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KINETICS OF COLOUR CHANGE AND QUALITY PARAMETERS OF UNCOATED AND SODIUM ALGINATE COATED DEHYDRATED PINEAPPLE SAMPLES DURING STORAGE

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ABSTRACT

Colour and quality characteristics of uncoated and sodium alginate coated dehydrated pineapple samples were studied during storage. The study was conducted by packaging samples in laminated pouches stored at 30 ± 1°C and 75% RH. Kinetic parameters for the colour change were determined using *L**, *a**, *b**, hue (h°), total colour difference (Δ*E*), and browning index (BI) values. The kinetics of colour change was evaluated using zero-order and first-order reaction kinetics. The corresponding reaction rate constants were determined by non-linear regression analysis. *L**, *b** and h° value decreased, while, *a**, Δ*E* and browning index increased during storage in both coated and uncoated samples. Both the models were found to describe the data of colour parameters adequately. The correlation coefficient value of colour parameters was more than 0.95 indicating good agreement between experimental and model predicted values. The reaction rate constant values of colour parameters were in the range of 0.0068 to 2.8367 day^{-1}. The uncoated pineapple samples showed more browning as compared to coated samples which augmented during the later periods of storage. The sensory scores of coated samples remained acceptable up to 18 months storage period. Rehydration ratio decreased and moisture content increased with increase in storage period.

Keywords: Pineapple, Osmotic dehydration, Sodium alginate, Colour, Storage

INTRODUCTION

The cultivated pineapple (*Ananas comosus* var. *comosus*) belongs to the family *Bromeliaceae*. The pineapple shares the distinction accorded to all major food plants of the world of having been selected, developed and domesticated by peoples of prehistoric times and passed on to us through earlier civilizations. Pineapple is now the third most important tropical fruit in world production after banana and citrus. According to Food and Agriculture Organization (FAO) statistics (Baker, 1990; Anon, 2002), total pineapple production was approximately constant in 1999-2001 period with mean world production for these years of 13,527,149 metric tonnes (t). Pineapple is loaded with vitamin C, B_1 and smaller amounts of B_2, B_3, B_5 and B_6. It is also an excellent source of manganese, copper, magnesium, potassium, beta-carotene, folic acid and dietary fibre. The processing of pineapple has made the fruit well known throughout the temperate developed world. Major pineapple products are canned slices, chunks, crush, concentrated pineapple juice and fresh juice. Despite the significance of canned pineapple in international trade, approximately 70% of the pineapple produced in the world is consumed as fresh fruit in the country of origin (Loeillet, 1997). Important pineapple producing countries, such as, Brazil, India, China, Nigeria, Mexico and Colombia produce fruit primarily for their own fresh-fruit markets and canning is a minor industry. Fruit may be processed at the production site and transported chilled at 0-1°C or shipped whole without the crown to large metropolitan centres and processed just before retail sales. The shelf life of this product is limited to 1-3 weeks unless the product is actually frozen.

Dehydrated fruits are consumed directly either as processed fruit products or used further in the processing of various foods, such as bakery foods, confectionery products, soups etc. Drying is one of the most important methods of food preservation primarily intended to inactivate enzymes, deteriorative microorganisms and reduce water activity by dehydration. However, during processing, the food material may be exposed to temperatures that have an adverse effect on quality and making these products susceptible to colour deterioration (Barreiro *et al.*, 1997; Lozano and Ibarz, 1997, Avila and Silva, 1999 and Maskan, 2001). During storage and distribution, foods are exposed to a wide range of environmental conditions such as temperature, humidity, oxygen, and light that can trigger several reaction mechanisms leading to food degradation. With the result, foods may be altered to such an extent that they are either rejected by the consumer or they may become harmful to the person consuming them (Pua *et al.*, 2008). In fruits, deleterious changes can occur during storage which affect their appearance, flavor and odour.

Colour is one of the most important appearance attribute of food materials, since it influences the consumer acceptability. The change of product colour is caused by the reactive components in the food activated during the drying process. Colour is maintained throughout storage till the product reaches the hands of consumers. It has been studied to a great extent in different products such as dried mango (Pott *et al.*, 2005), dried kiwifruit (Maskan, 2001) and dried banana (Demirel and Thuran, 2003). The colour measurements are used to estimate the colour changes in foods, as they are simpler and faster than chemical analysis. Hunter colour parameters (L^*, a^*, b^*, h°, ΔE, and browning index) have previously been proven to be valuable in describing visual colour deterioration and providing useful information for quality control in fruits such as grapes (Aguilera *et al.*, 1987), apples (Feng and Tang, 1998), concentrated fruit pulp (Lozano and Ibarz, 1997), tomato paste (Barreiro *et al.*, 1997), pear puree (Ibarz *et al.*, 1999), Banana (Maskan, 2000), and kiwifruit slabs (Maskan, 2001). The knowledge of kinetics of colour degradation in fruits has contributed to minimizing undesirable colour changes and maximizing colour retention (Kessler and Fink, 1986; Lund, 1975; Rhim *et al.*, 1989; Wells and Singh, 1988). Dehydrated products are usually rehydrated prior to their use and rehydration ratio is also a very important quality parameter.

