Effects of ascorbic acid, salt, lemon juice, and honey on drying kinetics and sensory characteristic of dried mango

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Summary

The effects of ascorbic acid, salt solution, lemon juice, and honey pretreatment on the drying kinetics and sensory characteristics were studied. Pretreatments used affected the effective moisture diffusivity and rehydration properties of the dried mangoes. The effective moisture diffusivity values were 2.22×10^{-10} m^2/s for ascorbic acid, 1.80×10^{-10} m^2/s for salt solution, 2.01×10^{-10} m^2/s for lemon juice, 1.93×10^{-10} m^2/s for honey pretreated mangoes, and 2.31×10^{-10} m^2/s for the control slices. Pretreatments enhanced the drying rate potential of mangoes. Among the thin-layer drying models fitted to the experimental data, the Middil model gave the best fit. The ascorbic acid pretreated samples were the best while the salt solution ones were the poorest with respect to reconstitution capacity. Consumer studies for overall preference for taste, colour, texture, flavour and chewiness of the dried products revealed that there was a higher preference for honey pretreated dried samples followed by the ascorbic acid, control, lemon juice, and salt solution pretreated samples. The results demonstrate that these pretreatments can be applied to enhance the moisture transport during drying and the quality of the dried products.

Keywords: mango slices, drying, modeling, effective moisture diffusivity, rehydration, sensory properties

Introduction

Mango (Mangifera indica) has been used as fruit for food purposes. In the diet of people, mango plays an important role; it provides the diet with colour, phytochemicals, and nutrients. The average mango composition is: water (83 g/100g), carbohydrate (15 g/100 g), sugar (13.7 g/100g), dietary fiber (1.6 g/100g), fats (0.38 g/100g), proteins (0.82 g/100 g), vitamins (mainly vitamin C: 36 mg/100g), minerals (mainly potassium 168 mg/100g, and phosphorous 14 mg/100g). The pulp is found to contain pigment carotenoids, polypenols, and omega-3 and 6 polyunstaturated fatty acids (USDA, 2010). Fresh ripe mango contains more than 80 g/100 g water within a soft-pulpy cell wall structure, which is responsible for the fast deterioration at postharvest. Therefore, the right postharvest processing method is required to prolong the shelf-life of mango. Drying is among the methods for producing high quality products, which can be consumed directly or used as ingredient for the preparation of chutneys, cakes, muesli, and oat granola. Drying can be defined as a simultaneous heat and mass transfer operation in which water activity of a material is lowered by the removal of water by evaporation into an unsaturated gas stream (Khaisheh et al., 1997). The basic objective in drying food products is the removal of water to a certain level at which microbial spoilage is avoided. Reduction of moisture content of food to between 10 and 20 % w.b. prevents bacteria, yeast, mold and enzyme damage. Longer shelf life and significant reduction in the volume and weight of the product are the major reasons for the popularity of dried food material (Prabhanjan et al., 1995; Andress and Harrison, 2006). The drying process causes many undesirable changes such as shinkage, texture hardness, colour changes, and reduction of functionality of the products.

Pretreatment is an essential step in the processing of food materials (Senadeera et al., 2000). Studies show that pretreatment can speed up drying rate, improve quality of dried product, prevent browning, and help keep volatile compounds (Jayaraman and Gupta, 2006; Singh et al., 2008; Suhaila and Tok, 1994). Studies conducted by Xiao et al. (2009), Singh et al. (2008), Gazanfer and Sefa (2006), and Doymaz (2004) showed that chemical pretreatment could significantly accelerate the drying process and remarkably improve the quality of dried sweet potatoes, mushooms, red pepper, and plums products. Quality is the product's ability to satisfy the needs of the user. In industrial food processing, the goal is to satisfy the consumer demand with product quality at

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a least cost. Quality is usually characterized by its nutritional value in terms of vitamin loss and protein denaturation, safety (browning, level of microbiological and toxicological contaminants) and acceptability with respect to colour, aroma, texture etc (Timoumia et al., 2007; Vadivambal and Jayas, 2007). Freshness, expected appearance, flavor, texture etc are indicators of good quality.

Therefore, the objective of the study was to investigate the effect of ascorbic acid, lemon juice, salt solution, and honey as pretreatments on drying kinetics such as moisture diffusivity, rehydrated properties and sensory characteristics (taste, flavour, colour, texture, and chewiness) of the dried mangoes.

