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Evaluating combined effect of microwave power - edible coating on physicochemical properties of dried apple slices

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ABSTRACT

The aim of this research was to investigate the effect of basil, sage and chitosan edible coatings on the physicochemical properties of microwave-dried apple slices. In this study, apple fruit slices were coated with basil, sage and chitosan in three concentrations (0, 0.5 and 1%) and dried at different microwave powers (90, 180 and 360 W). The drying kinetics, color, texture and antioxidant activity of apple slices were investigated.The analysis of the data indicated that the drying of the apple slices happened only in the range of the descending speed period.These data were fitted with 7 different experimental models, among the models, the most suitable models for basil, sage and chitosan coatings were Midili, Approximation of diffusion and Verma, respectively. Midili was able to predict moisture content more accurately than other models. Also, the amount of brightness, adhesivenes, cohesiveness and antioxidant activity increased with the increase of coating concentration and microwave power, but the amount of redness, yellowness, browning, general color change and hardness decreased. In general, edible coating is one of the new methods that increases the shelf life and quality of the final product. Therefore, it is recommended to treat fruits using edible coatings to increase the appearance quality and improve the color at the end of the drying process.

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1. Introduction

Tree apple is a very useful fruit and one of the most important components of the food basket all over the world. In Iran, tree apple is one of the horticultural products of the agricultural sector. According to the information of the Ministry of Agricultural Jihad, the area under apple cultivation was 247,447 hectares with a production of 4,217,172 tons in 2019 [1]. In general, fruits and vegetables are highly perishable products due to their high humidity [2]. Accordingly, compared to other plant products such as seeds, they show relatively high metabolic activity. This metabolic activity continues after harvesting, so it causes most fruits to be perishable and as a result the waste of agricultural products increases [3]. Apples are mostly consumed fresh. Also, it is vulnerable after harvest and prone to spoilage due to high moisture content. One of the effective ways to reduce the waste of agricultural products and prevent them from spoiling in the post-harvest stage is to reduce the moisture level of the product to the optimal level [4]. It reduces them [5]. Drying is one of the most significant and ancient methods of processing and preserving agricultural products, which by reducing the moisture content of the product, causes a reduction in the speed of chemical reactions such as browning and oxidation, and as a result, increases the shelf life of the products. In this way, food can be safely stored with a long shelf life or transported for export (while minimizing waste) [6]. The size and distribution of pores in the tissue of dried fruits is affected by the drying method [7]. Therefore, today the drying process is done in different ways. Microwave drying is known as a new drying method [8]. When microwaves pass through food, polar molecules such as water and salts vibrate and turn into heat energy. Unlike other drying methods where heat penetrates from the surface to the depth, in this method heat is produced in the food itself and therefore prevents the phenomenon of crust hardening [9, 10]. Edible coatings are thin layers of materials that create a barrier against the transfer of moisture, oxygen and substances dissolved in the product [11]. Covering fresh fruits is an alternative method for modified atmosphere storage and can be used by changing the quality and reducing the quantity by modifying and controlling the internal atmosphere of fruits [12]. Edible coatings prevent spoilage and microbial contamination and increase quality in three ways: unfavorable conditions for the growth and activity of microorganisms (such as water and oxygen activity), physical prevention of their penetration into the product, and the presence of antimicrobial compounds in edible coatings [13]. . The use of edible coatings has been noticed since 1995. Investigations showed that the use of edible coatings reduces the apparent density of the product [14]. Basil seed gum is one of the hydrocolloids on which many researches have been conducted recently. In 2010, Hosseini Peror et al. measured the chemical composition of basil seed gum. The polysaccharide extracted from basil seeds contains two main parts of glucomannan (43%) and xylan (24.29%) and also has a small part of glucan (2.31%). Also, the presence of highly branched arabinogalactan in addition to glucomannan and xylan has been reported [15]. The gum obtained from Meru seeds is an anionic galactomannan gum with a medium molecular weight (400 kDa) and a rigid rod structure. Like a rheologically soluble stemMaru seed gum shows loosening behavior with cutting [16]. Chitosan is a new edible coating that has a polysaccharide structure and is composed of glucosamine and N-acetyl glucosamine units with beta (1 and 4) linkages and is obtained from the shell of crustaceans such as crab and shrimp [17]. The most important aspect of drying technology is the mathematical modeling of drying processes and equipment. Among the most important mathematical models, we can mention the logarithmic, pitch, Midili, approximation, Verma, etc.[18]. Many researchers have documented the successful application of edible coatings made using many biopolymers to preserve the nutritional and organoleptic properties of various food products. Mei et al. (2002) showed that using starch and chitosan as an edible coating, pH value, soluble solids, titratable acidity, antioxidant activity, ascorbic acid concentration and phenolic content of dried banana were maintained [19]. Studies show that using the combined method of edible coatings and microwave energy will speed up and improve the drying process of apple slices,

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so the purpose of this research is to investigate the combined effect of microwave power and the concentration of edible coatings (basil, maru and chitosan) on the amount of changes Qualitative characteristics of apple leaves in microwave drying.

2- Materials and methods

2-1- Raw materials

In this research, apples with varieties*Golden Delicious* used. Basil and Marv seeds were procured from the local market of Sari city and their impurities were completely separated. Also, the chemicals used in this research were obtained from Sigma, America and Merck, Germany.

2-2- Preparation of edible coatings

To extract the gum from basil and marjoram seeds, first, the seeds were added to water at a ratio of 1:65 for 20 minutes and placed in a hot water bath at a temperature of 50 degrees Celsius. Then, a laboratory extractor was used to extract the gum from the seeds. The extracted gum was dried in an oven at a temperature of 70 degrees Celsius and after grinding and sieving (with 18 mesh), they were kept in moisture-proof packaging until the desired tests were performed. Also, to prepare the chitosan oral coating, the appropriate amounts of zero, 0.5, and 1% chitosan powder were dissolved in 50 milliliters of acetic acid and 900 milliliters of distilled water. 5 grams of sorbitol plasticizer was used. The pH of the solution was adjusted to 5 using 0.1 normal soda and finally the solution was brought to a volume of 1000 ml for use in tests [20, 21 and 22].