According to Brown and Williams (2003), shelf life testing is carried out by holding representative samples of the final product under conditions likely to mimic those that the product will encounter from manufacturer to consumption. It is a complex concept that is dependent on the nature of food product under consideration, the preservation technologies applied, and the environmental conditions to which the food product is exposed. Krokida and Marinos-Kouris (2003) examined the rehydration capacity of dehydrated apple, potato, carrot, banana, pepper, garlic, mushroom and tomato. Moisture of the product has a critical influence on its storage stability and moisture migration from the environment. The change in sensory quality was evaluated during storage in dehydrated ripe mango slices (Sagar *et al.*, 1998), dried mango slices (Kesarwani *et al.*, 2000), and guava fruit bar (Vijayanand *et al.*, 2000), respectively. In order to minimize colour deterioration, suitable designs are needed for manufacturing of processed fruit products (Maskan, 2001). But if fruits are coated with edible coatings, then osmotically dehydrated and finally air-dried, then this combined processes will help to maintain the colour of the fruits during storage.

In the past, several studies have been conducted on the kinetics of changes in fruits, but no work has been conducted on the kinetic studies related with colour change during storage of coated and dehydrated pineapple fruit. The purpose of this work is to study the kinetics of changes in colour parameters and the change in rehydration ratio, moisture content, and sensory parameters of the both uncoated and sodium alginate coated dehydrated pineapple samples during storage in laminates in order to evaluate the commercial shelf life of the product.

MATERIALS AND METHODS

MATERIALS

Pineapples were procured from the local market, Sangrur. Sucrose was used as the osmotic agent. Sodium alginate (Sisco Research Laboratories Private Limited, Mumbai) was used as coating agent. Calcium chloride (Sisco Research Laboratories Private Limited, Mumbai) was used as a cross linking agent.

METHODS

COATING PRIOR TO OSMOTIC DEHYDRATION

Pineapples were peeled and cut into cuboids of size 2.0x2.0x0.75 cm^3. Sodium alginate was used as a coating agent because of its hydrophilic properties and high performance ratio demonstrated in screening experiments. Six concentrations of sodium alginate solutions (0.5%, 1%, 2%, 3%, 4% and 5%, w/v) were prepared with distilled water. The sodium alginate solution was heated to 70ºC with stirring until a clear solution was obtained and then cooled to room temperature. The pineapple samples were weighed and dipped into the solution of coating agent for two different time of 60 s and 120 s. Pineapple samples were then taken out from the coating solution, drained to remove adhering solution for 30 s and then dipped into $CaCl_2$ solution (2% w/v) for 30 s for cross-linking. The samples were then taken out from the $CaCl_2$ solution and dried in a hot-air oven (1.5 m/s air velocity) at 50°C to fix the layer of coating for 10 and 40 min followed by osmotic dehydration, which was carried out at the optimized OD conditions as described below.

OSMOTIC DEHYDRATION (OD)

In the screening experiments, by using different levels of processing parameters in Central Composite Rotatable Design (CCRD), the conditions of OD were optimized. The processing parameters optimized were sucrose concentration of the osmotic solution, temperature during OD, time and fruit-solution ratio, whereas the response variables kept were water loss, solid gain and ratio of water loss to solid gain (WL/SG) with desired conditions of maximum water loss, minimum solid gain and maximum WL/SG ratio during the OD. The optimized conditions obtained were 62°Brix sucrose concentration, temperature of 30°C for 6 hours using 1:6 fruit-solution ratio (Singh *et al.*, 2008). After OD, samples were taken out of the osmotic medium, drained, then gently blotted with filter paper to remove adhering solution and weighed. Uncoated samples were also dehydrated osmotically by using sucrose solution for comparison of the mass transfer in coated samples to that in uncoated samples.