Materials and Methods

Sample preparation

Fresh mango fruits from the Kent cultivar were procured from the 'Abura' Market, Cape Coast, Ghana, and brought to the laboratory to find the initial moisture content according to AOAC (1990) method. The mangoes were cleaned, washed, peeled, and stone removed. It was sliced manually into 5 mm thickness with a sharp knife before pretreatment. The initial total soluble solid (Brix) was determined by refractometry to be 15.4 ^{o}Brix. Uniform slices of dimension (6.0 × 3.0 cm) were subjected to pretreatment of Ascorbic acid (AA, 4.17 mg/mL), salt solution (SS, 0.011 g/mL), lemon juice (LJ, 0.5 v/v), and honey dip (HD, 0.3 v/v) for 10 minutes.

Air drying

After the removal of the samples from the various solutions, they were drained and blotted with absorbent paper to remove excess solution. The samples (120g) were dried in thin layers on a round stainless steel meshed bowl and dried at a temperature of 70 ^{o}C in a Gallenkamp (Sanyo OMT oven) cabinet dryer. Selection of this temperature was on the basis of industrial practices and optimization studies carried out on a previous study (Abano and Sam-Amoah, 2011). During drying, the samples were weighed with a Satorius 2200S (Germany) balance of an accuracy of 0.01g every 2 h interval till the dynamic equilibrium between the sample moisture content and drying air humidity was reached, when the sample weight became constant. The average moisture content was used to plot the drying characteristic curves for the various pretreated mango slices with a dimensionless moisture ratio against drying time. On completion of drying, the samples were cooled in desiccators and packed into tightly zipped transparent bags for further analysis.

Drying kinetics of mango slices

The drying kinetics of mango slices were expressed in terms of empirical models, where the experimental data obtained was plotted in the form of a dimensionless moisture ratio (MR) against drying time (expressed in h). Fick's second law of diffusion Eq. [1] has been widely used to describe the drying process during the falling rate period for agricultural materials

$$\frac{\partial M}{\partial t} = \mathrm{D}_{\mathrm{eff}} \nabla^2 M \qquad (1)$$

Eq. [1] is solved by Crank (1975) for an infinite slab, assuming undimensional moisture movement volume change, constant temperature and diffusivity coefficient, and negligible external resistance. The solution is of the form:

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left[\frac{-(2n+1)^2 \pi^2 D_{eff} t}{4L^2}\right] \qquad (2)$$

For long drying times, Eq. [2] simplifies to a limiting form of the diffusion equation as given by Eq. [3]

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \exp\left(\frac{-\pi^2 D_{eff} t}{4L^2}\right) \qquad (3)$$

From Eq. [3], D_{eff} of the mango slices was obtained from the slope (K) of the graph of natural logarithm of MR (*lnMR*) against the drying time. *lnMR* versus time results in a straight line with negative slope and K is related to $\mathrm{D}_{\mathrm{eff}}$ by Eq [4].

$$K = \frac{\pi^2 D_{eff}}{4L^2} \qquad (4)$$

where MR is the dimensionless moisture ratio, D_{eff} is the effective moisture diffusivity (m^2/s), L is half the thickness of slice of the sample (m), M is the moisture content at any time, t, M_e is the equilibrium moisture content, and M_o is the initial moisture content.

The drying curves were fitted to the Page (1949) and Midilli et al. (2002) semi-empirical drying model (Eq. 5 and 6 respectively) widely used in scientific literature to describe the thin-layer drying kinetics of fruits and vegetables. *k* is the drying rate constant in h^{-1}, *n, a, and b* are the dimensionless model parameters, and *t* is the process time in h. Regression and correlation analysis are very useful tools in modeling the drying behavior of biological materials (Erbay and Icier, 2008). The primary criteria used to determine the goodness of fit to the Page (1949) and Midilli et al. (2002) models were the determination coefficient (R^2) [Eq. 7], the mean absolute error (MAE) [Eq. 8] and the reduced chi-square (χ^2) [Eq. 9]. The highest R^2, lowest χ^2 and MAE were used to determine the goodness of fit. Several workers have used these criteria to select the best models for drying mistletoe (Köse and Erentürk, 2010), onion slices (Mota et al., 2010), aromatic plants (Akpinar, 2006), olive leaves (Erbay and Icier, 2008), okra (Doymaz, 2005), thyme (Doymaz, 2010), and aloe vera (Vega-Galvez et al., 2007).