2-3-coating and drying process

Apple fruits were washed by hand and prepared by slicer in the same sizes and their initial weight was determined. Then, apple slices were immersed in coating solutions (for 30 seconds) at ambient temperature conditions, and a number of apple slices without coating were used as controls. After finishing the coating, the samples were transferred to the microwave at different powers of 90, 180 and 360. After drying the samples, the final tests were performed.

2-4- Modeling the drying process

The synthetic model of apple leaf drying was reported based on the moisture ratio (MR). In this research, the moisture content of fruit slices during the drying process was calculated from formula (1):

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (1)$$

that MR moisture ratio (dimensionless), M_t Moisture at time t (kg of water/kg of solid matter), $M_{It\ is}$Equilibrium moisture (kilogram of water/kilogram of solid matter) and M_0 It is the initial moisture content (kg of water/kg of solid matter).

Considering that usually the high initial moisture content of apple leaves (values of $M_{It\ is}$) compared to $M_t$and M_0The number is very small. Therefore, the error caused by not calculating it can be summarized in a simpler way (Formula 2):

$$MR = \frac{M_t}{M_0} \quad (2)$$

At first, ten experimental models were fitted according to the laboratory data and according to the three criteria of the coefficient of determination (R^2), chi-square (χ^2) and root mean square error (RMSE), seven models were selected (Table 1).

Table 1 Drying models used to fit data obtained during microwave drying of apple slices

Model	Equation	References
Midili et al.	$MR = a\exp(-kt^n) + bt$	[23]
Verma et al.	$MR = a\exp(-kt) + (1-a)\exp(-gt)$	[24]
Henderson and Pabis	$MR = a\exp(-kt)$	[25]
Logarithmic	$MR = a\exp(-kt) + c$	[26]
Approximation of diffusion	$MR = a\exp(-kt) + (1-a)\exp(-kbt)$	[27]
Page	$MR = \exp(-kt^n)$	[28]
Newton	$MR = \exp(-kt)$	[29]

The mentioned models were fitted with the humidity ratio obtained from different tests using MATLAB 2010 software:

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{\exp,i})^2}{\sum_{i=1}^{N}(\overline{MR}_{pre} - MR_{\exp,i})^2}\right]$$

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{\exp,i} - MR_{pre,i})^2}{N-m}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(MR_{pre,i} - MR_{\exp,i})^2}{N}}$$

that $MR_{exp,i}$ The experimental humidity ratio, $MR_{pre,i}$i is the predicted moisture ratio, N is the number of observations and m is the number of drying constants.

2-5- Image processing

Huntlab machine was used to check the color indices of dried apple slices and the mean and average of the results and color indices *L (transparency-opacity index), *a (red-green index), *b (yellow-blue index), browning index (BI), overall color changes (ΔE) were obtained.

2-6- histometry

Analysis of textural characteristics (hardness, adhesion and cohesion) was done using a texturizing machine. By applying pressure on the surface of apple slices, this device shows the amount of resistance in grams/force. In this way, the force required to penetrate a 36 mm probe with a needle end at a speed of 50 mm/min into the sample was calculated and reported in newtons.

2-7- Measurement of antioxidant activity

The antioxidant activity of the extracts will be determined by examining the DPPH free radical neutralization effect. For this purpose, dried apple leaf (10 grams) will be mixed with 100 cc of water-ethanol mixture (50-50) and kept on a shaker for 12 hours at room temperature.[1] It will be placed at a speed of 160 rpm. Then the supernatant solution will be filtered by Buchner funnel and Whatman No. 1 filter paper. In the next step, the extract containing the solvent will be spread on the surface of the glass plates and placed in the oven at a temperature of 40 degrees Celsius. After evaporation of the solvent, the extract will be placed in a desiccator until a constant weight is reached. The resulting extract will be kept at 4 degrees Celsius until the test. A solution of 0.006 percent DPPH free radical will be prepared in methanol, then one milliliter of the above solution will be added to the test tubes containing one milliliter of methanol sample solution with different concentrations (depending on the free radical inhibitory power). After vortexing, the test tubes will be kept in a dark place for one hour, and then their absorbance at 512 nm wavelength will be read against the witness by a spectrophotometer, and then the percentage of free radical inhibition will be measured according to the following equation. 30 [.

$$I\% = \left(\frac{A_{sample} - A_{blank}}{A_{sample}}\right) \times 100$$

In this formula A_{blank} Optical absorbance shows the negative control (no extract) and A_{sample} It expresses the amount of optical absorption of the extract.

8-2- Statistical design and data analysis

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Data analysis was done in the form of a completely random design and mean comparison was done using Duncan's test at a confidence level of 95%. Modeling was done with the help of MATLAB software and average comparison was done using SPSS software.

3. Results and Discussion

3-1- Drying kinetics and modeling

Figures 1, 2, and 3 show the simultaneous effect of 90, 180, and 360 W microwave power and zero, 0.5, and 1% concentrations of edible basil, maru, and chitosan coatings on the drying speed of apple leaves. As can be seen, the absence of a period of constant drying speed indicates that the drying process occurred within the range of the decreasing speed period, and in that the change in the moisture content of apple leaves was mainly done by diffusion. In other words, at the beginning of the drying process, the moisture content of the initial product was higher, but during the drying process and the passage of time, the moisture content decreased. The drying conditions determined the time required to reach the final moisture, so that the highest and lowest drying times were related to the 90 and 360 W samples, respectively. Probably due to the direct relationship between the drying speed and the output power of the microwave, with the increase of the microwave and as a result of the increase of the thermal gradient inside the sample, more mass transfer followed and as a result of the increase in the rate of moisture loss of the sample. In other words, increasing the power of the microwave increased the temperature from the inside to the surface of the drying material and reduced the relative humidity of the sample faster. Therefore, the moisture content of the sample decreased in less time. Also, comparing the drying time of apple leaves in three different concentrations of edible coatings of basil, maru and chitosan showed that the highest time was related to the use of low concentration of edible coatings and the lowest drying time was related to the use of the highest concentration.