MASS TRANSFER STUDIES

The evaluation of mass exchange was done at above optimized conditions of OD. The mass exchange between the solution and sample during OD were made by parameters such as water loss (WL), solid gain (SG) and performance ratio (PR).

$$PR = WL/SG \quad (1)$$

After carrying out mass transfer study, the coated sample with highest performance ratio (PR) was selected. The sample dipped in 2% sodium alginate solution for 120 s and later oven dried for 40 min was found to have highest PR (Charanjiv Singh *et al*, 2010). The WL was maximum and SG was minimum in this sample. Therefore, out of all the samples, further convective dehydration study was conducted only in this sample.

CONVECTIVE DEHYDRATION

The pineapple samples after coating and OD were dehydrated at 55°C temperature with an air velocity of 1.5 m/s in a tray drier along with uncoated sample. The uncoated sample was taken as a control sample in which OD without coating was performed. The weight of the samples during drying was monitored at different time intervals by a precision balance. The experiments were conducted in triplicate. The dried samples were cooled for 15 min and then packed in laminated pouches for further analysis.

PACKAGING AND STORAGE OF DEHYDRATED SAMPLES

The coated and uncoated dehydrated pineapple samples were packed in laminated pouches of 30 µm thickness. The material of pouches consisted of aluminium foil laminated with colourless low density polyethylene (LDPE). Unit pouches of the packaging material measuring 18 x 14 cm^2 were made for holding 200 g of dehydrated pineapple samples, and were sealed with heat sealing machine. A saturated salt solution of sodium chloride was prepared to obtain the required relative humidity. Desiccators were prepared using saturated salt solution. The sealed pouches were placed inside the airtight desiccators. The desiccators were then placed inside the incubator maintained thermostatically at 30 ± 1°C to maintain relative humidity at 75%. Evaluation of Hunter colour parameters, rehydration ratio, moisture content and sensory evaluation for both coated and uncoated samples was carried out after one month interval each. Each determination was replicated thrice and the data presented are averages of the three measurements. After sampling, the pouches were resealed and stored for subsequent sampling.

COLOUR MEASUREMENT

The colour of uncoated and coated dehydrated samples was measured using a Gretag Macbeth Colour i5 Spectrophotometer, which measures "L^*", "a^*", and "b^*" parameters. The instrument was calibrated against a white standard. Measurements were individually taken for five fresh, uncoated and coated samples, and the average of five readings was taken.

Total colour difference (ΔE) was calculated according to Hunter (1975) as:

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

The fresh pineapple samples were used as the reference.

Hue angle is used to characterise colour in food products. An angle of 0° or 360° represents red hue, while angles of 90°, 180° and 270° represent yellow, green and blue hue, respectively. It has been extensively used in the evaluation of colour parameters in green vegetables, fruits and meats (Barreiro *et al*., 1997; Lopez *et al.*, 1997).

Hue (h°) was calculated using the following equation:

$$h^o = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

Browning index (BI) was estimated according to the following equation:

$$BI = \frac{[100(x - 0.31)]}{0.17} \quad (4)$$

where

$$x = \frac{(a^* + 1.75 L^*)}{(5.645 L^* + a^* - 3.012 b^*)} \quad (5)$$

In the above equation, L^*, a^* and b^* are the respective colour values of both coated and uncoated samples (Maskan, 2001).

KINETICS OF COLOUR CHANGE DURING STORAGE

The change in food colour was studied by zero-order (Eq. 6) and first order (Eq. 7) degradation reaction kinetics

$$C = C_o \pm k_o t \quad (6)$$

$$C = C_o \exp(\pm k_1 t) \quad (7)$$

where, k_o is the reaction rate constant for the zero order model

k_1 is the reaction rate constant for the first order model

C is the measured colour scale value at time t

C_o is the initial colour scale value

The symbols, (+) and (-) indicated formation and degradation of quality parameters, respectively (Pua *et al.*, 2008; Chutintrasri and Noomhorm, 2007; Maskan, 2001).

Experimental data of colour parameters were fitted to kinetic models. Non-linear regression analysis was applied for the kinetics equations of zero-order and first-order. From the analysis, the best fit was selected and rate constants were determined for each model.

REHYDRATION RATIO

The rehydration ratio (*RR*) was used to express ability of the dried material to absorb water. A sample (10 g) of the dried material was weighed (initial weight) into 500 ml beaker containing 150 ml of distilled water and boiled for 5 min. After rehydration, the sample was weighed (final weight). The rehydration ratio was obtained by dividing the rehydrated weight by the initial weight (Prakash *et al.*, 2004).

ANALYSIS OF MOISTURE CONTENT

Moisture content of pineapple samples was determined by the oven drying method (AOAC, 1990). Samples were weighed and placed in an oven set at 70°C until a constant weight was reached. The samples were cooled down to room temperature in desiccators and weighed. The moisture content of the samples was then calculated from the weight of the sample before and after drying. The initial moisture content of fresh pineapple samples varied from 89% to 93% wet basis (w.b.).

