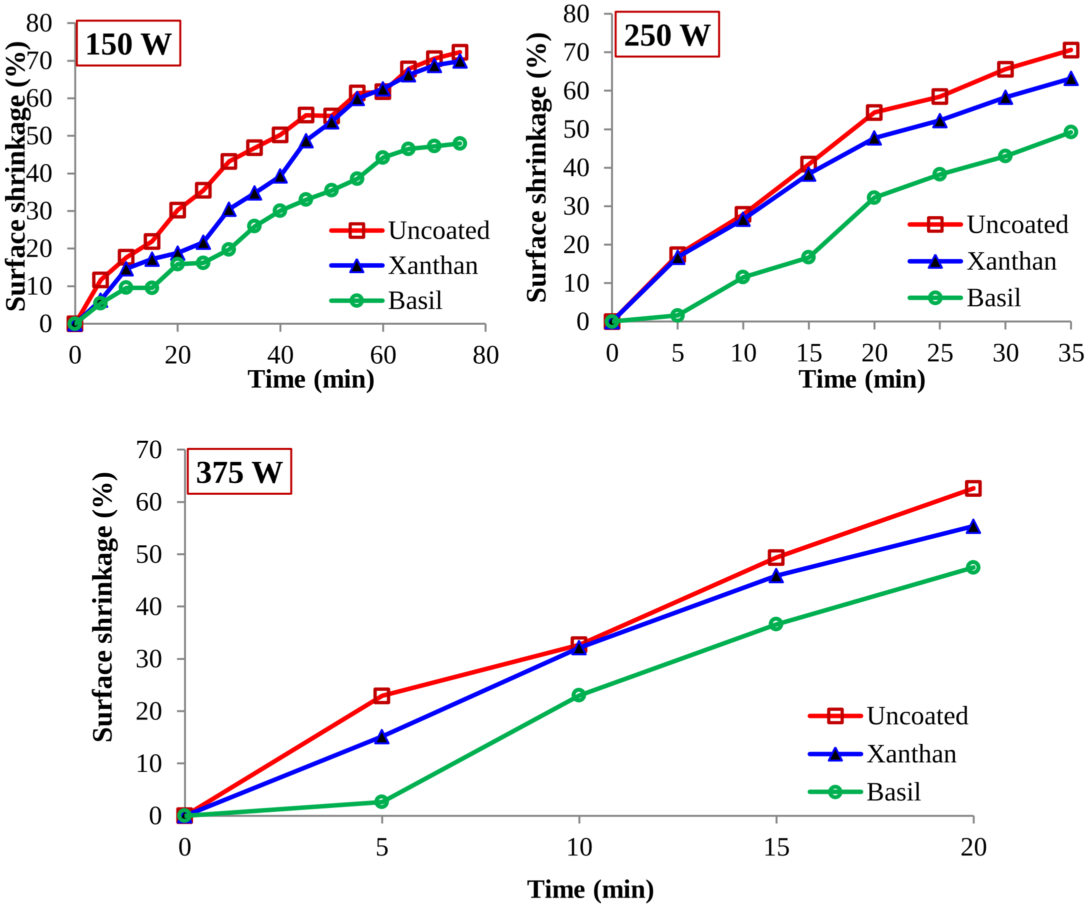

Fig. 6. Effect of coatings treatments and infrared intensity on the surface shrinkage of apple slices.

gets more intense at higher infrared radiation power. Different kinetic models were utilized to fitting the experimental total colour difference data. The results shows that the MMF equation was the best equation to describe the total colour difference data (r>0.986). The surface shrinkage % of the untreated and treated apple slices were increased over heating duration, however the speed of change was lower for the treated apple sample with the basil seeds gum. Overall, the present research indicated that basil seeds gum coating can potentially enhance the surface colour, appearance quality and marketable percentage of dried apple slices.

References

Amini, G., Salehi, F. & Rasouli, M. (2021). Drying kinetics of basil seed mucilage in an infrared dryer: Application of GA-ANN and ANFIS for the prediction of drying time and moisture ratio. *Journal of Food Processing and Preservation*, 45(3), e15258.