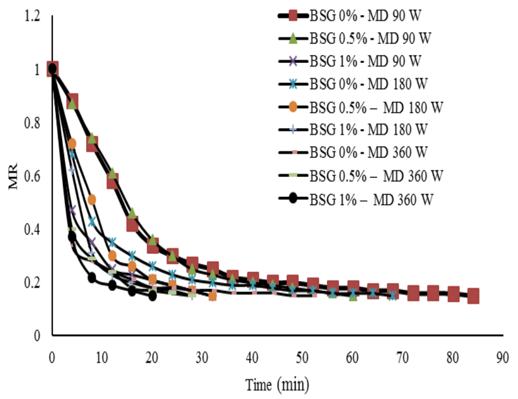

Fig 1 Drying kinetics of apple slices under combined effect ofmicrowave powers and BSG concentrations.

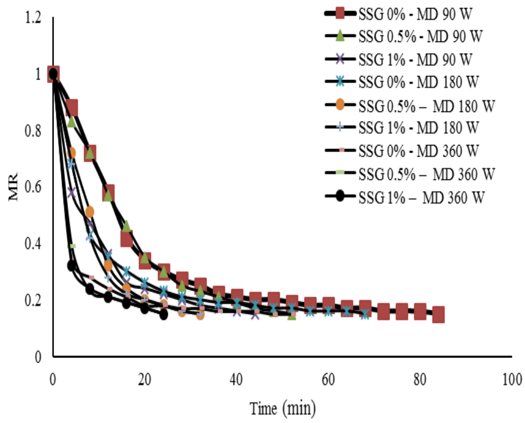

Fig 2 Drying kinetics of apple slices under combined effect of microwave powers and SSG concentrations.

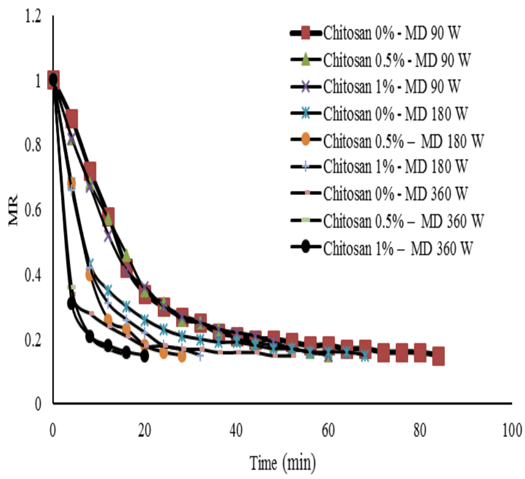

Fig 3 Drying kinetics of apple slices under combined effect of microwave powers and chitosan concentrations.

In addition, the amount of moisture in the coated samples with a concentration of 1% was low, and closeness was observed between the experimental data of the drying curves in all three types of edible coatings of basil, maru and chitosan. Probably, the reason for this is that the type of edible coatings had little effect on the amount of moisture during the drying process, and the main resistance to the diffusion of moisture was more related to the characteristics of the fruit texture. In fact, the epidermis of the fruit has cuticles that are composed of waxy materials and reduce the permeability of the cell walls. To model and predict the drying kinetics of apple leaves at different drying temperatures and concentrations of edible coatings, seven models were fitted to the drying curves obtained from the experimental data. (Tables 2, 3 and 4) and then according to the values of R^2, $h^2$and RMSE of the equations, the most suitable model was selected.

Table 2 Statistical results of different mathematical drying models for apple slices under combined effect of microwave powers andBSG concentrations.

	verma			Approximation of diffusion			Midili			Logarithmic			Page		
	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2
Basil seed gum coating															
BSG 0% – MD 90 W	0.0275	0.0143	0.9887	0.0275	0.0143	0.9887	0.0271	0.0133	0.9895	0.0249	0.0118	0.9907	0.0560	0.0628	0.9505
BSG 0.5+% – MD 90 W	0.0273	0.0097	0.9915	0.0273	0.0097	0.9915	0.0168	0.0003	0.9970	0.0284	0.0105	0.9908	0.0425	0.0252	0.9778
BSG 1% – MD 90 W	0.0091	0.0050	0.9991	0.0091	0.0005	0.9991	0.0063	0.0001	0.9997	0.0288	0.0053	0.9908	0.0105	0.0077	0.9987
BSG 0% – MD 180 W	0.0123	0.0024	0.9971	0.0123	0.0024	0.9971	0.0247	0.0091	0.9891	0.0191	0.0058	0.9930	0.0406	0.0281	0.9667
BSG 0.5% – MD 180 W	0.0267	0.0042	0.9939	0.0267	0.0042	0.9939	0.0262	0.0041	0.9941	0.0286	0.0049	0.9930	0.0415	0.0120	0.9827
BSG 1% – MD 180 W	0.0137	0.0050	0.9921	0.0317	0.0005	0.9921	0.0332	0.0044	0.9930	0.0326	0.0053	0.9916	0.0534	0.0171	0.9731
BSG 0% – MD 360 W	0.0159	0.0030	0.9953	0.0159	0.0030	0.9953	0.0071	0.0005	0.9991	0.0298	0.0106	0.9835	0.0114	0.0017	0.9973
BSG 0.5% – MD 360 W	0.0090	0.0004	0.9993	0.0090	0.0004	0.9993	0.0038	0.0000	0.9999	0.0280	0.0039	0.9931	0.0092	0.0005	0.9991
BSG 1% – MD 360 W	0.0016	0.0000	1	0.0016	0.0000	1	0.0098	0.0001	0.9996	0.0097	0.0002	0.9995	0.0195	0.0015	0.9972

* BSG = Basil seed gum
* MD = Microwave drying

Table 3 Statistical results of different mathematical drying models for apple slices under combined effect of microwave powers and SSG concentrations.