SENSORY EVALUATION

The sensory attributes of rehydrated samples were evaluated at one month interval in terms of colour, flavour, texture and overall acceptability. The rehydrated samples were presented to trained panellists, who evaluated the sensory characteristics of the samples on a nine point Hedonic scale (Ranganna, 1997a).

STATISTICAL ANALYSIS

t-test was used to assess whether difference in colour parameters, moisture content, rehydration ratio and sensory characteristics between coated and uncoated samples was significant or not, at all the months of storage (Ranganna, 1997b).

RESULTS AND DISCUSSION

COLOUR PARAMETERS

The colour value *"L*"* of both the sodium alginate coated and uncoated pineapple sample is presented in Fig. 1a. The *"L*"* value decreased with increase in storage period of both coated and uncoated samples. As the *"L*"* value is the measure of the colour in light-dark axis, so the decrease in the value indicates that the samples were becoming darker with increase in the storage period. Initially, the *"L*"* value of the uncoated samples was 64.19 which decreased to 42.72 at the end of storage period, whereas the value was 73.09 in coated samples when they were kept in the packaging material which later decreased to 55.13 at the end of storage study. Therefore, the coated samples were having more *"L*"* value at the beginning of the storage study as compared to uncoated samples indicating development of light coloured samples by the process of coating. The variation in the lightness of dried samples can be taken as a measurement of browning (Avila and Silva, 1999; Ibarz *et al.*, 1999). The development of discolouration of samples may be related to pigment destruction, ascorbic acid browning and non-enzymatic Maillard browning (Abers and Wrolstad, 1979; Skrede, 1985; Salunkhe *et al.*, 1991; Nazni and Anbu Malar, 2012). As both coated and uncoated samples were subjected to osmotic treatment, the infusion of sucrose in pineapple also caused a relative stability of colour parameter. The sucrose causes the relative inactivation of enzymes responsible for enzymatic browning. It may also result in the drop in water activity of the sample which in turn may reduce the non-enzymatic browning reaction. In addition, the layer of sodium alginate formed on the outer surface of the pineapple sample prevents direct contact with atmospheric oxygen, which is required for the oxidation of polyphenols by enzyme polyphenol oxidase during enzymatic browning. Therefore, the coated samples have higher *"L*"* values showing light coloured pineapple samples than uncoated samples during the entire storage study. The uncoated samples showed 33.44% decrease in *"L*"* values, whereas coated samples showed 24.57% decrease in *"L*"* value from the day they were stored in laminated pouches up to 18 months of storage. There was significant difference ($p \leq 0.05$) in the *"L*"* values between coated and uncoated samples at all the months under study.

Table 1-Non-linear regression analysis results of colour parameters from zero and first-order reaction kinetics in samples coated with sodium alginate

Sample	Parameter	Zero-order model			First-order model		
		k_o (day^{-1})	C_o	R^2	k_1 (day^{-1})	C_1	R^2
Uncoated	L*	1.3937	83.46688	0.975	0.0249	79.4282	0.988
	a*	1.7891	4.8292	0.990	0.0649	4.4859	0.974
	b*	0.1839	28.4673	0.964	0.0073	28.1246	0.969
	h°	2.1638	89.1344	0.991	0.0389	88.7213	0.989
	ΔE	1.2577	18.5261	0.987	0.0499	16.2210	0.951
	BI	2.8367	62.4944	0.992	0.0325	60.1388	0.990
Coated	L*	1.0909	65.2783	0.980	0.0103	63.7542	0.986
	a*	0.5236	1.9716	0.976	0.0443	3.7871	0.902
	b*	0.1320	25.6811	0.973	0.0068	24.4963	0.976
	h°	1.2781	81.6712	0.976	0.0152	51.6541	0.983
	ΔE	0.9634	8.6801	0.978	0.0322	6.2781	0.951
	BI	1.6894	42.4588	0.985	0.0282	40.5128	0.977