$$MR = \exp(-\mathrm{kt}^{\mathrm{n}}) \qquad (5)$$

$$MR = a\exp(-\mathrm{kt}^{\mathrm{n}}) + \mathrm{bt} \qquad (6)$$

$$R^2 = \frac{N\sum_{i=1}^{N} MR_{\mathrm{pred},i}MR_{\mathrm{expt},i} - \sum_{i=1}^{N} MR_{\mathrm{pred},i}\sum_{i=1}^{N} MR_{\mathrm{expt\,x},i}}{\sqrt{\left(N\sum_{i=1}^{N} MR^2_{\mathrm{pred},i} - \left(\sum_{i=1}^{N} MR_{\mathrm{pred},i}\right)^2\right)\left(N\sum_{i=1}^{N} MR^2_{\mathrm{expt},i} - \left(\sum_{i=1}^{N} MR_{\mathrm{expt},i}\right)^2\right)}} \qquad (7)$$

$$\mathrm{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|MR_{\mathrm{expt},i} - MR_{pred,i}\right| \qquad (8)$$

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{\mathrm{expt},i} - MR_{pred,i}\right)^2}{N - z} \qquad (9)$$

where $MR_{\mathrm{expt},i}$ and $MR_{\mathrm{pred},i}$ are the experimental and predicted dimensionless *MR* respectively, i is the experimental observation in a given N total number of observations, and z is the number of constants in the model. The constants of the models were determined with nonlinear regression of SPSS 16.0 (2007).

Rehydration characteristics

The rehydration tests were conducted to assess the reconstitution qualities of the dried mango slices. Five grams of the dried samples was soaked in 200 mL of water for 10 minutes at room temperature. The ratio of mass of rehydrated and dried samples was used to find the rehydration ratio (RR) [Eq. 10] and coefficient of rehydration (COR) [Eq. 11].

$$RR = \frac{C}{D} \qquad (10)$$

$$COR = \frac{C}{D} \times \frac{100 - A}{100 - B} \qquad (11)$$

where *A* is the moisture content of samples before drying (% w.b), *B* is the moisture content of the dried samples (% w.b), *C* is the mass of the sample after soaking (g), and *D* is the mass of the samples before soaking (g).

Sensorial analysis

A 20-member semi-trained panel evaluated the quality of the dried mango slices in terms of their physio-organoleptic properties such as taste, flavour, colour, texture, and chewiness. The most preferred sample was also recorded from the sensory analysis. The panelists were asked to check the dried mango slices employing the quantitative descriptive analysis on structured hedonic test (scale from 1 = extremely poor to 7 = excellent) using the technique suggested by Larmond (1985).

Results and Discussion

Hot air drying

The moisture content of the fresh ripe mango slices for both the control and the pretreated samples was found to be in the range of 82.3±1.75 % (w.b) which reduced to 11.91 % wet basis (14.0 % dry basis) and 20.09 % (25.0 dry basis) after air drying at 70 °C for 14 h. Fig. 1 displays the variation in moisture content with drying time for the control and various pretreated mango slices. The analysis of variance of the mean moisture content as a function of drying time is shown in Table 1. As expected, the moisture loss followed an exponential decay and it took nearly 14 h of drying to reduce moisture in the fresh mangoes to equilibrium moisture content. It can be seen that after 14 h of drying, the honey dip (HD) pretreated sample retained the highest amount of moisture (20.09 % w.b), followed by the control (CO) samples (17.29 % w.b), the salt solution (SS) samples (16.95 % w.b), the lemon juice (LJ) samples (12.28 % w.b) and finally the ascorbic acid (AA) pretreated samples (11.91 % w.b).