	verma			Approximation of diffusion			Midili			Logarithmic			Page		
	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2
Saliva seed gum coating															
SSG 0% – MD 90 W	0.0275	0.0143	0.9887	0.0275	0.0143	0.9887	0.0271	0.0133	0.9895	0.0249	0.0118	0.9907	0.0560	0.0628	0.9505
SSG 0.5% – MD 90 W	0.0343	0.0129	0.9865	0.0180	0.0035	0.9963	0.0161	0.0026	0.9972	0.0193	0.0041	0.9975	0.0272	0.0089	0.9908
SSG 1% – MD 90 W	0.0217	0.0047	0.9933	0.0217	0.0047	0.9933	0.0157	0.0022	0.9968	0.0282	0.0079	0.9887	0.0224	0.0055	0.9921
SSG 0% – MD 180 W	0.0123	0.0024	0.9971	0.0123	0.0024	0.9971	0.0247	0.0091	0.9891	0.0191	0.0058	0.9930	0.0406	0.0281	0.9667
SSG 0.5% – MD 180 W	0.0226	0.0030	0.9957	0.0226	0.0030	0.9957	0.0144	0.0010	0.9986	0.0272	0.0044	0.9938	0.0392	0.0107	0.9851
SSG 1% – MD 180 W	0.0719	0.0310	0.9537	0.0167	0.0016	0.9975	0.0182	0.0016	0.9975	0.0171	0.0017	0.9974	0.0394	0.1089	0.9838
SSG 0% – MD 360 W	0.0159	0.0030	0.9953	0.0159	0.0030	0.9953	0.0071	0.0005	0.9991	0.0298	0.0106	0.9835	0.0114	0.0017	0.9973
SSG 0.5% – MD 360 W	0.0040	0.0000	0.9999	0.0040	0.0000	0.9999	0.0138	0.0005	0.9990	0.0150	0.0009	0.9984	0.0196	0.0019	0.9965
SSG 1% – MD 360 W	0.0019	0.0000	1	0.0019	0.0000	1	0.0055	0.0000	0.9998	0.0265	0.0028	0.9949	0.0043	0.0000	0.9998

* SSG= Saliva seed gum

* MD = Microwave drying

Table 4 Statistical results of different mathematical drying models for apple slices under combined effect of microwave powers and chitosan concentrations.

	verma			Approximation of diffusion			Midili			Logarithmic			Page		
	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2	RMSE	h^2	R^2
Chitosan coating															
Ch 0% – MD 90 W	0.0275	0.0143	0.9887	0.0275	0.0143	0.9887	0.0271	0.0133	0.9895	0.0249	0.0118	0.9907	0.0560	0.0628	0.9505
Ch 0.5% – MD 90 W	0.0141	0.0025	0.9975	0.0135	0.0021	0.9979	0.0135	0.0021	0.9979	0.0139	0.0025	0.9975	0.0316	0.0140	0.9863
Ch 1% – MD 90 W	0.0148	0.0028	0.9971	0.0028	0.0028	0.9971	0.0172	0.0035	0.9963	0.0141	0.0026	0.9973	0.0333	0.0155	0.9841

Ch 0% – MD 180 W	0.0123	0.0024	0.9971	0.0123	0.0024	0.9971	0.0247	0.0091	0.9891	0.0191	0.0058	0.9930	0.0406	0.0281	0.9667
Ch 0.5% – MD 180 W	0.0242	0.0029	0.9951	0.0242	0.0029	0.9955	0.0201	0.0016	0.9975	0.0268	0.0036	0.9945	0.0423	0.0107	0.9836
Ch 1% – MD 180 W	0.0118	0.0008	0.9987	0.0118	0.0008	0.9987	0.0173	0.0015	0.9977	0.0128	0.0009	0.9985	0.0285	0.0057	0.9911
Ch 0% – MD 360 W	0.0159	0.0030	0.9953	0.0159	0.0030	0.9953	0.0071	0.0005	0.9991	0.0298	0.0106	0.9835	0.0114	0.0017	0.9973
Ch 0.5% – MD 360 W	0.0003	0.0000	1	0.0000	0.0000	1	0.0614	0.0000	0.9999	0.0085	0.0001	0.9997	0.0159	0.0007	0.9985
Ch 1% – MD 360 W	0.0050	0.0000	0.9999	0.0050	0.0000	0.9999	0.0033	0.0000	1	0.0141	0.0006	0.9989	0.0137	0.0007	0.9986

* Ch = Chitosan
* MD = Microwave drying

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The results are based on higher values of R^2 and lower values χ^2 And RMSE showed that for basil coating Midili et al.'s model, for Mero coating the penetration approximation model and for Chitosan coating Midili et al.'s model had the highest modeling accuracy and predicted moisture content changes well. In general, since the drying mechanism with microwaves is from the inside to the surface of the sample, it seems that by using this method, in addition to saving time and energy, the dried final product has a better appearance quality. Firozi et al. (1401) in the investigation of basil and chitosan coatings on drying apple leaves under hot air oven and under vacuum concluded that the Midilli model for basil gum coatings and the penetration approximation model for chitosan coatings are more accurate than other models. predicted the drying process of apple slices [31].

2-3- Color

Edible coating and drying process usually cause color change on the surface of the fruit. The effect of basil, marv and chitosan coatings in three concentrations of 0, 0.5 and 1% in different microwave powers of 90, 180 and 360 watts on the color characteristics of dried apple leaves are shown in tables 5, 6 and 7. Uncoated apple leaves at 360 W had the highest amount of redness (a*), yellowness (b*), browning index (BI) and overall color changes (ΔE) and the lowest brightness (L*), and on the other hand, the coated samples 1% at 90 watts had the lowest amount of redness, yellowness, browning index and overall color changes and the highest brightness. In general, when the microwave power increased, the amount of redness, yellowness, browning index and overall color changes increased, but the brightness decreased, so it can be concluded that the microwave caused an increase in Maillard browning reactions in apple leaves. With the increase in the concentration of the coatings, the amount of brightness increased, but the amount of redness, yellowness, browning index and overall color changes decreased, so it can be said that edible coatings have a protective effect against the color changes of apple slices and reduce the Maillard reaction and, as a result, reduce the density of brown pigments. They are microwaved on the surface of the sample during the drying process. Firozi et al. (1401) investigated the effect of basil and chitosan coatings on hot air and vacuum oven drying of apple leaves and reported that with increasing coating concentration in each of the oven temperatures (hot air and vacuum), the value of L* increased, but the amount of redness, yellowness, browning and overall color change decreased, therefore, the presence of a coating on the apple slices can prevent browning reactions as a protective layer against destructive factors (such as oxygen) [31]. Other researchers also reported that edible coatings act as a protective factor during the drying process and increase the transparency component and reduce the browning of Millard [26, 27 and 28]. Salehi and Kashaninejad (2017) by examining the effect of different drying methods. hot air oven with a temperature of 40 to 80 degrees Celsius, freezing and vacuum oven) on the rheological, textural properties and color changes of basil seed gum, showed that the overall color and brightness changes of basil seed gum decreased with increasing temperature [32]. Also, Satorabi et al. (2021) coated the leaves with xanthan gum and balingo seed (with a concentration of 0.6%) before drying the apricot leaves in the infrared system. These researchers reported that the coated dried apricot leaves were brighter and the coated samples had a higher brightness component. In addition, the brightness component calculated for the control samples, coated with xanthan gum and balingo seed was equal to 44.7, 48.7 and 53.2, respectively [33].