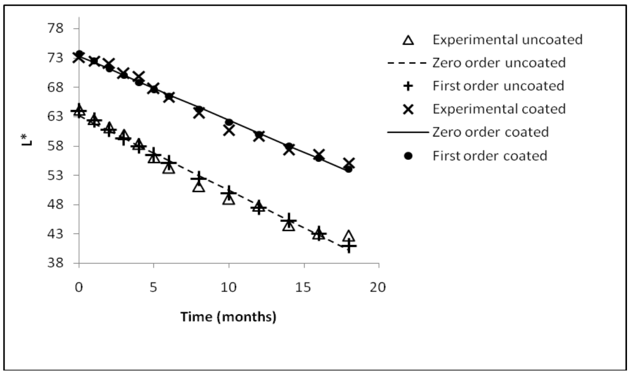
The colour value *"a*"* of both coated and uncoated pineapple samples is presented in Fig. 1b. The *"a*"* value increased with increase in the storage period in both coated and uncoated samples. The increase in the *"a*"* value denotes increase in the redness of the sample, which is also indicative of browning reaction. Therefore, browning increased in both the samples with increase in the storage time. This may be due to the decomposition of chlorophyll and carotenoid pigments (Kostaropoulos and Saravacos, 1995; Lee and Coates, 1999; Weemaes *et al.*, 1999) and formation of brown pigments (Rhim *et al.*, 1989; Lopez *et al.*, 1997; Maskan 2000). As browning increased, *"L*"* value decreased and *"a*"* value increased. The *"a*"* value of coated samples was less than the uncoated sample at the start and remained less throughout the storage period till the end of storage indicating less redness in coated samples as compared to uncoated samples. The *"a*"* value was 1.91 and 3.89 in coated and uncoated samples at the start of the storage period which subsequently increased to 11.55 and 13.87 after 18 months long storage. The decrease in *"L*"* value and increase in *"a*"* value with time is supported by various authors in their studies in: garlic slices (Prachayawarakorn *et al.*, 2004), jackfruit bulbs (Saxena *et al*., 2008), and jackfruit powder (Pua *et al.*, 2008). There was significant difference ($p \leq 0.05$) in the *"a*"* values between coated and uncoated samples throughout the storage study.

The *"b*"* values of both coated and uncoated pineapple samples decreased with increase in storage period (Fig. 1c). The *"b*"* values decreased by 11.25% and 8.07% in uncoated and coated samples from the first day of storage till the end of storage. The *"b*"* value of uncoated sample was more than the coated sample during the storage. The *"b*"* value at the beginning of the storage was 27.72 and 26.51 for uncoated and coated samples, which at the end of the storage period decreased to 24.60 and 24.37, respectively. The difference in the *"b*"* values between coated and uncoated samples was found to be significant ($p \leq 0.05$).

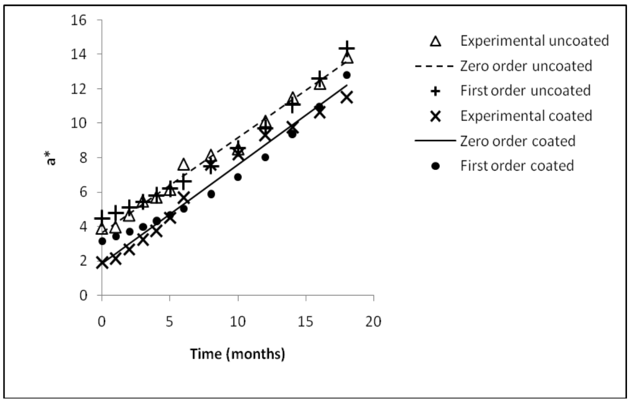
"h°" values of both coated and uncoated samples decreased with increase in the storage period (Fig. 1d). At the start of the storage period, *"h°"* values of uncoated and coated samples were 82.01 and 85.87 and decreased to 60.58 and 64.64 after 18 months of storage. *"h°"* values decreased by 26.13% and 24.72% in uncoated and coated samples from the start of the storage period till the end. *"h°"* values of coated samples were more than the uncoated samples during the entire storage study. High values of hue angle indicate less browning (Hawlader *et al*., 2006). Therefore, coated samples with higher *"h°"* values than the uncoated ones indicate lesser browning and this phenomenon was observed throughout the storage study.

The total colour difference (ΔE), which is a combination of parameters *"L*", "a*"* and *"b*"* values, is a colorimeter parameter used to characterize the variation of colours in foods during processing. ΔE values of both coated and uncoated samples increased with increase in the storage time (Fig. 1e). ΔE values of uncoated and coated samples were 13.19 and 7.02 in the beginning, which at the end of the storage study increased to 34.40 and 22.35, respectively. ΔE values of coated samples were less than the uncoated samples throughout the storage study. The increase in ΔE value with increase in the storage period was also observed by Pua *et al.* (2008) in jackfruit powder.