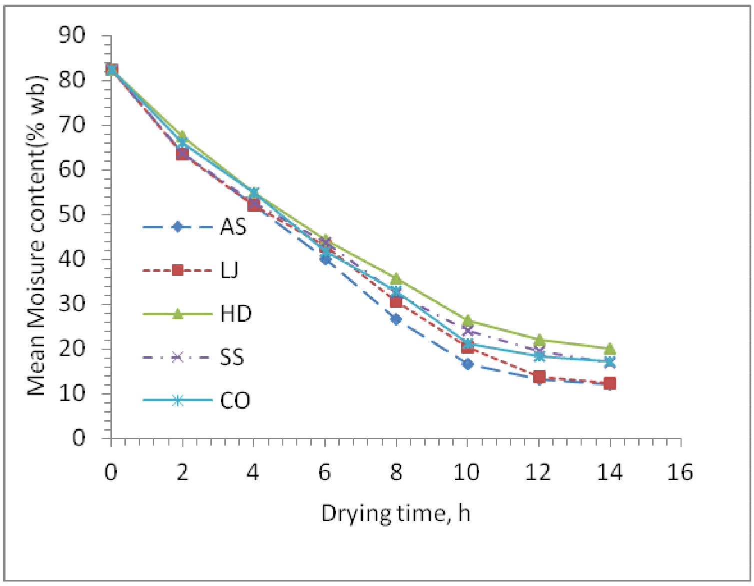

Fig. 1. Variations of moisture content versus drying time for the control and various pretreated mango slices

Table 1. Mean moisture content (%) of treated mango slices as a function of drying time

Drying time (h)	Pretreatment				
	AA	SS	LJ	HD	CO
0	82.3	82.3	82.3	82.3	82.3
2	63.76[a]	63.63[a]	63.42[a]	67.38[b]	66.12[b]
4	52.18[a]	52.67[a]	52.01[a]	54.97[b]	55.00[b]
6	40.08[a]	43.8b[c]	42.88[bc]	44.38[c]	41.89[ab]
8	26.66[a]	32.41[c]	30.69[b]	35.65[d]	32.99[c]
10	16.63[a]	23.98[c]	20.19[b]	26.31[d]	21.21[b]
12	13.26[a]	19.49[c]	13.8[a]	21.98[d]	18.30[b]
14	11.91[a]	16.95[b]	12.28[a]	20.09[c]	17.29[b]

Means in a row bearing the same letters are not significantly different at p = 0.05

The ANOVA results show that there was no significant difference between the moisture content of the AA, LJ, and SS pretreated mango slices in the first 2 h of drying. Here, the HD pretreated and the CO samples lost moisture steadily with no significant difference. This trend continued after 4 h of drying. However, after 6 h of drying there was an overlapping significant difference between the mean moisture content of all the samples. The AA and the CO samples had no significant moisture content difference existing between them. Also, the LJ, SS, and CO slices had no observable significant difference in moisture retention. The SS, LJ, and HD samples showed a similar trend. However, there were significant differences in moisture content between the AA and SS pretreated samples.

At 8 h of drying, the SS pretreated and the CO samples recorded no significant differences ($p = 0.05$) in moisture content but significant differences existed between the other treated samples. A similar trend continued in the 10th and 12th h of drying with no significant differences between AA and LJ pretreated samples. When drying was completed, the AA, SS, and HD pretreated samples showed significant differences in moisture content with no significant differences between the AA-LJ and SS-CO slices respectively.

The low moisture content in AA dried products could be due to the leaching effect of the ascorbic acid, which affected the fruit tissues, making it easier for water to diffuse though during drying. This is consistent with the observations of Fuente-Blanco et al. (2006) that the pretreatment affects fruit tissues, making it easier for the water to diffuse during air drying. Lemon juice which is acidic in nature with a major component being ascorbic acid might have caused a similar effect on the tissue of the mangoes. The evaporation rate of salt solution could also account for its sharp fall in the first four hours. Common salt, made of sodium chloride resulting from a reaction between an acid and base, evaporates rapidly on heating. This may have resulted in the relatively high loss of moisture in the samples pre-treated with the salt solution. The high moisture content retention in the honey dip pretreated samples might be due to the hygroscopic nature of honey. When it is exposed to hot air, casehardening is enhanced, which further slows down the heat and mass transfer within the tissues of the mangoes. The high sugar to acid ratio of the HD pretreated dried product may have enhanced the casehardening effect to slow down moisture transport. Sugar, when heated forms a gelatinous sticky coat around the mango slices, which is impermeable to moisture loss. This sticky coat prevents moisture loss from the samples pretreated with honey. More so, sugar becomes more viscous when melted, and this viscous fluid expanded to fill the pore spaces in the mango slices on heating and may have resulted in the high moisture content retention in the HD dried samples. Since samples pretreated with honey exhibited a viscous rather than an elastic behavior, it indicates that infusion of sugars caused plasticity of the mango slices. In drying of banana, apples, and kiwi in sucrose solution, similar results were reported by Panagiotou et al. (1998).