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Table 5 Color changes of dried apple slices under combined effect of microwave powers and BSG concentrations.

Basil seed gum coating	L*	a*	b*	WITH A	ΔE
BSG 0% – MD 90 W	78.42±1.09^{d}	4.25±1.20^{ab}	43.58±0.79^{c}	82.00±0.97^{c}	5.12±0.82^{c}
BSG 0.5% – MD 90 W	80.89±0.74^{b}	2.90±0.77^{c}	29.33±0.31$^{It\ is}$	46.38±0.69^{h}	4.02±0.63^{d}
BSG 1% – MD 90 W	81.59±0.48^{a}	2.69±0.31^{c}	28.14±0.62^{f}	44.24±0.47^{i}	3.15±0.50^{d}
BSG 0% – MD 180 W	75.39±1.32^{d}	5.25±0.90^{a}	45.72±0.81^{b}	92.94±1.40^{b}	6.25±1.20^{b}
BSG 0.5% – MD 180 W	78.49±0.54^{d}	3.10±0.42^{b}	29.39±0.79$^{It\ is}$	53.79±0.71$^{It\ is}$	5.02±0.37^{c}
BSG 1% – MD 180 W	79.14±0.31^{c}	2.90±0.37^{c}	29.24±0.63$^{It\ is}$	48.59±0.48^{g}	3.62±0.61^{d}
BSG 0% – MD 360 W	73.12±1.12^{g}	5.95±0.82^{a}	46.12±0.86^{a}	99.17±1.07^{a}	7.11±1.40^{a}
BSG 0.5% – MD 360 W	74.18±0.59^{f}	3.40±0.68^{ab}	30.38±0.65^{d}	55.19±0.69^{d}	5.18±0.77^{c}
BSG 1% – MD 360 W	75.98±0.33$^{It\ is}$	3.20±0.40^{ab}	30.17±0.01^{d}	50.30±0.74^{f}	3.82±0.81^{d}

* BSG = Basil seed gum
* MD = Microwave drying

Table 6 Color changes of dried apple slices under combined effect of microwave powers and SSG concentrations.

Saliva seed gum coating	L*	a*	b*	WITH A	ΔE
SSG 0% – MD 90 W	78.42±1.09^{b}	4.25±1.2^{ab}	43.58±0.79^{b}	82.00±0.97^{c}	5.12±0.82^{c}
SSG 0.5% – MD 90 W	79.72±0.41^{ab}	3.10±0.42^{b}	30.20±0.41^{c}	50.89±0.96^{g}	4.18±0.35^{d}
SSG 1% – MD 90 W	80.63±0.23^{a}	2.50±0.17^{c}	29.52±0.72^{d}	46.26±0.52^{h}	3.42±0.42$^{It\ is}$
SSG 0% – MD 180 W	75.39±1.32^{d}	5.25±0.90^{a}	45.72±0.81^{a}	92.94±1.40^{b}	6.25±1.20^{b}
SSG 0.5% – MD 180 W	76.59±0.42^{c}	3.50±0.61^{ab}	30.63±0.61^{c}	54.50±0.64$^{It\ is}$	5.12±0.79^{c}
SSG 1% – MD 180 W	78.81±0.21^{b}	3.20±0.22^{ab}	29.82±0.52^{d}	50.32±0.59^{g}	3.89±0.33$^{It\ is}$
SSG 0% – MD 360 W	73.12±1.12^{f}	5.95±0.82^{a}	46.12±0.86^{a}	99.17±1.07^{a}	7.11±1.14^{a}
SSG 0.5% – MD 360 W	73.96±0.61^{f}	3.80±0.71^{ab}	30.53±0.71^{c}	56.60±0.67^{d}	5.25±0.65^{c}
SSG 1% – MD 360 W	74.52±0.33$^{It\ is}$	3.50±0.31^{ab}	30.31±0.35^{c}	52.49±0.40^{f}	4.10±0.47^{d}

* SSG= Saliva seed gum
*MD = Microwave drying

Table 7 Color changes of dried apple slices under combined effect of microwave powers andchitosan concentrations.

Chitosan coating	L*	a*	b*	WITH A	ΔE
Ch 0% – MD 90 W	78.42±1.09^{b}	4.25±1.20^{b}	43.58±0.79^{c}	82.00±0.97^{c}	5.12±0.82^{c}
Ch 0.5% – MD 90 W	78.58±0.42^{b}	3.60±0.38^{c}	31.59±0.59$^{It\ is}$	51.01±0.65^{h}	5.02±0.41^{c}
Ch 1% – MD 90 W	79.83±0.37^{a}	3.42±0.50^{c}	30.62±0.42^{f}	50.67±1.12^{i}	4.42±0.58^{d}