Browning index (BI) represents the purity of brown colour and is considered as an important parameter in processes where enzymatic and non-enzymatic browning takes place (Palou *et al*., 1999). BI of uncoated samples increased from 59.43 to 105.80, whereas the value of coated samples increased from 45.83 to 72.48 from the beginning till the end of the storage study (Fig. 1f). BI of uncoated samples was more than the coated samples indicating more browning in uncoated samples. Therefore, coating with sodium alginate helped to maintain the colour of the dried pineapple close to the fresh fruit with minimum browning. There was significant difference ($p \leq 0.05$) between coated and uncoated values of *"h°"*, ΔE, and BI.



(a)



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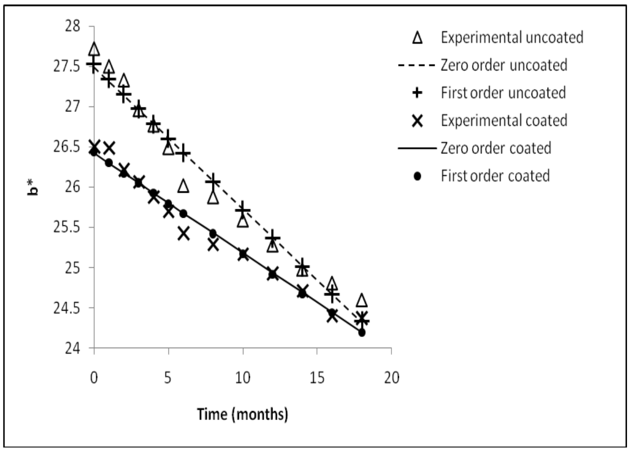

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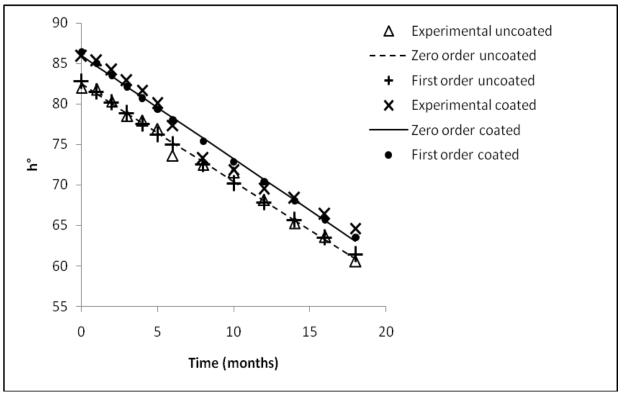

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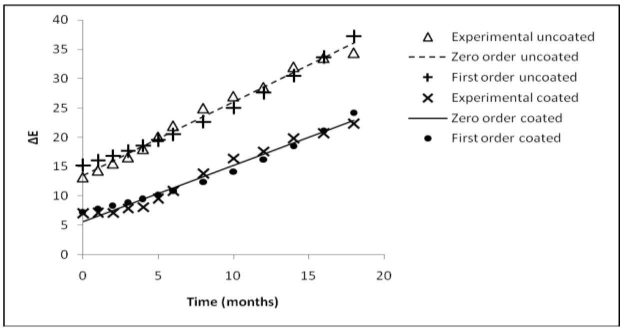

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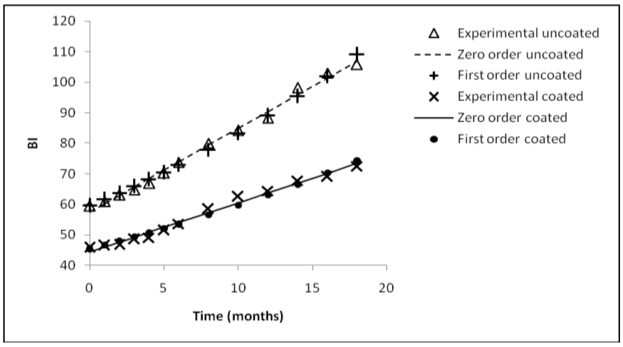

(f)

Fig. 1 Kinetics of change of colour parameters as a function of time during storage of uncoated and sodium alginate coated dehydrated pineapple samples (a) L* (b) a* (c) b* (d) h° (e) ΔE (f) BI

KINETICS OF COLOUR CHANGE DURING STORAGE

Kinetic modelling is a technique that is very useful in relation to food processing and food quality. The reason is twofold. First, changes in foods as a result of processing and storage lead to a change in quality, usually a quality loss. The processes involved are mainly biochemical and physical reactions. Such changes proceed at a certain rate and with certain kinetics. Kinetic modelling enables us to describe these changes and their rates quantitatively. Second, kinetic modelling is a powerful tool that can help to unravel basic reaction mechanisms. The understanding of the basic mechanisms is vital for quality modelling and quality control (Van Boekel and Tijskens, 2001). While analysing the effect of the experimental conditions on the process kinetics, experiments are often performed at different levels of the factor under study e.g. temperature. Each experiment allows for estimating the rate constant at a given level of the factor under study and analysis of the estimates obtained for the different levels allows for identifying how the rate constant depends on that factor. It is therefore important not only to estimate the rate constants, but also the parameters of the model that relates the rate constants to the factor of interest (Cunha *et al*., 2006).