Fitting of the Drying Curves

The mathematical modeling of the drying data using Eq. 5 and 6 for the control and pretreated mango slices dried at 70 °C air temperatures was performed. The results of such fitting, obtained with SPSS 16.0 software are shown in Table 2, which indicate the values of the estimated constants with the corresponding statistical R^2, MAE, and χ^2 values characterizing each fitting. From the results obtained it is possible to verify that the experimental data fitted well to the models used in this study. It can be seen that the drying rate constant, *k* was higher for the pretreated mango samples than the control. This indicates that the drying rate potential of mangoes was enhanced with the application of the various pretreatments. The drying rate constant was however higher in the Midilli et al. (2002) thin-layer drying model than the Page (1949) model. Azoubel et al. (2010) dried bananas pretreated at 24 kHz for 10, 20, and 30 min at 50 and 70 °C and found the k parameter in the Page (1949) model to increase with air temperature (except the samples pretreated for 30 min). Azzouz et al. (2002) concluded that k was a function of air temperature and initial moisture content of grapes.

The high values of R^2, and low values of MAE, and χ^2 recorded in this study show that the experimental data are closely bound to the simulated data for the models tested around logarithmic curves throughout the drying process. This means that the two models could satisfactorily describe the convective hot air drying of mangoes. The relatively higher R^2 and lower MAE and χ^2values indicate the suitability of the Midilli et al. (2002) model to describe the profile of the moisture ratio of mango slices to the temperature studied better than the Page (1949) model. Previous authors have used these models to accurately simulate the drying of banana (Azoubel et al., 2010), cashew apple (Azoubel et al., 2009), kiwi (Simal et al., 2005), mango (Abano et al., 2011), among others.

Table 2. Results of curve fitting to the Page (1949) and Midilli et al. (2002) models

Pretreatment	Model name & expression	Model constant	R^2	MAE	χ^2
AA	Page $MR = \exp(-\mathrm{kt}^{\mathrm{n}})$	k:0.080, n:1.442	0.98737	0.01369	0.002
SS		k:0.104, n:1.289	0.98636	0.01369	0.002
LJ		k:0.087, n:1.357	0.98226	0.0158	0.0026
HD		k:0.084, n:1.397	0.99241	0.01045	0.0011
CO		k:0.076, n:1.468	0.98855	0.01311	0.0018
AA	Midilli et al. $MR = a\exp(-\mathrm{kt}^{\mathrm{n}}) + \mathrm{bt}$	k:0.093, n:1.259 a:0.987, b:-0.007	0.99368	0.00968	0.0015
SS		k:0.133, n:0.989 a:0.995, b:-0.013	0.99547	0.0079	0.0010
LJ		k:0.115, n:1.009 a:0.993, b:-0.016	0.99446	0.0088	0.00125
HD		k:0.101, n:1.184 a:0.995, b:-0.008	0.99783	0.00559	0.0005
CO		k:0.088, n:1.288 a:0.989, b:-0.007	0.993758	0.00968	0.0015

Effective moisture diffusivity

Fig. 2 displays the variation of ln(MR) against drying time for the control and the various pretreated mangoes. In general, ln(MR) against drying time followed straight line equations with negative slopes. However in the latter part of the drying, the curves did not follow the straight line behavior. The pretreatments affected the effective moisture diffusivity coefficients. Under drying conditions of 70 °C air temperature and 5 mm sample thickness, the effective moisture diffusivity values were found to be 2.22×10^{-10} m^2/s, 1.80×10^{-10} m^2/s, 2.01×10^{-10} m^2/s, 1.93×10^{-10} m^2/s, and 2.31×10^{-10} m^2/s for AA, SS, LJ, HD, and control pretreated samples respectively. The values of the D_{eff} obtained from this research lie within the general range of $10^{-12} - 10^{-8}$ m^{2}s^{-1} for drying of food materials (Zogzas et al., 1996). The values of the correlation coefficients ranged between 0.8617 and 0.9294. The relatively high value of correlation coefficient indicates good fitness between experimental and predicted values. The effective moisture diffusivity (D_{eff}) values recorded for hot-air drying of mango slices are within those existing in the literature, such as 5.30-17.73 $\times 10^{-10}$ m^{2}s^{-1} for aloe vera (Vega et al., 2007), 1.345-2.658 $\times 10^{-8}$ m^{2}s^{-1}for onion slices (Lee and Kim, 2008), 1.097-5.991 $\times 10^{-9}$ m^{2}s^{-1} for thyme (Doymaz, 2010), and 5.13-10. 26$\times 10^{-10}$ m^{2}s^{-1} for tomato slices (Abano et al., 2011). The difference in moisture diffusivities values might be attributable to the different cell arrangements in different materials. The D_{eff} of a food material characterizes the internal mass transport property of moisture which includes molecular diffusion, liquid diffusion, vapour diffusion, hydrodynamics flow, and other possible mass transport mechanisms (Karthanos et al., 1990).