Ch 0% – MD 180 W	75.39±1.32^{d}	5.25±0.90^{a}	45.72±0.81^{b}	92.94±1.40^{b}	6.25±1.20^{b}
Ch 0.5% – MD 180 W	76.13±0.67^{c}	3.90±0.21^{c}	32.19±0.49^{d}	55.68±0.49^{f}	5.10±1.61^{c}
Ch 1% – MD 180 W	78.64±0.17^{b}	3.80±0.30^{c}	31.18±0.32$^{\text{I t is}}$	52.74±0.68^{g}	4.64±0.83^{d}
Ch 0% – MD 360 W	73.12±1.12^{f}	5.95±0.82^{a}	46.12±0.86^{a}	99.17±1.07^{a}	7.11±1.14^{a}
Ch 0.5% – MD 360 W	73.61±0.25^{f}	4.75±0.59^{b}	32.50±0.61^{d}	68.37±0.43^{d}	5.50±0.59^{c}
Ch 1% – MD 360 W	77.08±0.10^{c}	4.32±0.71^{b}	31.65±0.50$^{\text{I t is}}$	63.88±0.64$^{\text{I t is}}$	4.92±0.81^{c}

* Ch = Chitosan
* MD = Microwave drying

3-3- texture

Textural properties such as firmness, adhesion, and adhesion are essential mechanical properties of the sample. The effects of edible basil, marv, and chitosan coatings in concentrations of zero, 0.5, and 1% and microwave powers of 90, 180, and 360 watts on the textural characteristics of apple leaves are shown in Tables 8, 9, and 10. it has been shown. Edible coatings with increasing microwave power had significant effects on the hardness, adhesion and consistency of dried apple leaves (P<0.05). As can be seen, the dried apple leaves with 1% coating in 90 W microwave had the least stiffness and the most adhesion and cohesion, while the samples dried without coating in 360 W microwave had the highest stiffness and the least adhesion and adhesion. The results showed that with the increase of microwave power (at the same concentration levels as the coating), the stiffness value increased, but the adhesion and cohesion decreased. On the other hand, with the increase in the concentration of each of the basil, marvo and chitosan coatings in the same strength, the stiffness value decreased and the adhesion value increased. Firozi et al. (1401) by investigating the effect of basil and chitosan coatings on Hot air oven drying and under vacuum of apple leaves reported that by increasing the concentration of basil and chitosan coatings at the same temperatures, the amount of stiffness decreased and the amount of adhesion and cohesion increased, and this trend was observed in each of the methods of hot air oven drying and A vacuum was observed [31]. Rajendran and Marikani (2004) stated that the resistance of coated samples usually increases with increasing microwave powers [34]. Also, based on the research of Ogawa (1991), edible coatings show higher mechanical properties and have higher tensile strength, and the mechanical strength of edible coatings also depends on the preparation method and their concentration percentage [36]. In general, in this research, the textural characteristics of different coatings in different microwave powers were almost similar.

Table 8 Textural properties of dried apple slices under combined effect of microwave powers and BSG concentrations.

Basil seed gum coating	Hardness	Adhesivenes	Cohesivenes s
BSG 0% – MD 90 W	95.47±1.42^{c}	190.42±1.03$^{\text{I t is}}$	118.35±1.14$^{\text{I t is}}$
BSG 0.5% – MD 90 W	72.43±0.61^{of}	238.19±0.74^{b}	149.24±1.27^{b}
BSG 1% – MD 90 W	70.92±0.42$^{\text{It is}}$	240.61±0.29^{a}	151.27±0.42^{a}
BSG 0% – MD 180 W	101.36±1.17^{b}	183.27±0.72^{f}	107.72±0.93^{f}
BSG 0.5% – MD 180 W	75.62±0.69^{C}	234.18±0.63^{c}	145.42±0.88^{c}
BSG 1% – MD 180 W	73.15±0.43^{d}	237.59±0.33^{b}	149.47±0.65^{b}

BSG 0% – MD 360 W	112.73±1.62^{a}	177.82±1.14^{g}	100.45±0.97^{g}
BSG 0.5% – MD 360 W	79.47±1.12^{b}	230.72±0.75^{d}	140.81±0.78^{d}
BSG 1% – MD 360 W	76.17±0.82^{c}	233.27±0.42^{c}	144.72±1.11^{c}

* BSG = Basil seed gum
* MD = Microwave drying

Table 9 Textural properties of dried apple slices under combined effect of microwave powers and SSG concentrations.

Saliva seed gum coating	Hardness	Adhesivenes	Cohesiveness
SSG 0% – MD 90 W	95.47±1.42^{c}	190.42±1.03^{f}	118.35±1.14^{f}
SSG 0.5% – MD 90 W	74.12±0.39^{f}	234.15±0.79^{bc}	146.34±0.62^{b}
SSG 1% – MD 90 W	72.28±0.51^{g}	237.72±0.83^{a}	149.61±0.39^{a}
SSG 0% – MD 180 W	101.36±1.17^{b}	183.27±0.72^{g}	107.72±0.93^{g}
SSG 0.5% – MD 180 W	76.49±0.26^{Itis}	231.61±0.75^{d}	143.72±1.12^{c}
SSG 1% – MD 180 W	74.91±0.47^{f}	235.17±0.69^{b}	147.40±0.43^{b}
SSG 0% – MD 360 W	112.73±1.62^{a}	177.82±1.14^{h}	100.45±0.97^{h}
SSG 0.5% – MD 360 W	81.25±0.59^{d}	229.18±0.52^{Itis}	138.12±0.69^{Itis}
SSG 1% – MD 360 W	78.73±0.38^{Itis}	23.42±0.49^{c}	141.87±0.54^{d}

* SSG= Saliva seed gum
* MD = Microwave drying

Table 10 Textural properties of dried apple slices under combined effect of microwave powers and chitosan concentrations.