Kinetics modelling is necessary to derive basic information for a system in order to describe the reaction rate as a function of experimental variables and hence, to predict changes in a particular food during processing and storage (Van Boekel, 1996). Processing almost always require a compromise because besides the desired changes, undesired changes will also occur. For instance, during heat sterilization, enzymes and microorganisms are inactivated (desired reactions) but at the same time nutrients such as vitamins and amino acids are degraded (undesired reactions) and undesirable flavour and colour compounds may be formed. Various references on the kinetics of colour change of food materials are present in the literature.

The results of regression analysis of colour parameters from zero-order and first-order reaction kinetics in uncoated and sodium alginate coated samples are presented in Table 1. The analysis indicated that both zero-order and first-order reaction kinetics models can be used adequately for both uncoated and coated samples. The coefficient of determination (R^2) values for zero-order model varied from 0.964 to 0.992 in uncoated samples and 0.973 to 0.985 in coated samples, whereas, the R^2 values varied from 0.951 to 0.990 in uncoated samples and 0.902 to 0.986 in coated samples for first-order model. There was not much difference in R^2 values of colour parameters for the two models. Therefore, both the models fitted well with the data of colour parameters in both coated and uncoated samples. The regression explained more than 95% of the variation in all the colour parameters except *"a*"* value in coated sample in first-order model, where 90% of the variation in the colour value is explained by regression analysis. As the R^2 values of colour parameters in the models were more than 0.95, it indicated that there was good agreement between the model-predicted values and experimental values. Overall, both the zero-order and first-order model described adequately the change in colour parameters over the entire storage period.

Maskan (2001) reported that both zero-order and first-order reaction kinetic models can be used adequately to describe the colour changes in kiwifruits. Pua *et al*. (2008) observed that the treatments at various storage conditions followed the zero-order reaction, whereas Avila and Silva (1999) and Ibarz *et al*. (1999) have observed that first-order kinetic model fitted well for *"L*"* and *"b*"* values of peach puree and pear puree. The kinetic rate constants of all the colour parameters were more in zero-order model as compared to first-order model for uncoated samples (Table 1). The same behaviour was also observed for coated samples. The value of zero-order kinetic model constants for *"L*", "a*"* and *"b*"* of coated samples was found to be 1.909, 0.5236, 0.1320 whereas, first-order kinetic model constants were 0.0103, 0.0443 and 0.0068 day $^{-1}$, respectively. Within the zero-order model, the kinetic rate constants of all the colour parameters were more in uncoated samples as compared to coated samples. The same was also true in first-order model. The evident higher values of kinetic constants in uncoated samples confirmed that browning is more in uncoated samples than coated samples.

REHYDRATION RATIO AND MOISTURE CONTENT

The effect of storage on the rehydration ratio of uncoated and sodium alginate coated dehydrated pineapple samples is shown in Fig. 2. Rehydration ratio decreased with increase in storage time and the decrease in rehydration ratio was observed in both coated and uncoated samples. This may be due to the reason that the dehydrated pineapple cuboids may absorb some amount of moisture from the environment during storage. Rehydration ratio of coated samples was more than the uncoated samples during the entire storage study. This may be due to the fact that the layer of coating formed outside the coated samples didn't allow the moisture gain into the cuboid. Therefore, the internal structure of the cuboid was not as modified as compared to the uncoated sample, where the intake of moisture was more due to absence of coating. The decrease in rehydration ratio with increase in storage time was also observed in dried carrots by Prakash *et al*. (2004). There was significant difference ($p \leq 0.05$) in the rehydration ratio values between coated and uncoated samples.

The moisture content increased with increase in storage time in both coated and uncoated samples (Fig. 3). During the entire storage study, the moisture content increased by about 14.34% and 8.11% in uncoated and coated samples from the beginning to the end of the storage period. The higher percentage increase in the uncoated samples may be due to more absorptivity of moisture from the surroundings, while it was not so in samples coated with sodium alginate.