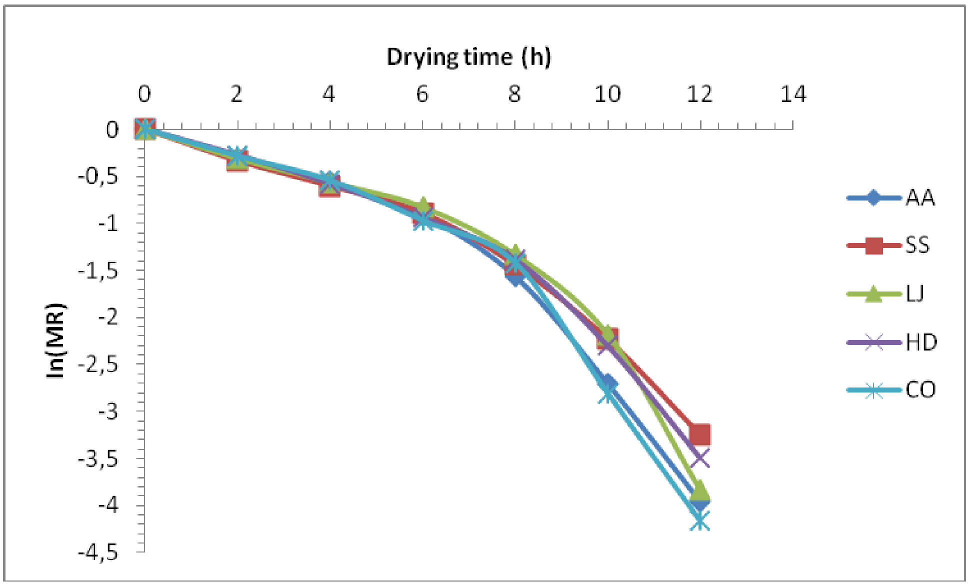

Fig. 2. Variation in In(MR) with time for the untreated(control) mango slices

Rehydration characteristics

Because most dried products are reconstituted prior to their final use, the rehydration properties of dried products are used as quality criteria to indicate the physical and chemical changes as a result of drying. They are affected by processing conditions, sample composition, and sample preparation and extent of structural and chemical disruptions induced by drying (Krokida and Maroulis, 2001). Higher values of coefficient of rehydration (COR) and rehydration ratio (RR) are considered better than lower ones (Vadiwambal and Jayas, 2007). Five-gram samples of dried mango slices were re-hydrated by soaking them in cold water at room temperature for 10 minutes. The minimum RR of 1.62 was obtained for 5 mm thick slices pretreated with salt solution and the maximum RR of 2.23 was obtained from ascorbic acid samples. RR and COR values are presented in Table 3. On rehydration, all the samples except the ascorbic acid mango slices absorbed water more slowly and did not regain the firm texture associated with the fresh mangoes. It can be seen that there is not much difference in the rehydration properties of the different pretreated samples. The highest RR in the AA pretreated samples indicates that there were stiffer and more open structures in the AA dried samples and the rehydrating water filled out the capillaries, making these samples to acquire less resistance to deformation and thereby promoting swelling of polymers and further water absorption. Abano and Sam-Amoah (2011) studied the rehydration properties of dried bananas (7mm thick and 60 and 70 °C air temperature) and observed minimum and maximum rehydrated capacities of 121.5 % and 171.6 % in banana slices pretreated with ascorbic acid and lemon juice respectively. In hot-air dried apple slices, Askari et al. (2006) reported a rehydration capacity of 404.6 % for rehydration characteristics. They concluded that intercellular gaps were created during drying, which absorbed a large amount of water during rehydrated to give rise to an increased rehydrated capacity. The AA pretreated samples may have resulted in creation of more intracellular gaps than the other pretreatments. Kathirvel et al. (2006) studied the RR characteristics of coriander (Coriander sativum L), mint (Mentha specata L), dill (Anethum graveolens L) and parsley (petroselinum crispum Mill) and reported that higher RR at higher microwave power can be attributed to the development of greater internal stresses during drying. Maskan (2001) studied the rehydrated characteristics of kiwi (Actinidia deliciosa) during hot air and microwave drying and observed a higher rehydration capacity and lower absorption rate for hot–air-dried samples than the microwave samples.