Chitosan coating	Hardness	Adhesivenes	Cohesiveness
Ch 0% – MD 90 W	95.47±1.42^{c}	190.42±1.03^{f}	118.35±1.14^{Itis}
Ch 0.5% – MD 90 W	75.36±0.29^{f}	229.52±0.52^{bc}	142.39±0.71^{b}
Ch 1% – MD 90 W	73.69±0.71^{g}	233.43±1.04^{a}	146.76±0.43^{a}
Ch 0% – MD 180 W	101.36±1.17^{b}	183.27±0.72^{g}	107.72±0.93^{f}
Ch 0.5% – MD 180 W	78.67±0.42^{Itis}	226.67±0.63^{d}	138.82±0.51^{c}
Ch 1% – MD 180 W	75.86±0.54^{f}	230.31±0.52^{b}	142.25±0.37^{b}
Ch 0% – MD 360 W	112.73±1.62^{a}	177.82±1.14^{h}	100.45±0.97^{g}
Ch 0.5% – MD 360 W	82.62±1.07^{d}	224.69±0.81^{Itis}	135.37±0.39^{d}
Ch 1% – MD 360 W	79.95±0.48^{Itis}	228.07±0.32^{c}	138.79±0.74^{c}

* Ch = Chitosan
* MD = Microwave drying

3-4- antioxidant activity

In Tables 11, 12 and 13, the results of the effect of edible coatings and the drying process with a microwave oven show the changes in the antioxidant activity by DPPH free radical inhibition methods of dried apple leaves. In general, with the increase of microwave power at the same coated concentrations, the amount of DPPH free radical inhibition decreased, which indicates the loss of antioxidant compounds due to increased oxidation during the microwave drying process, while Ozcan-Sinir et al. 2018) reported that drying increases phenolic compounds and antioxidant properties in kumquat [35]. With the increase in the concentration of edible coatings (Basil, Meru and Chitosan), the amount of antioxidant activity increased, the reason for this can be attributed to the antioxidant property of the coatings themselves and also their high ability to prevent the Maillard reaction (during drying). Firozi et al. (1401) stated that basil and chitosan edible coatings increase antioxidant properties in drying apple leaves with hot air oven and vacuum oven [31]. Oliveira and Silva (2017) used three different edible coatings including pectin (with and without glycerol) and soy protein isolate as drying pretreatment and evaluated their effect on mass transfer kinetics, vitamin C retention and color retention during the process. The results of these two researchers indicated that edible coatings (pectin and protein isolate) preserve antioxidant compounds in kiwi leaves to a greater extent [36].

Table 11 Antioxidant anctivity of dried apple slices under combined effect of microwave powers and BSG concentrations.

Basil seed gum coating	500 ppm	1000 ppm	2000 ppm	4000 ppm	8000 ppm
BSG 0% – MD 90 W	10.21±0.31$^{E}_{d}$	12.93±0.25^{Df}	22.41±0.37^{cf}	33.18±0.30$^{B}_{g}$	38.62±0.49^{At}
BSG 0.5% – MD 90 W	11.98±0.26$^{E}_{c}$	22.46±0.39$^{D}_{c}$	27.16±0.41$^{C}_{c}$	50.21±0.54$^{B}_{b}$	59.17±0.71$^{A}_{b}$
BSG 1% – MD 90 W	15.37±0.47$^{Y}_{es}$	25.18±0.42$^{A}_{nd}$	30.73±0.29$^{T}_{hat}$	54.16±0.62$^{N}_{ot}$	64.17±0.72$^{A}_{a}$
BSG 0% – MD 180 W	9.34±0.34^{Fe}	11.98±0.21$^{D}_{g}$	20.12±0.38$^{C}_{g}$	29.53±0.43$^{B}_{h}$	35.24±0.36$^{A}_{h}$
BSG 0.5% – MD 180 W	11.45±0.38$^{E}_{c}$	21.51±0.43$^{D}_{d}$	24.91±0.5^{This}	45.37±0.32$^{B}_{e}$	19.54±0.34$^{B}_{ut}$
BSG 1% – MD 180 W	14.73±0.52$^{E}_{b}$	24.32±0.39$^{D}_{b}$	28.62±0.54$^{C}_{b}$	49.81±0.67$^{B}_{c}$	58.27±0.51$^{A}_{nd}$
BSG 0% – MD 360 W	8.25±0.19^{Ff}	11.36±0.12$^{E}_{g}$	18.62±0.24$^{C}_{h}$	27.19±0.36$^{W}_{ith\ a}$	32.16±0.42^{Ai}
BSG 0.5% – MD 360 W	11.16±0.22$^{E}_{c}$	19.49±0.17^{Of}	22.42±0.33^{Cf}	42.64±0.41^{Bf}	51.72±0.35^{Of}
BSG 1% – MD 360 W	14.39±0.42$^{E}_{b}$	22.81±0.36$^{D}_{c}$	25.87±0.27$^{C}_{d}$	46.35±0.43$^{B}_{d}$	55.26±0.72$^{A}_{d}$

* Means within a row with the same uppercase letters are not significantly different at P>0.05.
* Means within a column with the same lowercase letters are not significantly different at P>0.05.
* BSG = Basil seed gum
* MD = Microwave drying

Table 12 Antioxidant anctivity of dried apple slices under combined effect of microwave powers and SSG concentrations.

Saliva seed gum coating	500 ppm	1000 ppm	2000 ppm	4000 ppm	8000 ppm
SSG 0% – MD 90 W	10.21±0.31$^{E}_{d}$	12.93±0.25^{Df}	22.41±0.37^{Cf}	33.18±0.30$^{B}_{g}$	38.62±0.49^{At}
SSG 0.5% – MD 90 W	11.42±0.21$^{E}_{c}$	22.12±0.21$^{D}_{c}$	26.82±0.49$^{C}_{c}$	49.12±0.52$^{B}_{b}$	57.16±0.78$^{A}_{b}$
SSG 1% – MD 90 W	14.92±0.47$^{Y}_{es}$	24.62±0.52$^{A}_{nd}$	29.42±0.37$^{T}_{hat}$	53.73±0.67$^{N}_{ot}$	61.00±0.63$^{A}_{a}$
SSG 0% – MD 180 W	9.34±0.34^{Eh}	11.98±0.21$^{D}_{g}$	20.12±0.38$^{C}_{h}$	29.53±0.43$^{B}_{h}$	35.24±0.36$^{A}_{h}$

SSG 0.5% – MD 180 W	11.12±0.17^{E} c	21.02±0.35^{D} d	24.14±0.30^{T} his	43.92±0.51^{B} e	52.26±0.54^{B} ut
SSG 1% – MD 180 W	14.20±0.52^{Y} es	23.94±0.31^{D} b	27.91±0.36^{C} b	47.62±0.44^{B} c	55.14±0.43^{A} nd
SSG 0% – MD 360 W	8.25±0.19^{If}	11.36±0.12^{E} g	18.62±0.24^{T} here	27.19±0.36^{W} ith a	32.16±0.42^{Ai}
SSG 0.5% – MD 360 W	10.92±0.24^{E} d	18.81±0.25^{Of}	21.90±0.19^{C} g	41.17±0.42^{Bf}	49.32±0.44^{Of}
SSG 1% – MD 360 W	13.84±0.34^{E} b	22.24±0.40^{D} c	25.14±0.47^{C} d	44.98±0.63^{B} d	53.42±0.57^{A} d

* Means within a row with the same uppercase letters are not significantly different at P>0.05.
* Means within a column with the same lowercase letters are not significantly different at P>0.05.
* SSG = Saliva seed gum
* MD = Microwave drying

Table 13 Antioxidant anctivity of dried apple slices under combined effect of microwave powers and chitosan concentrations.