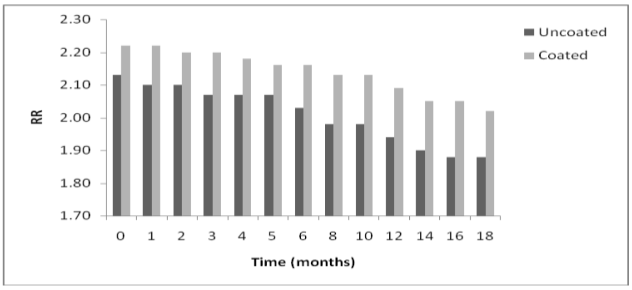

Fig. 2 Effect of storage time on the rehydration ratio of uncoated and sodium alginate coated dehydrated pineapple samples

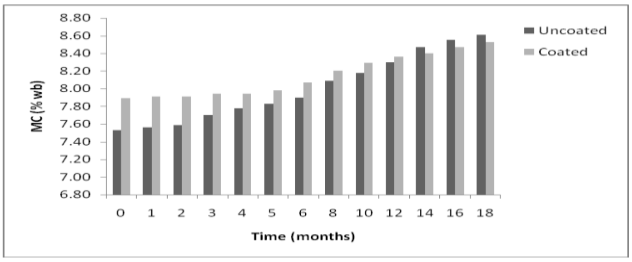

Fig. 3 Effect of storage time on the moisture content of uncoated and sodium alginate coated dehydrated pineapple samples

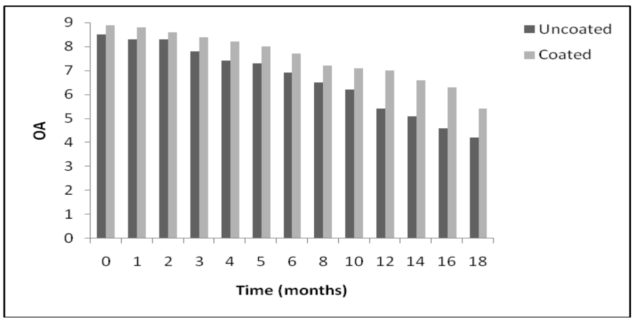

Fig. 4 Effect of storage time on the overall acceptability scores of uncoated and sodium alginate coated dehydrated pineapple samples.

SENSORY QUALITY DURING STORAGE

Shelf life refers to the end of consumer quality, and it is the time at which a percentage of consumers are displeased with the product (Labuza and Schmidl, 1985). Fig. 4 presented the sensory evaluation scores of both sodium alginate coated and uncoated samples as function of storage period. A steady decrease in the scores of colour, flavour, texture and overall acceptability was observed during storage. The difference between sensory evaluation values of coated and uncoated samples was found to be statistically significant ($p \leq 0.05$) corroborating that the coating influenced the variation in sensory quality. At the start of storage study, the uncoated samples were rated 8.9, 8.8, 7.9 and 8.5 for colour, flavour, texture and overall acceptability and decreased to 3.1, 5.1, 4.4 and 4.2 after 18 months, whereas the coated samples were rated 8.9, 8.9, 8.8 and 8.9 at the start of storage study, which later on decreased to 5.0, 5.8, 5.5 and 5.4, respectively after 18 months. The sensory evaluation scores of coated samples were more than the uncoated samples during the entire storage study. The sensory evaluation scores of the coated samples were more than 5 (5 = neither like nor dislike) even after the passage of 16 months. The colour, texture and overall acceptability scores of uncoated samples remain acceptable up to 10 months of storage but the flavour scores of uncoated samples were acceptable up to 14 months. The acceptability of coated samples was for 18 months whereas the uncoated samples were acceptable only for 10 months. Therefore, it was concluded that the shelf life of coated samples was more than the uncoated samples and coated samples remained stable and acceptable up to 18 months of storage. Pua *et al*. (2008) in jackfruit powder and Lee and Resurreccion (2006) in roasted peanuts also predicted the shelf life with consumer acceptance of more than 5.0 for all acceptance attributes.

CONCLUSION

The study demonstrated that all the colour parameters were found to be significantly affected by the coating treatment. Untreated pineapple samples were characterized by significant browning upon storage, whereas the browning was less in the coated samples. *"L*", "b*"* and *"h°"* decreased, whereas, *"a*"*, ΔE and BI increased during the storage in both coated and uncoated samples. Colour change reactions followed both zero-order and first-order reaction kinetics over the entire storage period. The kinetic rate constants of colour parameters were more in uncoated samples than coated samples in both the models. The correlation coefficient values for most of the colour parameters in the models were more than 0.95. Rehydration ratio decreased and moisture content increased with increase in storage time in both coated and uncoated samples. Sensory evaluation scores decreased steadily during the storage period but the sensory quality of coated samples was better than the uncoated samples till the end of storage period. The coated samples were acceptable up to 18 months of storage.

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