Artnaseaw, A., Theerakulpisut, S. & Benjapiyaporn, C. (2010). Development of a vacuum heat pump dryer for drying chilli. *Biosystems Engineering,* 105(1), 130-138.

Chong, C.H., Law, C.L., Cloke, M., Abdullah, L.C. & Daud, W.R.W. (2008). Drying kinetics, texture, color, and determination of effective diffusivities during sun drying of chempedak. *Drying Technology*, 26(10), 1286-1293.

Dadali, G., Demirhan, E. & Özbek, B. (2007). Color change kinetics of spinach undergoing microwave drying. *Drying Technology,* 25(10), 1713-1723.

Fakhouri, F.M., Fontes, L.C.B., Gonçalves, P.V.d.M., Milanez, C.R., Steel, C.J. & Collares-Queiroz, F.P. (2007). Filmes e coberturas comestíveis compostas à base de amidos nativos e gelatina na conservação e aceitação sensorial de uvas Crimson. *Food science and technology*, 27(2), 369-375.

Garcia, C.C., Caetano, L.C., de Souza Silva, K. & Mauro, M.A. (2014). Influence of edible coating on the drying and quality of papaya (*Carica papaya*). *Food and Bioprocess Technology*, 7(10), 2828-2839.

Hawlader, M.N.A., Perera, C.O. & Tian, M. (2006). Properties of modified atmosphere heat pump dried foods. *Journal of Food Engineering,* 74(3), 392-401.

Ponkham, K., Meeso, N., Soponronnarit, S. & Siriamornpun, S. (2012). Modeling of combined far-infrared radiation and air drying of a ring shaped-pineapple with/without shrinkage. *Food and Bioproducts Processing,* 90(2), 155-164.

Rahman, S., Nassef, A.M., Al-Dhaifallah, M., Abdelkareem, M.A. & Rezk, H. (2020). The effect of a new coating on the drying performance of fruit and vegetables products: experimental investigation and artificial neural network modeling. *Foods*, 9(308), 1-13.

Rani, P. & Tripathy, P.P. (2020). Modelling of moisture migration during convective drying of pineapple slice considering non-isotropic shrinkage and variable transport properties. *Journal of Food Science and Technology*, 57(10), 3748-3761.

Salehi, F. (2019). Color changes kinetics during deep fat frying of kohlrabi (*Brassica oleracea var. gongylodes*) slice. *International Journal of Food Properties,* 22(1), 511-519.

Salehi, F. (2020a). Edible coating of fruits and vegetables using natural gums: A review. *International Journal of Fruit Science,* 20(S2), S570-S589.

Salehi, F. (2020b). Recent applications and potential of infrared dryer systems for drying various agricultural products: A review. *International Journal of Fruit Science,* 20(3), 586-602.

Salehi, F. & Satorabi, M. (2021). Effect of basil seed and xanthan gums coating on colour and surface change kinetics of peach slices during infrared drying. *Acta Technologica Agriculturae,* 24(**3**), 150-156.

Satorabi, M., Salehi, F. & Rasouli, M. (2021a). Effect of edible coatings on the color and surface changes of apricot slices during drying in infrared system. *Food science and technology*, 18(112), 21-30.

Satorabi, M., Salehi, F. & Rasouli, M. (2021b). The influence of xanthan and balangu seed gums coats on the kinetics of infrared drying of apricot slices: GA-ANN and ANFIS modeling. *International Journal of Fruit Science*, 21(1), 468-480.

Seerangurayar, T., Al-Ismaili, A.M., Janitha Jeewantha, L.H. & Al-Habsi, N.A. (2019). Effect of solar drying methods on color kinetics and texture of dates. *Food and Bioproducts Processing*, 116, 227-239.

Silva, K.S., Garcia, C.C., Amado, L.R. & Mauro, M.A. (2015). Effects of edible coatings on convective drying and characteristics of the dried pineapple. *Food and Bioprocess Technology*, 8(7), 1465-1475.