Table 3. Rehydration properties of mango slices dried at 70 °C

Treatments	Rehydration ratio (RR)	Coefficient of rehydration (COR)
Ascorbic acid	2.23^{a}	0.44^{a}
Lemon juice	1.84^{ab}	0.37^{c}
Honey dip	1.72^{c}	0.38^{b}
Salt solution	1.62^{d}	0.35^{d}
Control	1.84^{ab}	0.39^{b}

Means in column bearing the same letter are not significant at p=0.05

Sensorial characteristics

A sensorial analysis was done to determine the quality of the dried mangoes in terms of taste, flavour, colour, texture, and chewiness. On the basis of taste, statistical analysis of the hedonic test showed that HD pretreated slices scored the highest (5.40±1.47), followed by CO (4.50±0.83), AA (4.20±1.11), LJ (4.15±0.88), and finally the SS pretreated mango slices (3.70±1.34). All the dried products with the exception of the SS pretreated samples scored at least good. In terms of the flavour, there was a decreasing preference for the HD pretreated products (4.95±1.36), followed by the CO (4.20±0.83), SS (4.20±0.89), LJ (4.00±0.73), and AA (4.00±0.79). A similar trend was observed for colour and texture as shown in Table 3. However, a different trend was observed for chewiness. The degree of preference was highest in HD pretreated dried products (4.63±0.96), followed by AA (4.37±1.01), LJ (4.32±0.95), CO (4.16±0.96) and SS (4.11±0.99) in that order. In terms of flavour, texture, and chewiness, the panelists scored all at least good. The overall preference by the semi-trained panelist for the dried products is shown in Fig. 3. Honey dip treated samples had the highest score (45 %), with the control and ascorbic acid treated samples scoring the same mark of 20 %. Lemon juice samples scored 15 % while the salt treated samples scored nil.

The highest overall preference for honey pretreated products could be attributable to the sugar content (75-80 %), resulting in the sweet taste and subsequent preference by panelists. Also, the preference of panelist for ascorbic acid treated products could be due to the taste of vitamin C tablet, which positively influenced the original taste of the mango slices. The taste of lemon treated products was influenced by the sour nature of the lemon juice, which may have affected the taste of the dried products negatively. The taste of salt treated products, which was least preferred, might be due to the chemical reaction of the salt solution with the sugary nature of the mango slices. Unsurprisingly, in Ghana, many people dislike such combination of salt and sugar in food processing. The preference for the control products indicated that pre-treatments had no remarkable influence on the panelist preference for taste, flavour, texture, and colour of the treated mango slices with the exception of the chewiness. More so, it was revealed in Table 4 that pretreatment had influence on the panelist scores for colour, flavour and texture of the dried samples. This is because honey and ascorbic acid treated samples, which had highest and lowest scores respectively in colour, also had the same trend for flavour and texture. There was however no direct correlation between the ranking for taste, flavour, and chewiness as is shown by the hedonic test. Nevertheless, the flavour and chewiness of the dried mangoes should not be taken for granted. Nutritionally, the taste of dried foods is related by their flavour and texture.