Chitosan coating	500 ppm	1000 ppm	2000 ppm	4000 ppm	8000 ppm
Ch 0% – MD 90 W	10.21±0.31^{E} c	12.93±0.25^{Df}	22.41±0.37^{C} d	33.18±0.30^{B} g	38.62±0.49^{At}
Ch 0.5% – MD 90 W	10.92±0.21^{E} c	19.92±0.27^{D} c	24.61±0.35^{C} c	48.24±0.38^{B} b	56.27±0.42^{A} b
Ch 1% – MD 90 W	13.72±0.45^{Y} es	22.82±0.31^{A} nd	28.17±0.42^{T} hat	51.62±0.4^{Not}	60.41±0.47^{A} a
Ch 0% – MD 180 W	9.34±0.34^{Fd}	11.98±0.21^{D} g	20.12±0.38^{T} his	29.53±0.43^{B} h	35.24±0.36^{A} h
Ch 0.5% – MD 180 W	10.61±0.27^{E} c	18.12±0.19^{D} d	22.75±0.21^{C} d	42.19±0.44^{B} e	51.52±0.37^{B} ut
Ch 1% – MD 180 W	13.25±0.36^{Y} es	20.72±0.22^{D} b	25.91±0.3^{Cb}	47.25±0.39^{B} c	54.12±0.49^{A} nd
Ch 0% – MD 360 W	8.25±0.19^{Fe}	11.36±0.12^{E} g	18.62±0.24^{C} g	27.19±0.36^{W} ith a	32.16±0.42^{Ai}
Ch 0.5% – MD 360 W	9.81±0.24^{Ed}	15.83±0.33^{Of}	19.61±0.16^{Cf}	39.71±0.34^{Bf}	47.64±0.43^{Of}
Ch 1% – MD 360 W	12.91±0.17^{E} b	18.74±0.24^{D} d	22.54±0.32^{C} d	43.51±0.45^{B} d	52.61±0.36^{A} d

* Means within a row with the same uppercase letters are not significantly different at P>0.05.
* Means within a column with the same lowercase letters are not significantly different at P>0.05.
* Ch = Chitosan
* MD = Microwave drying

4 - Conclusion

In this research, the simultaneous effect of microwave power (90, 180 and 360 W) and concentration (zero, 0.5 and 1%) of edible basil, maru and chitosan coatings on drying kinetics, color, texture and antioxidant properties of dried apple slices. was investigated. The results showed that for the coating of basil, marv and chitosan, according to Midili et al.'s models, penetration approximation and Midili et al.'s models have R^2 More and χ^2 and RMSE were lower, so they explained well the removal of moisture from apple slices during the microwave drying process. By reducing the microwave power or increasing the concentration of the food coating, the amount of redness, yellowness, browning index, general color changes, firmness decreased, but the brightness, adhesion, cohesiveness and antioxidant activity increased, so it can be concluded that microwaves increase the browning reactions. The formation of Maillard in apple leaves and the higher concentration of food coatings had a protective effect against the color changes of apple leaves and reduced the Maillard reaction during the drying process.

5- Resources

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اثر ترکیبی توان مایکروویو – غلظت پوشش خوراکی بر خصوصیات فیزیکوشیمیایی برش‌های میوه سیب خشک شده

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چکیده

هدف از این پژوهش، بررسی اثر پوشش‌های خوراکی ریحان، مرو و کیتوزان بر خصوصیات فیزیکوشیمیایی برش‌های خشک‌شده میوه سیب در مایکروویو بود. در این پژوهش، برش‌های میوه سیب در سه غلظت (۰، ۰/۵ و ۱ درصد) باریحان، مرو و کیتوزان پوشش‌دهی شدند و تحت تیمار با امواج مایکروویو در توان‌های مختلف (۹۰، ۱۸۰ و ۳٦۰ وات) قرار گرفتند. مولفه‌های سینتیک خشک‌کردن، رنگ، بافت و فعالیت آنتی‌اکسیدانی برگه‌های سیب بررسی شد. تجزیه و تحلیل داده‌ها حاکی از آن بود که خشک‌کردن ورقه‌های سیب تنها در محدوده دوره سرعت نزولی اتفاق افتاد. این داده‌ها با ۷ مدل تجربی متفاوت برازش شدند که از بین این مدل‌ها، مناسب‌ترین مدل براپوشش‌هایصمغریحان، مرو و کیتوزان به ترتیب، مدل میدیلی و همکاران، تقریب و ورما بود که میدیلی و همکاران با دقت بیشتری نسبت به سایر مدل‌ها قادر به پیش‌بینی محتوی رطوبتی بود. همچنین، مقدار مولفه‌های روشنایی، چسبندگی، پیوستگی و فعالیت آنتی-اکسیدانی با افزایش غلظت پوشش و توان ماکروویو، افزایش اما مقدار قرمزی، زردی، قهوه‌ای شدن، تغییر رنگ کلی و سفتی کاهش یافت. به‌طور کلی، پوشش‌دهی خوراکی یکی از روش‌های نوین که سبب افزایش مدت‌زمان نگه‌داری و کیفیت محصول نهایی می‌شود. لذا، تیمار میوه‌ها با استفاده از پوشش‌های خوراکی برای افزایش کیفیت ظاهری، بهبود رنگ در انتهای فرآیند خشک-کردن پیشنهاد می‌گردد.