The texture of the dried samples was described as tough. It was tender and quite chewy and generally pleasant. The colour of the dried mango slices ranged from light brown to yellowish-brown. Changes in the texture of dried foods are an important cause of quality deterioration. It has been explained that loss of texture is caused by gelatinization of starch, crystallization of cellulose, and localized variations in the moisture content during drying, which set up internal stresses leading to rupture (Fellows, 1998). The rupture compresses and permanently distorts the relatively rigid cells, to give food a shrunken shiveled appearance. This may be responsible for the variation in the quality of texture and the collapsed cell structure of the dried mangoes. Lin et al. (1998) studied the sensory properties of air-dried and microwave-vacuum-dried carrot slices, which were water blanched initially. The vacuum-microwave-dried carrot slices received the highest ratings for texture, odor and overall acceptability as compared to the air-dried carrot slices. Fathima et al. (2001) studied the sensory attributes (appearance, colour, odour and overall quality) of coriander (*Coriander sativum*), mint (*Mentha spicata*), fenugreek (*Trigonella foenum-graceum*), amaranth (*Amaranthus sp.*) and shepu (*Peucedanum graveolens*). Amaranth had similar scores for fresh and dried ones; however, there was a significant decrease for the sensory attributes of other greens.

Table 4. Hedonic test scores of dried mango slices for the various pre-treatments

Sensory property	Pretreatment				
	AA	SS	LJ	HD	CO
Taste	4.20±1.11^{c}	3.70±1.34^{d}	4.15±0.88^{c}	5.40±1.47^{a}	4.50±0.83^{b}
Flavour	4.00±0.79^{c}	4.20±0.89^{b}	4.00±0.73^{c}	4.95±1.36^{a}	4.20±0.83^{b}
Colour	3.95±0.95^{d}	4.20±0.89^{b}	4.10±0.85^{c}	4.65±1.46^{a}	4.30±0.80^{b}
Texture	4.00±0.80^{c}	4.10±1.07^{c}	4.00±1.17^{c}	4.45±1.19^{a}	4.20±1.06^{b}
chewiness	4.37±1.01^{b}	4.11±0.99^{c}	4.32±0.95^{b}	4.63±0.96^{a}	4.16±0.96^{c}

Means in row bearing the same letter are not significant at p=0.05. Values are means plus or minus standard deviation.

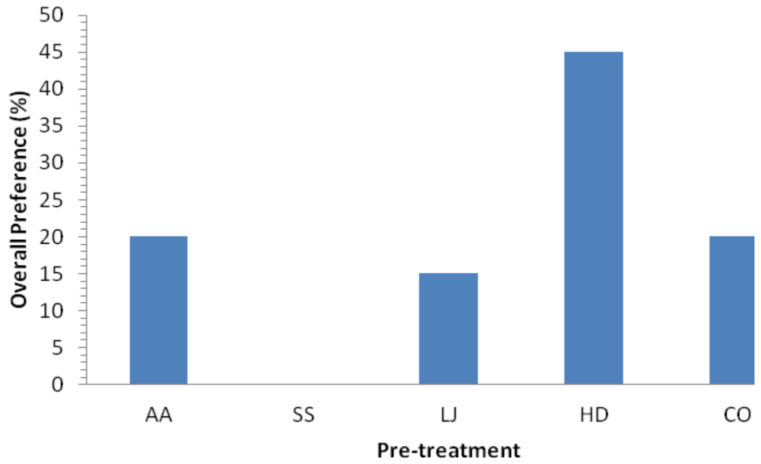

Fig. 3. Panelists overall preferences for the dried mango slices

Conclusions

This work focused on the effect of different pretreatments on the drying characteristics of mango slices and the physio-organoleptic properties of dried products. Pretreatments affected the drying kinetics and rehydration properties of the dried mangoes. The moisture diffusivity coefficient was found to be 2.22 × 10^{-10} m^2/s, 1.80 × 10^{-10} m^2/s, 2.01 × 10^{-10} m^2/s, 1.93

$\times 10^{-10}$ m^2/s, and 2.31 $\times 10^{-10}$ m^2/s for AA, SS, LJ, HD pretreated and control (CO) samples respectively. The minimum rehydration ratio of 1.62 was obtained for the slices treated with salt solution while the maximum rehydration capacity of 2.23 occurred in the ascorbic acid dried samples. Honey treated mango slices had the highest score (45 %) for overall acceptability, followed by the control and ascorbic treated samples with a score of 20 %, then lemon juice with a score of 15 %, with salt treated samples scoring the least (zero percent). Formation of open structure due to ascorbic acid pretreatment was concluded on the basis of the result obtained during drying of mangoes. The ascorbic acid removed bridges in the dried mango tissues promoting polymer hydration and swelling. It resulted in better rehydrated properties than the other dried products. Enhanced drying rate, rehydrated properties, and acceptability are advantages of pretreatment prior to food dehydration.

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